

Structure Foundation Exploration Report



LIC-CR41-5.60

**Mink Street Bridge over Muddy Fork
Pataskala, Ohio**

For:



Submitted By:

GFT

Author: Thomas L. Monaco, TMonaco@ gfn.net, (330) 612-4903

July 2026



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July 8, 2026
GFT Project No. 078318

Alan W. Haines, P.E.
Public Service Director
City of Pataskala
621 W. Broad St., Suite 2B
Pataskala, Ohio 43062

Re: LIC-CR41-5.60 PID 119707, Mink Street Bridge Replacement

Dear Mr. Haines:

GFT Infrastructure, Inc. is pleased to submit the Structure Foundation Exploration Report for the Mink Street Bridge Replacement over Muddy Fork (LIC-CR41-5.60 PID 119707), GFT Project Number 078318. The work was completed in accordance with the Scope of Services under the Agreement executed on April 5, 2024. The following report summarizes the findings of the subsurface exploration with laboratory testing results as well as the calculations for the proposed foundation designs for the bridge replacement.

Sincerely,
GFT Infrastructure, Inc.

A handwritten signature in blue ink, appearing to read "Thomas Monaco", is written over a light blue horizontal line.

Thomas L. Monaco, P.E.
Principal Geotechnical Engineer
cc:

Structure Foundation Exploration Report

LIC-CR41-5.60

PID 119707

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Structure Foundation Exploration Report

LIC-CR41-5.60

PID 119707

EXECUTIVE SUMMARY

The city of Pataskala hired GFT to develop the bridge foundation designs and to generate the Structure Foundation Exploration Report for the LIC-CR41-5.60 (PID No. 119707) project in Licking County. This Structure Foundation Exploration Report is part of the Structure Type Study and Stage 1 design for the replacement of the existing Mink Street bridge over Muddy Fork (SFN 4563743).

Between May 21st and May 22nd, 2024, two exploratory borings were advanced. The borings were designated B-001-0-24 and B-002-0-24. The project exploration was developed and completed in accordance with the Ohio Department of Transportation's (ODOT) *Specifications for Geotechnical Explorations* (SGE), dated January 19, 2024.

The proposed one-span bridge is to be supported by integral abutments. The integral abutments will be supported on a single row of piles. GFT recommends utilizing fourteen-inch diameter, driven cast-in-place (CIP) concrete pipe piles.

The report was compiled using the current ODOT *Specifications for Geotechnical Exploration* (SGE) as a guideline. It was presumed that the current versions of ODOT's *Construction and Material Specifications* (CMS), ODOT's *Bridge Design Manual* (BDM), and ODOT's *Geotechnical Design Manual* (GDM) will be utilized as the controlling design and material specifications.

Structure Foundation Exploration Report**LIC-CR41-5.60****PID 119707****1.0 INTRODUCTION**

The city of Pataskala hired GFT to develop the bridge foundation designs and to generate the Structure Foundation Exploration Report for the LIC-CR41-5.60 (PID No. 119707) project in Licking County, with an estimated project length of 600 feet. This Structure Foundation Exploration Report is part of the Structure Type Study and Stage 1 design for the Mink Street bridge replacement over Muddy Fork. The project will completely replace the structurally deficient single-span Bridge No. LIC-C0041-03050 (SFN 4563743). Figure 1.0 shows the location of the site. This Structure Foundation Exploration Report summarizes the subsurface exploration and the proposed bridge foundation exploration parameters and designs.



Figure 1.0 Site Location for LIC-CR41-5.60

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Literature Review

According to the Ohio Department of Natural Resources' (ODNR) *Physiographic Regions of Ohio*, the site lies within the Galion Glaciated Low Plateau physiographic region, within the glacial margin which consists of ground moraine varying in drift thickness of 211 to 330 feet. The bedrock below the site consists of the Mississippian-age shales and sandstones with siltstone and conglomerate and minor limestone of marine to marginal marine origin.

A search of ODNR's *Mines of Ohio Interactive Mapping* website determined there is no mining activity within the area. According to the Ohio Karst Areas Map, this area is not known to have karst bedrock. Water wells located in the area encountered mostly interbedded sand and gravel with clay.

According to the United States Department of Agriculture (USDA), the entire bridge is located within the Medway silt loam. This surficial soil classifies as AASHTO A-4 and ML based on the Unified Soil Classification System (USCS). Deeper deposits may consist of a variety of CL-ML and SC-SM (USCS) or A-4 to A-6, A-7 and A-1-b to A-2 (AASHTO). This soil is rated low for corrosion of concrete, but high for corrosion of steel. The material is rated fair as a roadfill source based on wetness; however, the soil is rated very limited for shallow excavations in Ohio due to the depth to saturated zone and flooding. The summary report of findings from the Web Soil Survey completed for the project is included in Appendix A.

Referenced Bibliography

Brockman, Scott C., 1998, *Physiographic Regions of Ohio*. Division of Geological Survey, Ohio Department of Natural Resources (ODNR) Map.

Ohio Department of Natural Resources, *Mines of Ohio*, Website, Accessed April 2024,

<https://gis.ohiodnr.gov/website/mrm/OhioMines/>

Ohio Department of Transportation (ODOT), Transportation Mapping Information System (TIMS), Accessed April 2024, [Geotechnical | ODOT TIMS \(state.oh.us\)](https://geotechnical.odot.state.oh.us)

Ohio Division of Geological Survey, 1999 (rev. 2022, 2006), *Known and Probably Karst in Ohio*, Ohio Department of Natural Resources, Division of Geological Survey Map EG-1, generalized page sized version with text, 2 p. scale 1:2,000,000.

Ohio Division of Geological Survey, 2004, *Shaded Drift Thickness Map of Ohio*, Ohio Department of Natural Resources, Division of Geological Survey Map SG-3, generalized page sized version with text, 3 p. scale 1:2,000,000.

Ohio Division of Geological Survey, 2005, *Glacial Map of Ohio*, Ohio Department of Natural Resources, Division of Geological Survey Map, page sized map with text, 2 p. scale 1:2,000,000.

Ohio Division of Geological Survey, 2006, *Bedrock Geological Map of Ohio*. Division of Geological Survey, Ohio Department of Natural Resources Map BG-1, generalized page-size version with text, 2 p., scale 1:2,000,000.

Ohio Division of Geological Survey, *Geologic Interactive Map*, Ohio Department of Natural Resources, Accessed April 2024, [ODNR Ohio Geology Interactive Map \(ohiodnr.gov\)](https://ohiodnr.gov/geologic-interactive-map)

United States Department of Agriculture and Natural Resources Conservation Services, *Web Soil Survey*, website, Accessed April 2024, <http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>

2.2 Site Reconnaissance

The site reconnaissance was performed by GFT Infrastructure, Inc. (GFT) personnel through desktop research and a field visit by Christopher Hallahan, PE on May 13, 2024, prior to the subsurface exploration. Scour was observed along the South Abutment to several inches below the current water level (West side). No or little scour was observed along the North Abutment. The stream flows is from West to East.

It was observed that a mix of timber and steel H piles with wood lagging support the abutments and wing walls. Several members combined timber piles with H-pile extensions to the superstructure. Superstructure I-beams are in general good condition with some spot rust areas. The corrugated bridge deck underlay is highly weathered and rusted.

Overhead electric lines run along the West side of the roadway, well off the road. A sanitary sewer runs along the West side of the roadway closely along the electric alignment. A sanitary lift station appears to be located north of the bridge along the sewer alignment. Fiber optic lines run along the East side of the roadway shoulder and under the stream. Another telecom line runs underground along the East side at the bottom of the roadway embankment and then becomes overhead as it passes by the bridge and over the stream. Both telecom lines are buried well beyond the North and South limits of the bridge and stream. Water lines run along the West side of the road, South of the Bridge, and along the East side of the road, North of the bridge (as indicated by observed valve covers and fire hydrants). The water lines appear to be several feet off the paved roadway in the observed locations. No manholes, valve cover, or utility markers for the water line were observed near the bridge. Gas line markers were observed near houses located South of the bridge; however, no gas line markers were observed near the bridge.

The boring locations were proposed and laid out by GFT. Both borings were marked with white survey paint in the Northbound (NB) Lane of Mink Street (CR-41). B-001 was staked approximately six feet South of the South Abutment Joint and approximately 4 feet West of the edge of roadway NB. B-002 was staked approximately six feet North of the North Abutment Joint and approximately 4 feet West of the edge of roadway NB.

3.0 EXPLORATION

3.1 Historical Explorations

Based on the ODOT Transportation Information Mapping System (TIMS), no previous explorations were available within or near the limits of the project site.

3.2 2024 Project Exploration

Between May 21st and May 22nd, 2024, two exploratory borings were advanced. The borings were designated B-001-0-24 and B-002-0-24. The project exploration was developed and completed in accordance with the Ohio Department of Transportation's (ODOT) *Specifications for Geotechnical Explorations* (SGE), dated January 19, 2024.

A Mobile B-57 track-mounted rig was used to advance both the borings, utilizing a 3.25-inch diameter hollow stem augers and 2.0-inch outside diameter split spoon samplers. The energy ratio of the hammer was 76.8% and was last calibrated on May 1, 2023. CTL Engineering, Inc. performed the soil sampling of the borings. All field samples were sealed in glass jars and transported to CTL's laboratory in Columbus, Ohio for testing. The borings were backfilled or sealed according to ODOT's SGE. The stations and offsets of the borings are found on the logs in Appendix B: Subsurface Exploration and Laboratory Testing Results and Appendix C: Structural Foundation Exploration Sheets.

3.2.1 Laboratory Testing

In the laboratory, all samples from the 2024 borings were visually classified and tested for natural moisture content. Complete classifications (grain size gradations, 2-hour hydrometer, and liquid and plastic limits) were performed on selected fine-grained material, and grain-size analyses were performed on selected non-plastic samples. Hand penetrometer readings were taken in the field and in the lab, where applicable. A summary of the laboratory testing samples for the 2024 borings is presented in Table 3.2.1-1. All testing data can be found on the boring logs in Appendix B: Subsurface Exploration and Laboratory Testing Results.

Table 3.2.1-1: 2022 Exploration Soil Classification Testing

SOIL CLASSIFICATION	AVERAGE GROUP INDEX	MECHANICAL CLASSIFICATION	VISUAL CLASSIFICATION
A-1-b	0	2	8
A-2-4	0	2	6
A-4a	4	8	16
A-6b	6	1	1
A-7-5	20	1	1

4.0 FINDINGS

All the boring logs in 8.5 in. x 11 in. format from the 2024 exploration are presented in Appendix B: Subsurface Exploration and Laboratory Testing Results. The boring locations are shown on the Structure Foundation Exploration sheets for the proposed bridge, in Appendix C: Structure Foundation Exploration Sheets.

4.1 Subsurface Stratigraphy

The site consists of mostly loose to medium dense stone fragments or gravel with sand and silt with minor layers of medium stiff elastic clay, stiff silty clay, or sandy silt, overlying very stiff sandy silt and very dense sandy silt with boulders.

Stratum 1: Elastic Clay

Minor, shallow brown medium stiff elastic clay (ODOT A-7-5) "and" silt, little sand, trace gravel fill present only in boring B-001-0-24.

Stratum 2: Stone Fragments with Sand and Silt

Very Loose to medium dense gravel with sand and silt, trace clay or medium dense (ODOT A-2-4).

Stratum 3: Silty Clay or Sandy Silt

Minor, two to two and a half feet of stiff brown to gray, damp to wet sandy silt (ODOT A-4a), little gravel, some clay in B-001-0-24 and stiff brown to black moist silty clay (ODOT A-6b), little gravel, some sand in B-002-0-24.

Stratum 4: Gravel with Sand

Dense gray, moist to wet gravel with sand, little silt, trace clay (ODOT A-1-b) twelve to thirteen feet thick. It was noted that there was a petroleum odor and uncontrolled fill to a depth of 21 feet BGE in boring B-001-0-24.

Stratum 5: Sandy Silt

Very stiff, dark gray, damp sandy silt (ODOT A-4a) with a little to some gravel and some clay. After the boulder zone in boring B-002-0-24, the boring transitions back to cohesive, very stiff to hard sandy silt until termination.

Stratum 5a: Sandy Silt with Boulders

Very dense sandy silt with limited recovery (ODOT A-4a) containing boulders was encountered at the same elevation (EL 986.0) in both borings. This layer transitions into visually classified, very dense gravel with sand (ODOT a-2-4) and silt until boring B-001-0-24 was terminated.

4.2 Groundwater

A groundwater investigation, including a study of seasonal fluxes in the natural water table, was not completed as part of this geotechnical exploration. As such, only observations made during the exploration at the specific locations of each boring were available for interpretation regarding the groundwater conditions at the site. The contractor should make their own assessments for the need of ground water control during excavation.

The groundwater was encountered at 10 feet BGE within the stiff sandy silt interbed within the gravel with sand and silt in Boring B-001-0-24 and 10 feet BGE within the granular stone fragments with sand and silt in B-002-0-24.

5.0 BRIDGE FOUNDATION ANALYSIS AND RECOMMENDATIONS

The calculations discussed in this section are based on the preliminary plans produced by GFT's Structure and Roadway Engineering groups. The calculations and analyses in this report have been completed in accordance with the Ohio Department of Transportation (ODOT) *Bridge Design Manual (BDM)*, 2020 Edition, updated July 2024, the ODOT *Geotechnical Design Manual (GDM)*, July 2024, and ODOT *Specifications for Geotechnical Explorations (SGE)*, January 2024.

5.1 Scour Analysis

Based on the laboratory results, the following scour parameters in Table 5.1-1 were calculated based on ODOT's GDM, Section 1302. The Scour Analysis can be found in Appendix D. High plastic soil sample was encountered at the top 6.5 feet of B-001-0-24. SS-1 and SS-2 of B-001-0-24 contains PI exceeds the range for the application of the equation of τ_c and $D_{50, equiv}$, it is recommended that the top two samples were ignored from the scour analysis since they are also above bottom of footing.

Table 5.1-1: Summary of Soil Parameters for Scour Analysis

Boring ID	Elevation	D_{50}	τ_c	$D_{50, equiv}$	Erosion Category
		(mm)	(psf)	(mm)	(EC)
B-001-0-24	1038.1' to 1036.6'	0.008	0.507*	24.286*	3.947
	1035.6' to 1034.1'	-	0.112*	5.369*	3.947
	1033.1' to 1031.6'	0.130	0.129	6.166	3.168
	1030.6' to 1029.1'	0.039	0.199	9.541	2.868
	1028.6' to 1027.1'	0.883	0.018	0.883	2.135
	1027.1' to 1025.6'	1.744	0.036	1.744	2.490
	1025.6' to 1024.1'	1.744	0.036	1.744	2.490
B-002-0-24	1038.1' to 1036.6'	1.635	0.034	1.635	2.456
	1035.6' to 1034.1'	1.424	0.030	1.424	2.384
	1031.6' to 1030.1'	0.187	0.002	0.090	1.325
	1030.1' to 1028.6'	-	0.243	11.646	3.612
	1028.6' to 1027.1'	0.067	0.149	7.133	3.612
	1027.1' to 1025.6'	1.139	0.024	1.139	2.268
	1025.6' to 1024.1'	1.139	0.024	1.139	2.268
	1024.1' to 1022.6'	1.139	0.024	1.139	2.268

Note: Since the top two samples of B-001-0-24 contain soil samples with PI over 25, the scour parameters was developed with assumed PI of 25 for those two samples.

5.2 Foundation Recommendation

The bridge is to be supported on twelve-inch diameter, driven cast-in-place concrete pipe piles (CIP). The piles will be driven to the designed Ultimate Bearing Value (UBV). Static analyses and dynamic analyses were performed for both abutments and the results are summarized in Table 5.2-1.

Table 5.2-1 Friction Pile Design Summary at Abutments

Sub-structure	Bottom of Footing Elevation ¹	Max. Factored Axial Pile Load (kips)	Pile Diameter (inches)
Rear Abutment	1031.80	213.5	12
Forward Abutment	1032.10	213.5	12

Note: 1. All the Elevation data has been rounded to 0.1 feet.

Scour analysis indicates the 50-year and 100-year scour elevation is very close, 100-year scour elevation is therefore used for design. A contraction scour elevation of 1029.4 and 1033.6 for rear abutment and forward abutment, respectively, and a local scour elevation of 1026.3 and 1033.8 for rear abutment and forward abutment, respectively. Since the difference between the contraction scour and local scour is minimum, the local scour is ignored for forward abutment.

The boring log indicates that the free water level is very close to the bottom of footing elevation, water level was therefore modeled at the bottom of footing elevation for the pile design. The dense bouldery zone layers were modeled as cohesionless soil with high friction angles.

The components of the nominal pile side resistance were determined according to the ODOT BDM 2020 Eq. C305.3.2.4-1, and the setup factors for side friction were determined based on ODOT soil classification according to BDM 2020, Table 305-2. At both abutments, the contribution of setup due to the cohesive subsurface soil is considered by performing a "driving resistance" analysis considering the driving losses with pile setup factors. An ultimate resistance bearing analysis was also performed for the long-term condition after pile setup has occurred. The estimated driving resistance indicates that driving losses would increase the length of the pile during driving by less than 10 feet with End of Initial Driving (EOID) conditions, and therefore, setup is not included in the design.

Dynamic drivability analyses were then performed with an ultimate bearing value with setup factors. The assumed energy of the hammer used in the GRLWEAP analysis for all the substructures was 43.240 kip-ft/kw (Delmag D-19-42), which is common in Ohio practice. The Estimated Pile Lengths and Order Lengths were calculated based on recommendations in the ODOT BDM 2020, Section 305.3.5.2. The steel grade and pile wall thicknesses were determined by the results of the drivability analysis. The FHWA soil model was used in the drivability analysis with soil parameters imported in the static analysis and modified per ODOT's GDM. The APILE static analysis design values for each substructure are summarized in Table 5.2-2. The GRLWEAP parameters can be found along with the full calculation in Appendix D.

Table 5.2-2 APILE Static Analysis Design Parameters

Sub-structure	Boring	Soil Strata	Bottom El.	Depth below Ground	Depth below Ground after Scour	γ_m (pcf)	γ' (pcf)	Φ (deg)	S_u^1 (psf)	APILE Reduction Factor
Rear Abutment	B-001-0-24	A-4a	1029.0	2.8	NA	118	55.6	NA	1125	0.75
		A-2-4	1027.5	4.3	NA	128	65.6	39.2	NA	0.83
		A-1-b	1022.0	9.8	5.2	128	65.6	41.2	NA	1.00
		A-1-b	1018.5	13.3	8.7	125	62.6	37.3	NA	1.00
		A-1-b	1016.0	15.8	11.2	128	65.6	41.0	NA	1.00
		A-4a	1012.0	19.8	15.2	125	62.6	NA	3000	0.67
		A-4a	1007.5	24.3	19.7	132	69.6	NA	5000	0.67
		A-4a	997.5	34.3	29.7	120	57.6	NA	1563	0.67
		A-4a	993.0	38.8	34.2	122	59.6	NA	2125	0.67
		A-4a	986.0	45.8	41.2	132	69.6	NA	5125	0.67
		A-2-4 ²	966.0	65.8	61.2	140	77.6	40	NA	0.83
Forward Abutment	B-008-0-21	A-2-4	1030.5	1.6	NA	118	55.6	30.9	NA	0.83
		A-6b	1028.0	4.1	NA	128	65.6	NA	4000	0.57
		A-1-b	1021.0	11.1	6.2	128	65.6	41.5	NA	1.00
		A-1-b	1016.0	16.1	11.2	132	69.6	42.0	NA	1.00
		A-4a	1011.0	21.1	16.2	125	62.6	NA	3375	0.67
		A-4a	1009.0	23.1	18.2	140	77.6	NA	6163	0.67
		A-4a	996.0	36.1	31.2	122	59.6	NA	2000	0.67
		A-4a	986.0	46.1	41.2	140	77.6	NA	6934	0.67
		A-2-4 ²	971.0	61.1	56.2	140	77.6	40	NA	0.83

Note: 1. For cohesive layers, the undrained shear strength (S_u) of the layer was calculated based on $S_u = f_1 \times N_{60} \times p_a / 1000$, per stroud (1997, 1989).

2. The very dense bouldery zone layers were modeled as cohesionless soil with a high friction angle.

The estimated pile tip elevations were linearly interpreted from the static friction pile analyses (APILE) and are presented in Table 5.2-3, along with the Estimated Pile Lengths and Order Lengths in Table 5.0-4. The pile tip elevation was determined based on the "Scour Condition" analysis. The "No Scour Condition" analysis was used to determine the UVB and R_{ssc} (nominal amount of side resistance (kips) that must be overcome during driving through the soil in the scour zone) at the abutments. Since there will be no soil overburden for both abutments at the time of construction. Therefore, the subsurface model starts at the bottom of the footing for No Scour Condition. For Scour Condition, the subsurface model starts from the channel (contraction) scour elevation with zero-friction length down to the local scour elevation.

Table 5.2-3 Friction Pile Design Summary

Sub-structure	Pile Diameter (in.)	Pile Length including initial loss (ft)	Pile length without initial loss (ft)	UBV (kips)	EOID (kips)	R _{SSC} (kips)	R _{SSU} (kips)	R _n (kips)	Bottom of Footing El. (ft)	Pile Tip Elevation (ft)
Rear Abutment	12	45.9	45.20	343.2	NA	38.2	NA	305	1031.8	986.6
Forward Abutment	12	46.7	40.8	305	NA	NA	NA	305	1032.1	991.3

The required UBV, required pile wall thicknesses, and steel grades are also presented in Table 5.2-4. Pile wall thickness of 0.33 and Grade 3 steel are recommended for both abutments, for construction purposes. The estimated driving resistance indicates driving losses would increase the length of the pile during driving by less than 10-ft with EOID compared to the UBV, therefore pile setup is not accounted for those two piles in the design.

All pile design calculations are presented in Appendix D.

Table 5.2-4 Pile Lengths Per ODOT BDM

Sub-structure	Pile Size (in)	UBV (Kips)	Estimated Pile Cutoff Elevation ¹	Estimated Pile Tip Elevation	Estimated Pile Length (ft.)	Order Length (ft.)	Thickness (inch)	Steel Grade
Rear Abut.	12	343.2	1032.8	986.6	50	55	0.28	3
Forward Abut.	12	305	1033.1	991.3	45	50	0.28	3

Note:

1. Estimated Pile Cutoff elevation is one foot above the bottom of footing for each abutment.

The following foundation note is provided for the inclusion in plans.

PILE DESIGN LOADS (ULTIMATE BEARING VALUE): The Ultimate Bearing Value (UBV) is 343.2 kips per pile for rear abutment piles, and 305 kips per pile for forward abutment. The UBV for the rear abutment piles includes an additional 38.2 kips per pile due to the possibility of losing 5.5 ft. of frictional resistance due to scour. Drive the rear abutment piles to the UBV or a tip elevation of 986.6 and drive forward abutment to the UBV or a tip elevation of 991.3, whichever is deeper.

Rear Abutment Piles:

12" CIP piles 55 feet long, order length

1 Dynamic load tests

Provide plain Grade 3 cylindrical casings with a minimum pile wall thickness of 0.28 inch for the cast-in place reinforced concrete piles.

Forward Abutment Piles:

12" CIP piles 50 feet long, order length

1 Dynamic load tests

Provide plain Grade 3 cylindrical casings with a minimum pile wall thickness of 0.28 inch for the cast-in-place reinforced concrete piles.

6.0 QUALIFICATIONS

The analyses and recommendations mentioned within this Structure Foundation Exploration report are based upon the data obtained from the project borings advanced at the specific locations shown in the Geotechnical Profile (Appendix C). Variations between these locations and other onsite areas may not become evident until construction. If any such variations from the logged material is encountered, ODOT and GFT should be informed so that recommendations can be adjusted accordingly.

We appreciate the opportunity of providing our services to you. If you have any questions, please contact me.

Sincerely,
GFT Infrastructure, Inc.

A handwritten signature in blue ink, appearing to read 'Thomas Monaco', is positioned above the printed name.

Thomas L. Monaco, P.E.
Principal Geotechnical Engineer
Geotechnical Group

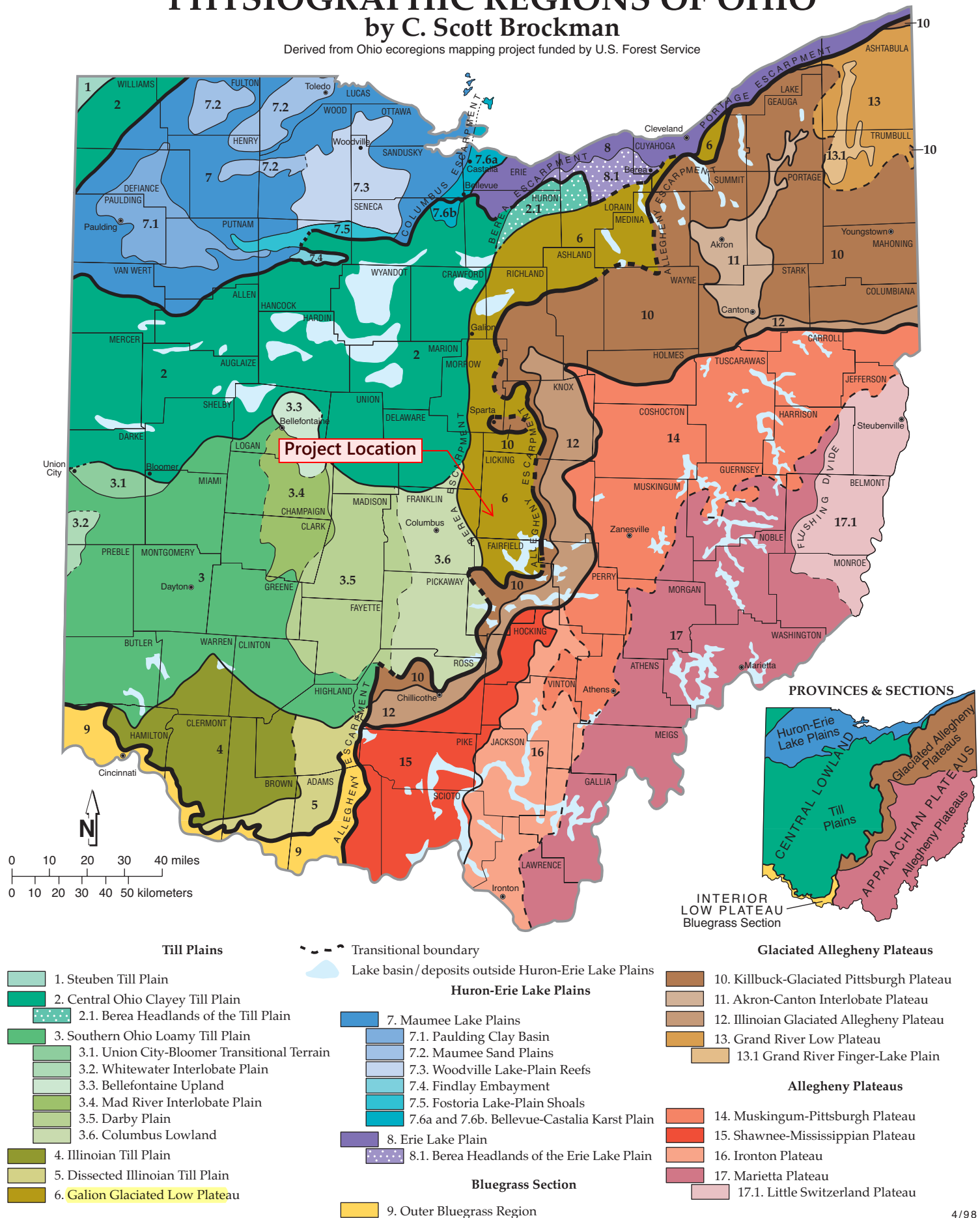
APPENDIX A

Geological Information

PHYSIOGRAPHIC REGIONS OF OHIO

by C. Scott Brockman

Derived from Ohio ecoregions mapping project funded by U.S. Forest Service

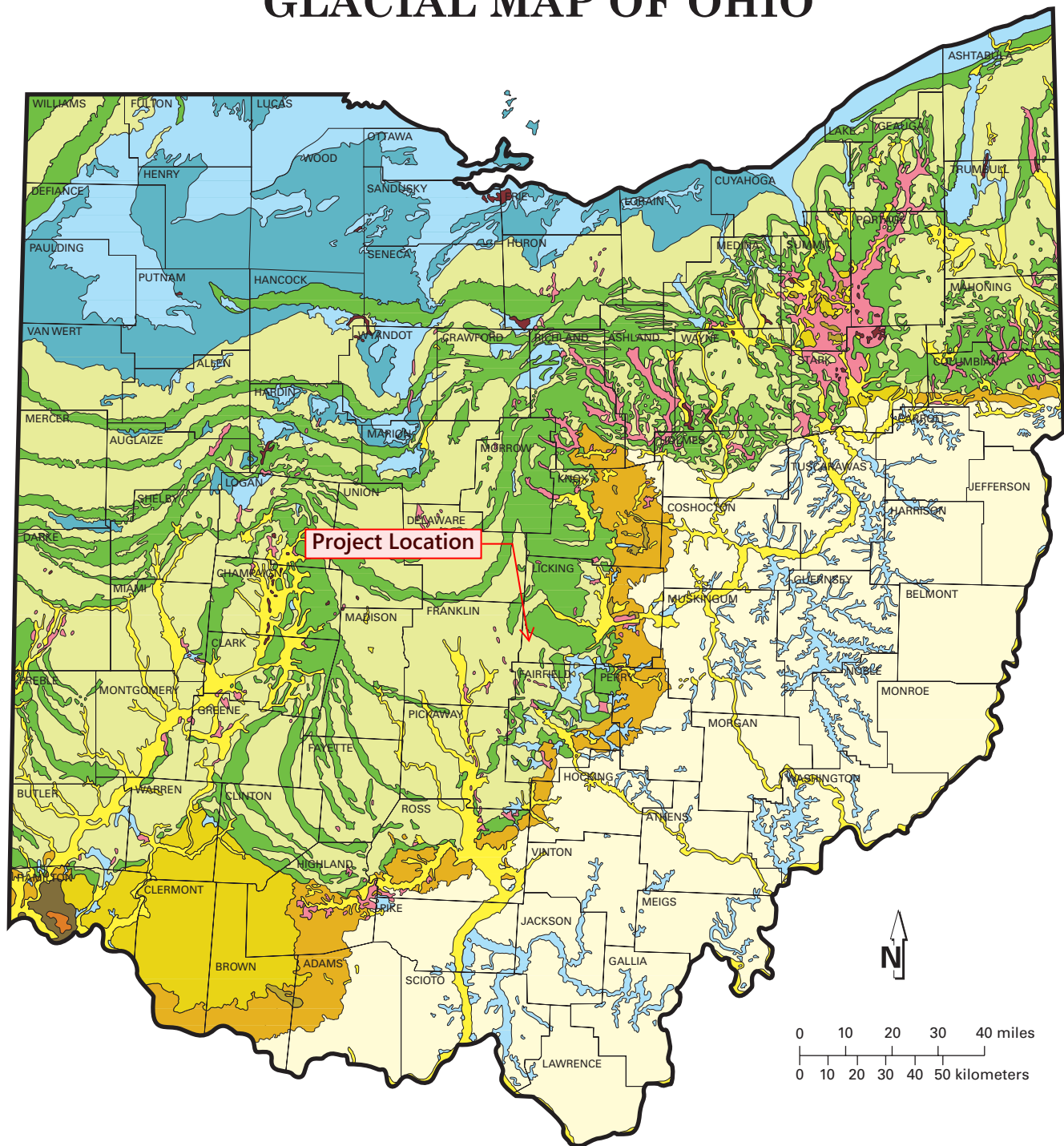


PHYSIOGRAPHIC REGIONS OF OHIO

Major Divisions	CENTRAL LOWLAND			INT. LOW PLATEAUS			
	Provinces	Sections *	Till Plains				
DISTINGUISHING CHARACTERISTICS OF REGIONS & DISTRICTS				GEOLOGY		BOUNDARIES	
1. Steuben Till Plain. Hummocky terrain with rolling hills, interspersed flats and closed depressions; wetlands, few streams, deranged drainage; only a small part of the region is in Ohio; elevation 950'-1100', moderately low relief (60')				Wisconsinan-age (latest Ice-Age) loamy till from a northern source (Saginaw glacial lobe) over Mississippian-age Coldwater Shale		Southeast: edge of Wabash Moraine	
2. Central Ohio Clayey Till Plain. Surface of clayey till; well-defined moraines with intervening flat-lying ground moraine and intermorainal lake basins; no boulder belts; about a dozen silt-, clay- and till-filled lake basins range in area from a few to 200 square miles; few large streams; limited sand & gravel outwash; elevation 700'-1150', moderate relief (100')				Clayey, high-lime Wisconsinan-age till from a northeastern source (Erie glacial lobe) and lacustrine materials over Lower Paleozoic-age carbonate rocks and, in the east, shales; loess thin to absent		North: Lake Plain; northeast: limit of Berea Sandstone; east: Berea Escarpment; south: Powell and Union City/Bloomer Moraines; northern segment boundaries: Wabash Moraine and lake plain	
2.1. Berea Headlands of the Till Plain. Gently rolling to flat terrain of thin drift descending to Lake Erie; punctuated by more than 20 streamlined "whalebacks" of Berea Sandstone, 0.5 to 2.5 miles long, 30'-60' high; somewhat poorly drained; elevation 800'-1000', low relief (20')				Thin, clayey, medium-lime Wisconsinan-age till over resistant Mississippian-age Berea Sandstone		South: limit of Berea Sandstone; elsewhere: Berea Escarpment and/or margin of highest Pleistocene lake	
3. Southern Ohio Loamy Till Plain. Surface of loamy till; end and recessional moraines, commonly associated with boulder belts, between relatively flat-lying ground moraine, cut by steep-valleyed large streams; stream valleys filled with outwash and alternate between broad floodplains and narrows; buried valleys common; elevation 530'-1150', moderate relief (200')				Loamy, high-lime Wisconsinan-age till, outwash, and loess over Lower Paleozoic-age carbonate rocks and, in the east, shales		East: Berea and Allegheny Escarpments; north: Powell and Union City/Bloomer Moraines; south: limit of Wisconsinan-age till	
3.1. Union City-Bloomer Transitional Terrain. Well-defined moraines with low-relief, hummocky ground moraine like the Central Ohio Clayey Till Plain to the north; loamy till with loess cap like Southern Ohio Loamy Till Plain to the south; elevation 920'-1075', moderately low relief (30')				Loamy, high-lime Wisconsinan-age till with thin loess cap over Silurian-age dolomites		North: Bloomer Moraine and limit of loamy till; south: Union City Moraine	
3.2. Whitewater Interlobate Plain. An upland between two converging glacial lobes with hummocky moraines, moraine complexes, kames, boulder belts, and broad outwash trains/plains; contains highest elevations in Indiana (1257') and in adjacent Ohio counties (1240'); elevation in Ohio 980'-1240', moderate relief (150')				Loamy, high-lime Wisconsinan-age till and sand and gravel outwash over resistant Silurian-age carbonate rocks (north) and less resistant Ordovician-age shales and limestones (south)		North: limit of Knightstown/Farmersville Moraines and kame fields; east: high, dissected hills draining to Whitewater River	
3.3. Bellevue Upland. Moderately high relief (250') dissected topography with moraine complexes, boulder belts, high-gradient major streams, caves and sinkholes; few glacial depressions/kettles compared to surrounding areas; elevation 1100'-1549', includes highest elevation in Ohio (Campbell Hill, 1549')				Loamy, high-lime Wisconsinan-age till over generally deeply buried Silurian- to Devonian-age carbonate rocks and Ohio Shale		North: areas with hilltops above 1200'; elsewhere: hilltops above about 1300'	
3.4. Mad River Interlobate Plain. Area between two major converging glacial lobes with extensive outwash, outwash terraces, and bordering moraines; springs and cool, ground-water-fed surface waters; elevation 800'-1350', moderate relief (200')				Loamy, high-lime Wisconsinan-age till and sand and gravel outwash over Silurian- to Devonian-age carbonate rocks and Ohio Shale		East and north: rear edge of Cable Moraine Complex; south: outwash to Clifton Gorge; west: western edge of Mad River Outwash	
3.5. Darby Plain. Moderately low relief (25'), broadly hummocky ground moraine with several broad, indistinct recessional moraines; between hummocks are broad, poorly drained swales which held wet prairies/meadows in pioneer days; few large streams; elevation 750'-1100'				Loamy, high-lime Wisconsinan-age till and sparse outwash over Silurian- and Devonian-age carbonate rocks and Ohio Shale in the southeast		South and west: front of Reesville and rear of Cable Moraines; North: Powell Moraine; east: increasing eastward slope (see 3.6)	
3.6. Columbus Lowland. Lowland surrounded in all directions by relative uplands, having a broad regional slope toward the Scioto Valley; many larger streams; elevation 600'-850' (950' near Powell Moraine), moderately low relief (25')				Loamy, high-lime (west) to medium-lime (east) Wisconsinan-age till and extensive outwash in Scioto Valley over deep Devonian- to Mississippian-age carbonate rocks, shales, and siltstones		North: Powell Moraine; east and south: Berea and/or Allegheny Escarpments; west: flatter and higher Darby Plain	
4. Illinoian Till Plain. Rolling ground moraine of older till generally lacking ice-constructional features such as moraines, kames, and eskers; many buried valleys; modern valleys alternating between broad floodplains and bedrock gorges; elevation 600'-1100', moderately low relief (50')				Silt-loam, high-lime, Illinoian-age till with loess cap; soils leached several feet; underlain by Ordovician- and Silurian-age carbonate rocks and calcareous shales		North: Wisconsinan glacial margin (Cuba and Hartwell Moraines); elsewhere: limit of common till-covered hillslopes	
5. Dissected Illinoian Till Plain. Hilly former till plain in which glacial deposits have been eroded from many valley sides; relatively high stream density; elevation 600'-1340', moderate relief (200')				Hilltops of high-lime Illinoian-age till with loess cap; slopes of bedrock- and till-derived colluvium and Ordovician- and Silurian-age carbonate rocks and calcareous shales		East: maximum glacial margin; elsewhere: limit of general absence of till on hillslopes	
6. Galion Glaciated Low Plateau. Rolling upland transitional between the gently rolling Till Plain and the hilly Glaciated Allegheny Plateau; mantled with thin to thick drift; elevation 800'-1400', moderate relief (100')				Medium- to low-lime Wisconsinan-age till over Mississippian-age shales and sandstones		North: limit of Berea Sandstone; west: Berea Escarpment; south and east: Allegheny Escarpment	
7. Maumee Lake Plains. Flat-lying Ice-Age lake basin with beach ridges, bars, dunes, deltas, and clay flats; contained the former Black Swamp; slightly dissected by modern streams; elevation 570'-800', very low relief (5')				Pleistocene-age silt, clay, and wave-planed clayey till over Silurian- and Devonian-age carbonate rocks and shales		Northeast: Lake Erie; elsewhere: margin of highest Pleistocene lake	
7.1. Paulding Clay Basin. Nearly flat lacustrine plain; most clayey of all Lake Plain subregions; low-gradient, highly meandering streams; easily ponded soils; elevation 700'-725', extremely low relief (less than 5')				Pleistocene-age lacustrine clay over clay till and Silurian-age dolomites		Northeast: subdued ("drowned") remnant of Defiance Moraine; elsewhere: limit of lacustrine clay	
7.2. Maumee Sand Plains. Lacustrine plain mantled by sand; includes low dunes, inter-dunal pans, beach ridges, and sand sheets of glacial lakeshores; well to poorly drained; elevation 600'-800', very low relief (10')				Late Wisconsinan-age sand over clay till and lacustrine deposits; Silurian- and Devonian-age carbonate rocks and shales buried deeply.		Limit of sandy deposits and/or low dunes	
7.3. Woodville Lake-Plain Reefs. Very low relief (10') lacustrine plain with low dunes and lake-margin features, punctuated by more than 75 ancient bedrock reefs rising 10' to 40' above the level of the plain and ranging in area from 0.1 to 3.0 square miles; the oblong reefs are thinly draped with drift; elevation 600'-775'				Thin to absent Wisconsinan-age wave-planed clay till, lacustrine deposits, and sand over Silurian-age reefal Lockport Dolomite		Limit of thinly mantled Lockport Dolomite (Bowling Green Fault to the west and the Defiance Moraine to the south)	
7.4. Findlay Embayment. Very low relief (10'), broadly rolling lacustrine plain; embayment of ancestral Lake Erie in which relatively coarse lacustrine sediments collected; elevation 775'-800'				Silty to gravely Wisconsinan-age lacustrine deposits and wave-planed clayey till over Silurian-age Lockport Dolomite		West: 775' beach ridge; north: Defiance Moraine; south: margin of highest Pleistocene lake level	
7.5. Fostoria Lake-Plain Shoals. Portion of the Defiance Moraine lightly eroded by shallow Lake Maumee with low north-south trending hillocks and shallow, closed depressions; many sandy areas; elevation 750'-825', low relief, decreasing westward (10'-15')				Silty to gravely Wisconsinan-age lacustrine deposits and wave-planed clay till over deeply covered Silurian-age dolomite		South and east: unmodified Defiance Moraine; elsewhere: very low-relief lake plain	
7.6a and 7.6b. Bellevue-Castalia Karst Plain. Hummocky plain of rock knobs and numerous sinkholes, large solution features, and caves; large springs; thinly mantled by drift; region straddles both Lake Plain (7.6a) and Till Plain (7.6b); 7.6a has greatest relief of any Lake Plain region (25'); elevation 570'-825'				Columbus and Delaware Limestones overlain by thin clay till in 7.6b, and thin siltly and sandy Wisconsinan-age lacustrine deposits and wave-planed clay till in 7.6a		Limit of thinly mantled Columbus and Delaware Limestones, which is marked in the west by the Columbus Escarpment	
8. Erie Lake Plain. Edge of very low-relief (10') Ice-Age lake basin separated from modern Lake Erie by shoreline cliffs; major streams in deep gorges; elevation 570'-800'				Pleistocene-age lacustrine sand, silt, clay, and wave-planed till over Devonian- and Mississippian-age shales and sandstones		North: Lake Erie; south: margin of highest Pleistocene lake	
8.1 Berea Headlands of the Erie Lake Plain. Portion of the Erie Lake Plain underlain by resistant Berea Sandstone; several large sandstone headlands jut into the Ice-Age lake basin; contains several streamlined "whalebacks" of Berea Sandstone, 0.5 to 2.0 miles long, 20'-35' high; poorly drained; elevation 670'-800', very low relief (10')				Thin lacustrine deposits over thin, wave-planed, clayey, medium-lime Wisconsinan-age till; underlain by resistant Berea Sandstone		North: portion of Lake Plain underlain by soft shales; south: margin of highest Pleistocene lake	
9. Outer Bluegrass Region. Moderately high relief (300') dissected plateau of carbonate rocks; in east, caves and other karst features relatively common; in west, thin, early drift caps narrow ridges; elevation 455'-1120'				Ordovician- and Silurian-age dolomites, limestones, and calcareous shales; thin pre-Wisconsinan drift on ridges in west; silt-loam colluvium		Eastern segment: maximum glacial margin and high eastern ridges capped by noncarbonate rocks; connected by Ohio River bluffs to western segment which is bounded by nondissected till plain	
10. Killbuck-Glaciated Pittsburgh Plateau. Ridges and flat uplands generally above 1200', covered with thin drift and dissected by steep valleys; valley segments alternate between broad drift-filled and narrow rock-walled reaches; elevation 600'-1505', moderate relief (200')				Thin to thick Wisconsinan-age clay to loam till over Mississippian- and Pennsylvanian-age shales, sandstones, conglomerates and coals		West and north: resistant sandstones of the Allegheny and Portage Escarpments; south and east: Wisconsinan glacial margin	
11. Akron-Canton Interlobate Plateau. Hummocky area between two converging glacial lobes dominated by kames, kame terraces, eskers, kettles, kettle lakes, and bogs/fens; deranged drainage with many natural lakes; elevation 900'-1200', moderate relief (200')				Sandy Wisconsinan-age and older drift over Devonian- to Pennsylvanian-age sandstones, conglomerates and shales		Limit of common, sandy ice-contact features and deposits	
12. Illinoian Glaciated Allegheny Plateau. Dissected, rugged hills; loess and older drift on ridgetops, but absent on bedrock slopes; dissection similar to unglaciated regions of the Allegheny Plateau; elevation 600'-1400', moderate relief (200')				Colluvium and Illinoian-age till over Devonian- to Pennsylvanian-age shales, siltstones and sandstones		North and west: Wisconsinan glacial margin; south and east: Illinoian (maximum) glacial margin	
13. Grand River Low Plateau. Gently rolling ground and end moraine having thin to thick drift; poorly drained areas and wetlands relatively common; elevation 760'-1200', low relief (20') except near Grand River Valley (200')				Clayey, low-lime Wisconsinan-age till over deeply buried, soft Devonian-age shales and near-surface Mississippian-age sandstones and shales		North: Portage Escarpment; south and west: Defiance Moraine; southeast: increasing relief from proximity of buried Pennsylvanian-age sandstones	
13.1. Grand River Finger-Lake Plain. Very low relief (10') lake deposits in steep-sided troughs (200' relief) within the Grand River Low Plateau; cut by glacial and stream erosion; extensive wetlands; elevation 800'-900'				Surficial lacustrine clay and drift over deeply buried, soft Devonian-age shales		Margins of steeply sloping troughs containing the Grand River and parts of Rock and Mosquito Creeks	
14. Muskingum-Pittsburgh Plateau. Moderately high to high relief (300'-600') dissected plateau having broad major valleys that contain outwash terraces, and tributaries with lacustrine terraces; medium-grained bedrock sequences coarser than those in Marietta Plateau (17) but finer than those in Ironton Plateau (16); remnants of ancient Teays-age drainage system uncommon; elevation 650'-1400'				Mississippian and Pennsylvanian-age siltstones, shales, sandstones and economically important coals and claystones; Wisconsinan-age sand, gravel, and lacustrine silt; silt-loam colluvium		North and west: maximum glacial margin; southeast: transition to finer grained bedrock; southwest: transition to coarser grained bedrock	
15. Shawnee-Mississippian Plateau. High relief (400'-800'), highly dissected plateau of coarse and fine grained rock sequences; most rugged area in Ohio; remnants of ancient lacustrine clay-filled Teays drainage system are extensive in lowlands, absent in uplands; elevation 490'-1340'				Devonian- and Mississippian-age shales, siltstones, and locally thick sandstones; Pleistocene-age sandy outwash in Scioto River; Teays-age Minford Clay; silt-loam and channery colluvium		North: Maximum glacial margin; west: carbonate bedrock; east: limit of Mississippian-age bedrock	
16. Ironton Plateau. Moderately high relief (300') dissected plateau; coarser grained coal-bearing rock sequences more common than in other regions of the Allegheny Plateau; common lacustrine clay-filled Teays Valley remnants; elevation 515'-1060'				Pennsylvanian-age (Pottsville, Allegheny and Conemaugh Groups) cycles of sandstones, siltstones, shales and economically important coals; Pleistocene (Teays)-age Minford Clay; silt-loam and channery colluvium		West: limit of common Pennsylvanian-age bedrock; north and east: gradation to finer rock sequences	
17. Marietta Plateau. Dissected, high-relief (generally 350', to 600' near Ohio River) plateau; mostly fine-grained rocks; red shales and red soils relatively common; landslides common; remnants of ancient lacustrine clay-filled Teays drainage system common; elevation 515'-1400'				Pennsylvanian-age Upper Conemaugh Group through Permian-age Dunkard Group cyclic sequences of red and gray shales, and siltstones, sandstones, limestones and coals; Pleistocene (Teays)-age Minford Clay; red and brown silty-clay loam colluvium; landslide deposits		North and west: transition to medium-grained Lower Conemaugh rocks; east: Flushing Divide	
17.1. Little Switzerland Plateau. Highly dissected, high-relief (generally 450', to 750' along Ohio River) plateau; mostly fine-grained rocks; red shales and red soils relatively common; landslides common; high-gradient shale-bottomed streams subject to flash flooding; no remnants of ancient Teays drainage system; elevation 540'-1400'				Similar to Marietta Plateau but lacking Pleistocene (Teays)-age Minford Clay		North: transition to medium-grained rocks; west and south: Flushing Divide; east: Ohio River	
APPALACHIAN HIGHLANDS				APPALACHIAN PLATEAUS			
Allegheny (Kanawha) Plateaus				Glaciated Allegheny (Southern New York) Plateaus		10. Killbuck-Glaciated Pittsburgh Plateau. Ridges and flat uplands generally above 1200', covered with thin drift and dissected by steep valleys; valley segments alternate between broad drift-filled and narrow rock-walled reaches; elevation 600'-1505', moderate relief (200')	
						11. Akron-Canton Interlobate Plateau. Hummocky area between two converging glacial lobes dominated by kames, kame terraces, eskers, kettles, kettle lakes, and bogs/fens; deranged drainage with many natural lakes; elevation 900'-1200', moderate relief (200')	
						12. Illinoian Glaciated Allegheny Plateau. Dissected, rugged hills; loess and older drift on ridgetops, but absent on bedrock slopes; dissection similar to unglaciated regions of the Allegheny Plateau; elevation 600'-1400', moderate relief (200')	
						13. Grand River Low Plateau. Gently rolling ground and end moraine having thin to thick drift; poorly drained areas and wetlands relatively common; elevation 760'-1200', low relief (20') except near Grand River Valley (200')	
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						15. Shawnee-Mississippian Plateau. High relief (400'-800'), highly dissected plateau of coarse and fine grained rock sequences; most rugged area in Ohio; remnants of ancient lacustrine clay-filled Teays drainage system are extensive in lowlands, absent in uplands; elevation 490'-1340'	
						16. Ironton Plateau. Moderately high relief (300') dissected plateau; coarser grained coal-bearing rock sequences more common than in other regions of the Allegheny Plateau; common lacustrine clay-filled Teays Valley remnants; elevation 515'-1060'	
						17. Marietta Plateau. Dissected, high-relief (generally 350', to 600' near Ohio River) plateau; mostly fine-grained rocks; red shales and red soils relatively common; landslides common; remnants of ancient lacustrine clay-filled Teays drainage system common; elevation 515'-1400'	
						17.1. Little Switzerland Plateau. Highly dissected, high-relief (generally 450', to 750' along Ohio River) plateau; mostly fine-grained rocks; red shales and red soils relatively common; landslides common; high-gradient shale-bottomed streams subject to flash flooding; no remnants of ancient Teays drainage system; elevation 540'-1400'	

* Section names modified from Fenneman (1938, 1946).

GLACIAL MAP OF OHIO



WISCONSINAN (14,000 to 24,000 years old)	ILLINOIAN (130,000 to 300,000 years old)	PRE-ILLINOIAN (older than 300,000 years)	
Ground moraine	Ground moraine	Ground moraine	Kames and eskers
Wave-planed ground moraine	Dissected ground moraine	Dissected ground moraine	Outwash
Ridge moraine	Hummocky moraine		Lake deposits
			Peat
			Colluvium



GLACIAL DEPOSITS OF OHIO

Although difficult to imagine, Ohio has at various times in the recent geologic past (within the last 2.6 million years) had almost three-quarters of its surface area covered by vast sheets of ice perhaps as much as 1 mile thick. This period of geologic history is referred to as the Pleistocene Epoch or, more commonly, the Ice Age, although there is abundant evidence that Earth has experienced numerous other "ice ages" throughout its 4.6 billion years of existence.

Ice Age glaciers invading Ohio formed in central Canada in response to climatic conditions that allowed massive buildups of ice. Because of their great thickness these ice masses flowed under their own weight and ultimately moved south as far as northern Kentucky. Oxygen-isotope analysis of deep-sea sediments indicates that more than a dozen glaciations occurred during the Pleistocene. Portions of Ohio were covered by the last two glaciations, known as the Wisconsinan (the most recent) and the Illinoian (older), and by an undetermined number of pre-Illinoian glaciations.

Because each major advance covered the deposits left by the previous ice sheets, pre-Illinoian deposits (dark brown area on map) are exposed only in extreme southwestern Ohio in the vicinity of Cincinnati. Although the Illinoian ice sheet covered the largest area of Ohio, its deposits (light brown area on map) are at the surface only in a narrow band from Cincinnati northeast to the Ohio-Pennsylvania border. Most features shown on the map of the glacial deposits of Ohio are the result of the most recent or Wisconsinan-age glaciers.

The material left by the ice sheets consists of mixtures of clay, sand, gravel, and boulders in various types of deposits of different modes of origin. Rock debris carried along by the glacier was deposited in two principal fashions, either directly by the ice or by meltwater from the glacier. Some material reaching the ice front was carried away by streams of meltwater to form outwash deposits (yellow areas on map). These deposits normally consist of sand and gravel. Sand and gravel deposited by water on and under the surface of the glacier itself formed features called kames and eskers (red areas on map), which are recognized by characteristic shapes and composition. The distinctive characteristic of glacial deposits that have been moved by water is that the material was sorted by the water that carried it. The large

boulder-size particles were left behind and the smaller clay-size particles were carried far away, leaving the intermediate gravel- and sand-size material along the stream courses.

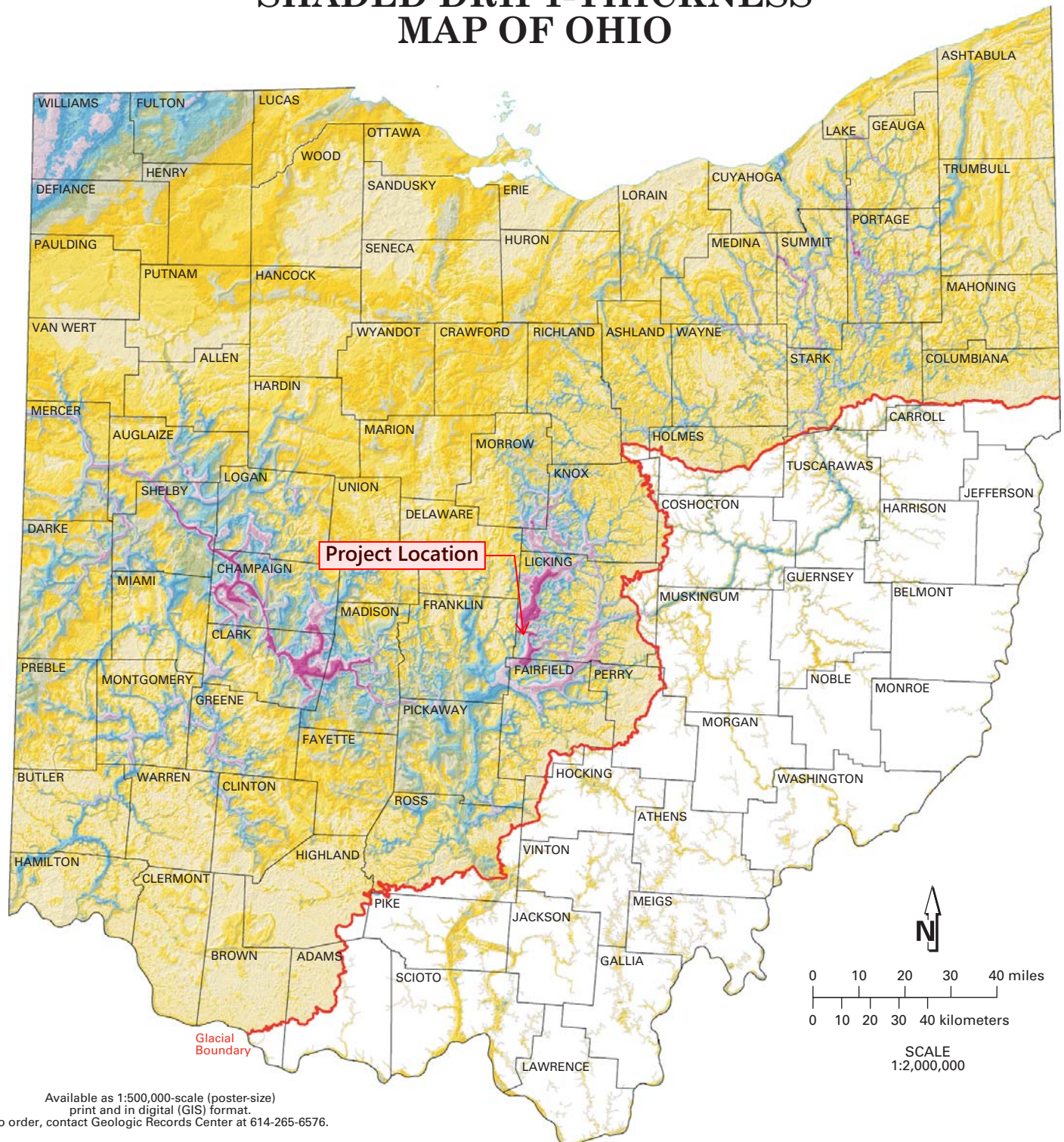
Clay- to boulder-size material deposited directly from the ice was not sorted. Some of the debris was deposited as ridges parallel to the edge of the glacier, forming terminal or end moraines (dark-green areas on map), which mark the position of the ice when it paused for a period of time, possibly a few hundred years. When the entire ice sheet receded because of melting, much of the ground-up rock material still held in the ice was deposited on the surface as ground moraine (light-green areas on map). The term glacial drift commonly is used to refer to any material deposited directly (*e.g.*, ground moraine) or indirectly (*e.g.*, outwash) by a glacier. Because the ice that invaded Ohio came from Canada, it carried in many rock types not found in Ohio. Pebbles, cobbles, and boulders of these foreign rock types are called erratics. Rock collecting in areas of glacial drift may yield granite, gneiss, trace quantities of gold, and, very rarely, diamonds. Most rocks found in glacial deposits, however, are types native to Ohio.

Many glacial lakes were formed during the time that ice covered Ohio. Lake deposits (light blue areas on map) are primarily very fine grained clay- and silt-size sediments. The most extensive area of lake deposits is in northern Ohio bordering Lake Erie. These deposits represent early stages in the development of Lake Erie as it is presently known. Other lake deposits accumulated in stream valleys whose outlets were temporarily dammed by ice or outwash. Many outwash-dammed lake deposits are present in southeastern Ohio far beyond the glacial boundary.

Certain deposits left behind by the ice are of economic importance, particularly sand and gravel, clay, and peat. Sand and gravel that have been sorted by meltwater generally occur as kames or eskers or as outwash along major drainageways. Sand and gravel are vital to Ohio's construction industry. Furthermore, outwash deposits are among the state's most productive sources of ground water.

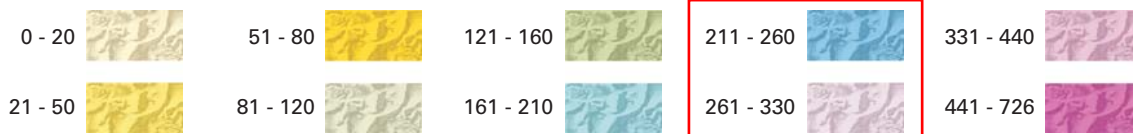
Glacial clay is used in cement and for common clay products (particularly field tile). The minor quantities of peat produced in the state are used mainly for mulch and soil conditioning.

SHADED DRIFT-THICKNESS MAP OF OHIO



EXPLANATION

Thickness (in feet) of drift in glaciated areas and some non-glaciated areas along glacial boundary, and of outwash and glaciolacustrine deposits in sediment-filled valleys beyond the glacial boundary.



Recommended citation: Ohio Division of Geological Survey, 2004, Shaded drift-thickness map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map SG-3, generalized page-size version with text, 3 p., scale 1:2,000,000.



SHADED DRIFT-THICKNESS MAP OF OHIO

INTRODUCTION

The drift-thickness map of Ohio depicts the thickness and distribution of glacially derived sediments (called drift) and post-glacial stream sediments overlying the buried bedrock surface. This map was produced by subtracting bedrock-surface elevations from land-surface elevations to produce a residual map of drift thickness. Colors portray thickness intervals of glacial and modern sediments, which can range up to several hundred feet.

Prior to the onset of continental glaciation in the Early Pleistocene Epoch, approximately 1.8 million years before present, the Ohio landscape was dominated by rolling hills and deeply incised, mature rivers and streams. A reduced version of the Division of Geological Survey's Shaded-Bedrock Topography map of Ohio (fig. 1) reveals some aspects of this old land surface. Erosion and deposition by Ice-Age continental glaciers advancing into northern and western Ohio produced a low-relief land surface compared to the unglaciated, high-relief land surface of southeastern Ohio (fig. 2). Comparing the shaded elevation map (fig. 2) with the shaded bedrock-topography map (fig. 1) reveals the dramatic impact of glaciation on the state's current landscape.

Drift thickness in western and northern Ohio (fig. 3) is highly variable, a consequence of numerous geologic factors acting in combination or alone. In some areas, drift has been deposited on a relatively flat bedrock surface and changes in drift thickness are primarily the result of variations in the amount of glacial material deposited. In other areas, drift has infilled a deeply incised buried-bedrock surface, and changes in drift thickness are primarily the result of variations in bedrock-surface elevation. In still other instances, the drift surface parallels the underlying bedrock surface to produce areas of relatively uniform drift thickness.

Distinct, narrow linear patterns of thick drift in western and central Ohio are the result of deep incisions in the underlying limestone and

dolomite bedrock by a large, northwest flowing drainage system, the Teays Valley system, that existed prior to and during early glaciations (fig. 1). The main Teays Valley entered the state at Wheelersburg (Scioto County), where remnants of the Teays Valley are still evident on the modern land surface. At Chillicothe (Ross County), the valley disappears under glacial sediments which cover western Ohio. However, the valley continues north, below the surface, to Circleville (Pickaway County) and then northwest to Mercer County where the valley exits the state into Indiana. Early southward-advancing glaciers blocked the north-flowing river system of the Teays and created immense lakes in southeastern Ohio.

In northeastern Ohio, narrow thick-drift areas south of Lake Erie were also preglacial bedrock valleys. These valleys were partially filled with thick deposits of till and glaciolacustrine (glacial lake) sediment and then re-excavated by later northward-flowing rivers such as the Cuyahoga River and the East Branch of Rocky River.

In northwestern Ohio, repeated scouring of the relatively soft bedrock surface by glacial ice flowing southwestward from the Lake Erie Basin destroyed most pre-existing drainage systems. In this part of Ohio, the bedrock surface is smooth and the upper surface of the drift has been planed off by wave action and deposition by a post-glacial, high-level ancestral Lake Erie. In the extreme northwest corner of Ohio, in Williams County and portions of Defiance County, drift thickens considerably because of numerous moraines that formed along the northwestern edge of the Erie Lobe.

In western Ohio, draping linear features of thick drift, called ridge moraines, formed along the temporarily stationary ice-front as glacial sediment was released from the ice. These ribbons of thick drift define the lateral dimensions of glacial ice lobes, particularly those of the last Wisconsinan ice sheet (figure 4). Many ridge moraines in western and northeastern Ohio have a draped appearance because south-flowing ice, impeded by bedrock highlands, moved more easily along major lowlands. The numerous resistant bedrock highlands in northeastern Ohio caused ridge moraines to be especially arcuate and closely stacked.

Southeastern Ohio is unglaciated and devoid of ice-deposited sediment (glacial till). Many southeast Ohio valleys, however, carried

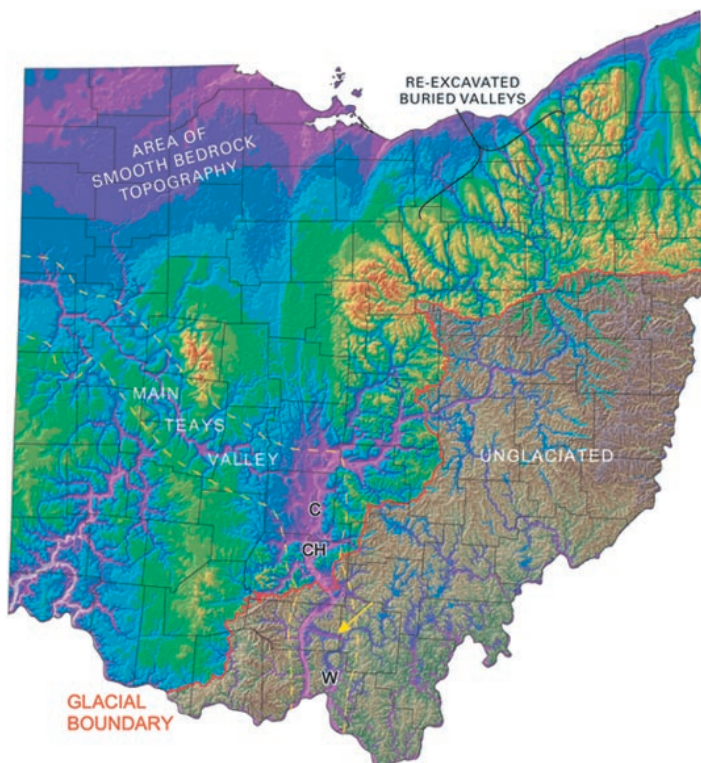


FIGURE 1.—Shaded bedrock-topography map of Ohio showing the sculpted bedrock surface that lies beneath glacial drift in northern and western Ohio and the land surface in unglaciated southeastern Ohio. Note the surface expression of the Teays Valley System south of the glacial boundary (arrow), the location of the main Teays Valley (between yellow dashed lines), the area of smooth bedrock topography, and the area of re-excavated preglacial bedrock valleys in northeastern Ohio. (W = Wheelersburg, C = Circleville, CH = Chillicothe) (modified from Ohio Division of Geological Survey, 2003).

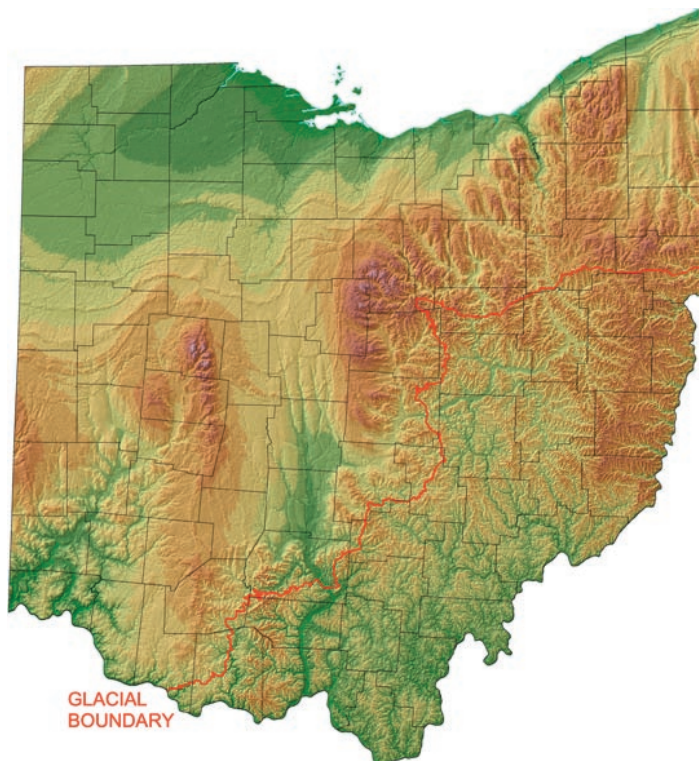
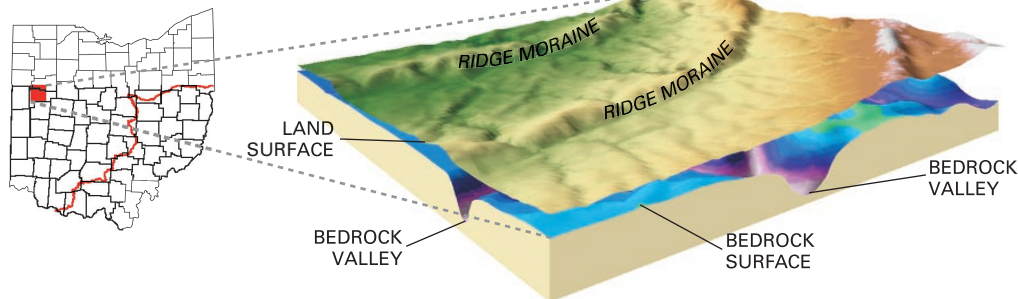


FIGURE 2.—Shaded elevation map of the land surface of Ohio with glacial boundary. Note the smooth landscape of glaciated northern and western Ohio compared to the high-relief landscape of unglaciated southeastern Ohio (modified from Powers, Laine, and Pavey, 2002).

FIGURE 3.—Schematic cross section of glacial drift overlying the bedrock surface. Note areas where drift thickness is controlled by thickening of glacial sediment over a relatively flat bedrock surface, by drift infilling bedrock valleys, or by fluctuations in both the land surface and the bedrock surface. Also note areas where valleys in the buried-bedrock surface are not evident on the land surface (illustration by Donovan M. Powers).



huge volumes of glacial meltwater away from the ice front and toward the Ohio River. In the process, many of these valleys were at times made deeper by the erosive force of fast-flowing meltwater streams, and at other times were partially filled with sediment. Some valleys in unglaciated Ohio contain thick deposits of clay and silt that accumulated on the bottoms of lakes that formed when glacial ice blocked the flow of rivers or when rapidly accumulating meltwater sediments blocked the mouths of smaller tributaries.

METHODS

Two digital data layers are required to generate the drift-thickness map: the surface-elevation layer and the bedrock-topography layer. Drift thickness is calculated by subtracting the bedrock-topography elevation from the land surface elevation. The bedrock-topography component is one of the products resulting from a multi-year effort by the ODNR, Division of Geological Survey to map the bedrock geology of Ohio. Bedrock-topography maps are required to determine the relief on the bedrock surface beneath thick layers of glacial drift. Bedrock-topography maps were created by the Division of Geological Survey for all 788 7½-minute topographic quadrangles in the state as part of a process to produce accurate bedrock-geology maps for glaciated portions of Ohio and for those areas beyond the glacial boundary where valleys are infilled with sediment. Data concentration and contour intervals on the original, hand-drawn bedrock-topography maps vary widely across the state in response to changing geologic and topographic conditions. These data consist mainly of water-well logs on file at the ODNR, Division of Water, supplemented by outcrop data, Ohio Department of Transportation bridge-boring data, and oil-and-gas-well data. During the course of mapping, over 162,000 data points were interpreted for bedrock-surface elevation and in some cases drift thickness. These points were plotted on maps and used as control for the bedrock-topography lines. Individual 24,000-scale bedrock-topography maps are available from the Division's Geologic Records Center.

Elevation contours and data points from the 788 bedrock-topography maps were digitized and compiled for the glaciated portions of the state and for the valleys beyond the glacial boundary containing significant accumulations of sediment deposited during and after glaciation. The bedrock-topography contours were digitally converted in an ArcGIS environment to create a continuous grid model (60 meter grid spacing). A statewide compilation map and digital dataset of the bedrock topography of Ohio (modified from Ohio Division of Geological Survey, 2003) are available from the Division of Geological Survey.

Uncolored areas of southeastern Ohio represent extensive portions of unglaciated Ohio where the land surface and the bedrock surface are essentially the same. On the original maps in these areas, bedrock-topography lines were restricted to the buried-valley portions of the map and were not drawn in upland portions.

The second component needed to create the drift-thickness map, the land-surface topography, is based largely on data derived from the U.S. Geological Survey's National Elevation Dataset (30 meter grid spacing). These data have been modified extensively by the Ohio Division of Geological Survey to replace some anomalous errors that are inherent in portions of the National Elevation Dataset. A statewide compilation map and digital dataset of the shaded elevation of Ohio (modified from Powers, Laine, and Pavey, 2002) are available from the Division of Geological Survey.

A grid of the digitized bedrock-topography contours was subtracted from a grid of the land-surface Digital Elevation Model to derive a third grid (60 meter grid spacing) representing the thickness of the drift. This grid surface was shaded from the northwest, slightly above the horizon, to produce the appearance of a three-dimensional surface.

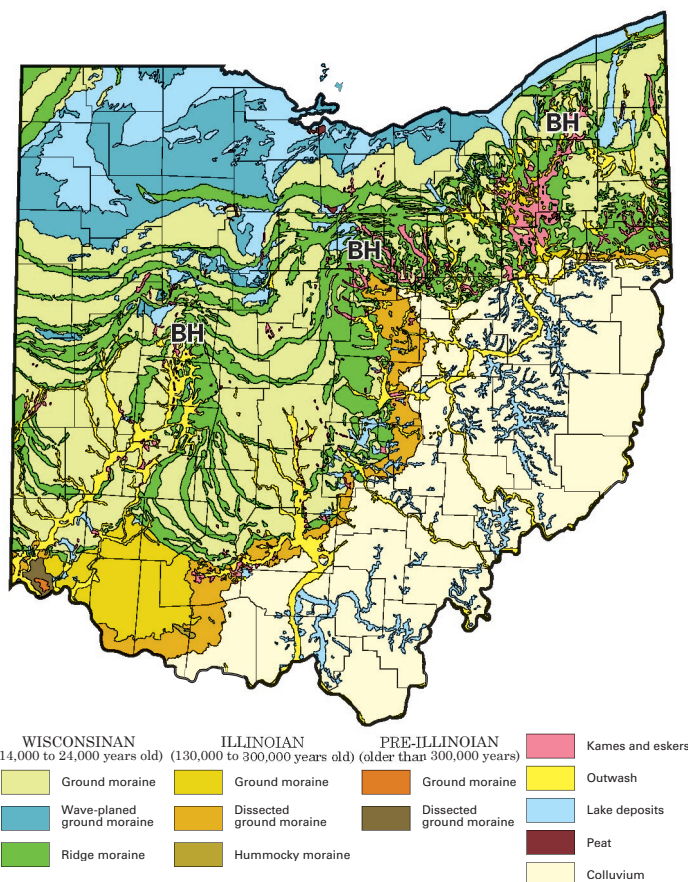


FIGURE 4.—Glacial map of Ohio showing the distribution of glacial sediments and their relative ages. Note glaciated northern and western Ohio, unglaciated southeastern Ohio, and the position of ridge moraines and the lake deposits and wave-planed ground moraine of the Lake Erie Basin. Bedrock highlands (BH) impeded the southward advance of glacial ice causing the moraines to form a lobate configuration (illustration by Lisa Van Doren; modified from Pavey and others, 1999).

REFERENCES

- Ohio Division of Geological Survey, 2003 (revised 2004), Shaded bedrock-topography of Ohio (ver. 1.1): Ohio Division of Geological Survey, Map BG-3, scale 1:500,000.
- Pavey, R. R., Goldthwait, R. P., Brockman, C. S., Hull, D. N., Swinford, E. M., and Van Horn, R. G., 1999, Quaternary Geology of Ohio: Ohio Division of Geological Survey Map 2, scale 1:500,000.
- Powers, D. M., Laine, J. F., and Pavey, R. R., 2002 (revised 2003), Shaded elevation map of Ohio: Ohio Division of Geological Survey MG-1, scale 1:500,000.

This map is a generalization of the Bedrock Geologic Map of Ohio (Slucher and others, 2006)—the first statewide 1:500,000-scale bedrock-geology map compiled by the Ohio Division of Geological Survey since 1920 and the first to properly portray the bedrock geology that exists beneath the extensive deposits of Quaternary sediments that cover much of the bedrock in the state. Overall, the bedrock geology of Ohio consists of flat lying to gently dipping carbonate, siliciclastic, evaporite, and organoclastic strata of sedimentary origin that range in age from Upper Ordovician to Upper Carboniferous-Lower Permian. At depth, as illustrated in the cross section, older sedimentary, igneous, and metamorphic rocks that range from Lower Ordovician to Mesoproterozoic in age occur. At the surface, an irregular veneer of mainly unconsolidated Quaternary sediments conceal most bedrock units occurring northward and westward of the glacial margin.

Strata of the Ordovician System are the oldest exposed rocks in Ohio and consist mainly of alternating shale and limestone sequences. Silurian System strata are mostly dolomites with lesser amounts of shale. Rocks of the Devonian System consist of two contrasting types. Lower and Middle Devonian-age strata are mainly carbonate rocks whereas Upper Devonian-age rocks consist mostly of clastic rocks. In Champaign and Logan Counties, Devonian rocks occur on a small erosional remnant referred to as the Bellefontaine Outlier by geologists. Coincidentally, the highest topographic point in Ohio (Campbell Hill—1,549 feet above sea level) occurs also in this area.

The Carboniferous System is divided into two Subsystems, the Mississippian and Pennsylvanian. Mississippian strata are mostly shales and sandstones that occur locally in various proportions. Pennsylvanian strata consist mainly of a diverse array of alternating sandstones, siltstones, shales, mudstones, limestones, and underclays; economic coal beds occur also in portions of this sequence. The youngest interval of sedimentary rocks in Ohio, the Dunkard Group, occurs only in southeastern Ohio and consists of strata similar in composition to the underlying Upper Pennsylvanian-age rocks; however, the age of the Dunkard Group has been debated since the late 1800s. Dunkard strata contain a well-studied late Pennsylvanian-age assemblage of plant fossils with infrequent early Permian-age forms. Yet, fossil plant spores found in coal beds in the interval only support a late, but not latest Pennsylvanian age. Thus, until more definitive fossils are found, geologists are unable to determine the exact age of the Dunkard Group beyond a combined Permian-Pennsylvanian age assignment.

In west-central Ohio, the ancient Teays River system extended across much of Ohio during the late Neogene to early Quaternary Periods and sculptured an extensive network of deeply dissected valleys into the bedrock surface. The spatial configuration of many geologic units on this map clearly reflects the major channel networks of these former drainage systems. Also, four major regional structural geology elements affect the spatial distribution of rocks in Ohio: the Appalachian and Michigan basins, and the Cincinnati and Findlay arches which occur between the two basins. Locally, several high-angle normal faults displace rocks in the state.

The Serpent Mound Impact Structure in southern Ohio is a circular area of deformed and broken rocks that is approximately four and one-half miles in diameter. Recent investigations indicate the feature is the result of a meteorite impact believed to have occurred between 256 and 330 million years ago.

Cross section A-A' traverses Ohio from the northwest to the southeast and intersects the southern portion of the Michigan Basin, the area between the Cincinnati and Findlay arches, and the western Appalachian Basin, respectively. The stratigraphic units shown in this profile illustrate the broad, arching geometric distortion to the bedrock in Ohio created mainly by periods of tectonic subsidence within these regional structural basins. For specific details on the various rock units, economic commodities, and geologic hazards within Ohio, see either the printed or digital version of the Bedrock Geologic Map of Ohio (Slucher and others, 2006). Both products are available for purchase by contacting the ODNR Geologic Records Center by calling 614-265-6576 or emailing: geo.survey@dnr.state.oh.us.

 **Quaternary** (about 1.8 million years ago to present)—Unconsolidated sediments: till, gravel, sand, silt, clay, and organic debris. Continental origin. (Shown in cross section only)

Period of widespread erosion

 **Permian and Pennsylvanian** (about 298 to 302 million years ago)—Sedimentary rocks: mainly shale, sandstone, siltstone, mudstone, and minor coal. Continental origin.

 **Pennsylvanian** (about 302 to 307 million years ago) Sedimentary rocks: mainly shale, sandstone, siltstone, mudstone, limestone, and some coal. Continental and marine origin.

 **Pennsylvanian** (about 307 to 318 million years ago)—Sedimentary rocks: mainly sandstone, siltstone, shale, and conglomerate, with some coal and limestone. Deltaic and marine origin.

Period of widespread erosion

 **Mississippian** (about 322 to 359 million years ago)—Sedimentary rocks: sandstone, shale, siltstone, conglomerate, and minor limestone. Marine to marginal marine origin.

 **Devonian** (about 359 to 385 million years ago)—Sedimentary rocks: mainly shale and siltstone with some sandstone. Marine to marginal marine origin.

 **Devonian** (about 385 to 407 million years ago)—Sedimentary rocks: mainly limestone and dolomite with some shale, and minor sandstone. Marine and eolian origin.

Period of widespread erosion

 **Silurian** (about 416 to 423 million years ago)—Sedimentary rocks: dolomite, anhydrite, gypsum, salt, and shale. Marine and restricted marine origin.

 **Silurian** (about 423 to 435 million years ago)—Sedimentary rocks: dolomite and shale with some limestone. Marine origin.

Period of widespread erosion

 **Ordovician** (about 446 to 450 million years ago)—Sedimentary rocks: shale and limestone. Marine origin.

 **Ordovician** (about 450 to 460 million years ago)—Sedimentary rocks: limestone and shale. Marine origin.

Period of widespread erosion

 **Ordovician and Cambrian** (about 486 to 510 million years ago)—Sedimentary rocks: mainly dolomite, sandstone, shale, with minor limestone. Marine origin. (Shown in cross section only)

Period of widespread erosion

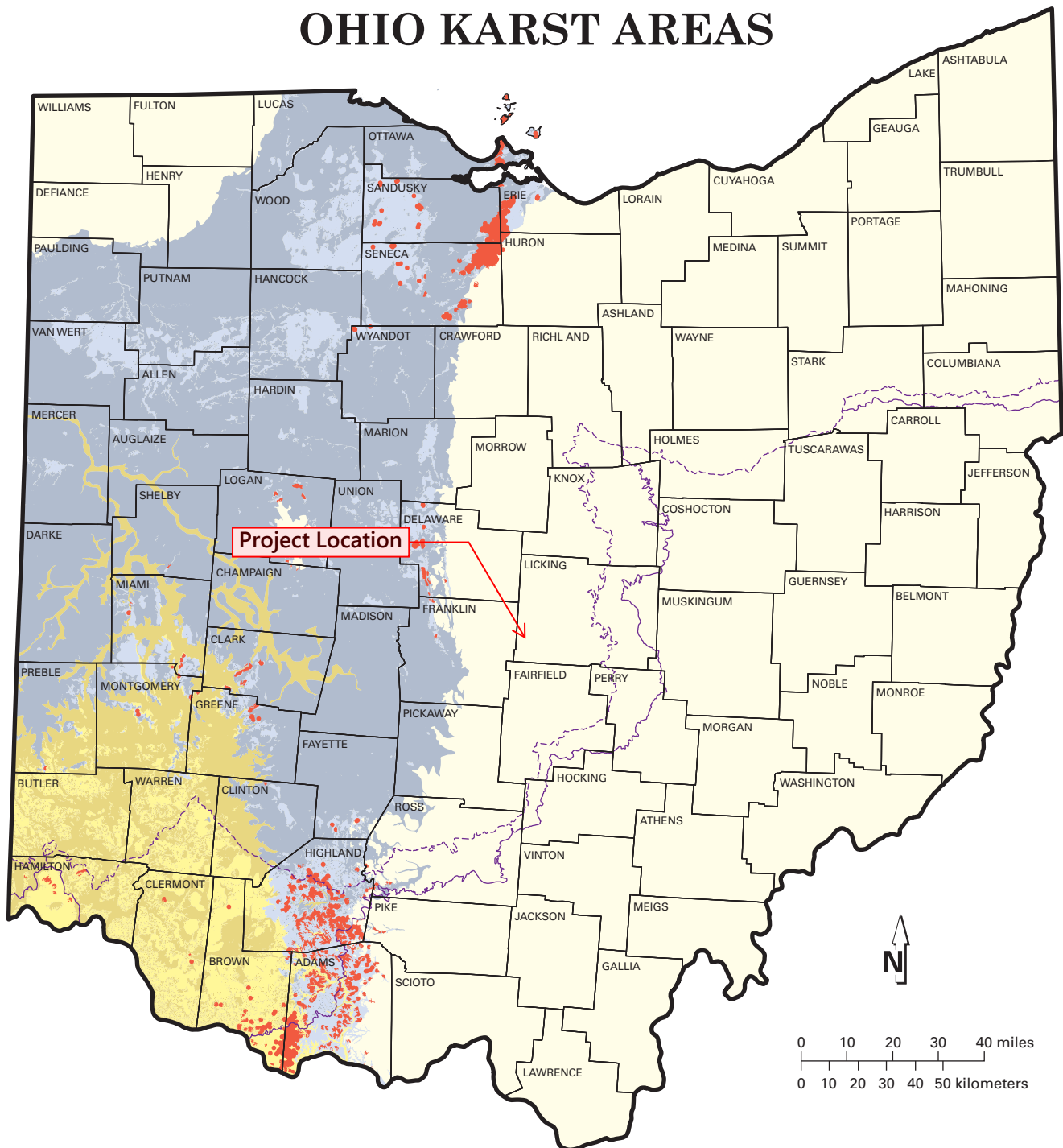
 **Neoproterozoic** (between 900 million and 1 billion years ago)—Metamorphic rocks: gneiss, schist, amphibolite, and marble; and igneous rocks: granite. Form during collision of tectonic plates. (Shown in cross section only)

 **Mesoproterozoic** (between 1.0 and 1.2 billion years ago)—Sedimentary rocks: sandstone and siltstone; and igneous rocks: basalt and rhyolite. Form during rifting of continental landmass. (Shown in cross section only)

Period of widespread erosion

 **Mesoproterozoic** (between 1.45 and 1.52 billion years ago)—Igneous rocks: granite and rhyolite. Formed during crustal evolution and differentiation. (Shown in cross section only)

OHIO KARST AREAS



EXPLANATION

- | | | | |
|---|---|---|--|
|  | Silurian- and Devonian-age carbonate bedrock overlain by less than 20 feet of glacial drift and/or alluvium |  | Probable karst areas |
|  | Silurian- and Devonian-age carbonate bedrock overlain by more than 20 feet of glacial drift and/or alluvium |  | Area not known to contain karst features |
|  | Interbedded Ordovician-age limestone and shale overlain by less than 20 feet of glacial drift and/or alluvium |  | Wisconsinan Glacial Margin |
|  | Interbedded Ordovician-age limestone and shale overlain by more than 20 feet of glacial drift and/or alluvium |  | Illinoian Glacial Margin |



Recommended citation: Ohio Division of Geological Survey, 1999 (rev. 2002, 2006), Known and probable karst in Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map EG-1, generalized page-size version with text, 2 p., scale 1:2,000,000.



OHIO KARST AREAS

Karst is a landform that develops on or in limestone, dolomite, or gypsum by dissolution and that is characterized by the presence of characteristic features such as sinkholes, underground (or internal) drainage through solution-enlarged fractures (joints), and caves. While karst landforms and features are commonly striking in appearance and host to some of Ohio's rarest fauna, they also can be a significant geologic hazard. Sudden collapse of an underground cavern or opening of a sinkhole can cause surface subsidence that can severely damage or destroy any overlying structure such as a building, bridge, or highway. Improperly backfilled sinkholes are prone to both gradual and sudden subsidence, and similarly threaten overlying structures. Sewage, animal wastes, and agricultural, industrial, and ice-control chemicals entering sinkholes as surface drainage are conducted directly and quickly into the ground-water system, thereby posing a severe threat to potable water supplies. Because of such risks, many of the nation's state geological surveys, and the U.S. Geological Survey, are actively mapping and characterizing the nation's karst regions.

The five most significant Ohio karst regions are described below.

BELLEVUE-CASTALIA KARST PLAIN

The Bellevue-Castalia Karst Plain occupies portions of northeastern Seneca County, northwestern Huron County, southeastern Sandusky County, and western Erie County. Adjacent karst terrain in portions of Ottawa County, including the Marblehead Peninsula, Catawba Island, and the Bass Islands, is related in geologic origin to the Bellevue-Castalia Karst Plain. The area is underlain by up to 175 feet of Devonian carbonates (Delaware Limestone, Columbus Limestone, Lucas Dolomite, and Amherstburg Dolomite) overlying Silurian dolomite, anhydrite, and gypsum of the Bass Islands Dolomite and Salina Group.

The Bellevue-Castalia Karst Plain is believed to contain more sinkholes than any of Ohio's other karst regions. Huge, irregularly shaped, closed depressions up to 270 acres in size and commonly enclosing smaller, circular-closed depressions 5 to 80 feet in diameter pockmark the land between the village of Flat Rock in northeastern Seneca County and Castalia in western Erie County. Surface drainage on the plain is very limited, and many of the streams which are present disappear into sinkholes called swallow holes.

Karst in the Bellevue-Castalia and Lake Erie islands region is due to collapse of overlying carbonate rocks into voids created by the dissolution and removal of underlying gypsum beds. According to Verber and Stansbery (1953, Ohio Journal of Science), ground water is introduced into Salina Group anhydrite (CaSO_4) through pores and fractures in the overlying carbonates. The anhydrite chemically reacts with the water to form gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), undergoing a 33 to 62 percent increase in volume in the process. This swelling lifts overlying strata, thereby opening fractures and creating massive passageways for conduction of greater volumes of ground water through the Silurian Bass Islands Dolomite and into underlying Salina Group strata. Gypsum, being readily soluble in water, is dissolved, creating huge voids. Overlying carbonates then collapse or break down, leaving surface depressions similar to those resulting from roof failure of an underground mine.

DISSECTED NIAGARA ESCARPMENT

The dissected Niagara Escarpment of southwestern Ohio includes the largest single area of karst terrain in the state and the greatest number of surveyed caves. It also is estimated to include the second-largest number of sinkholes in the state. The area is underlain by Silurian rocks of the Peebles Dolomite, Lilley Formation, Bisher Formation, Estill Shale, and Noland Formation in Adams, Highland, and Clinton Counties and the Cedarville Dolomite, Springfield Dolomite, Euphemia Dolomite, Massie Shale, Laurel Dolomite, Osgood Shale, and Dayton Formation in Greene, Clark, Miami, Montgomery, and Preble Counties. The Peebles-Lilley-Bisher sequence and the Cedarville-Springfield-Euphemia sequence constitute the Lockport Group.

Most karst features along the Niagara Escarpment in southwestern Ohio are developed in Lockport Group strata. More than 100 sinkholes and caves developed in the Lockport have been documented in the field, and more than 1,000 probable sinkholes in the Lockport have been identified on aerial photographs, soils maps, and topographic maps. As with most karst terrain, sinkholes developed on the Niagara Escarpment commonly show linear orientations aligned with prevailing joint trends in the area. The greatest concentration of sinkholes on the escarpment is south of the Wisconsin glacial border in southern Highland and Adams Counties, where highly dissected ridges capped by Silurian carbonate rocks rise 150 to 200 feet above surrounding drainage. Illinoian till in these areas is thin to absent, and soils are completely leached with respect to calcium and calcium-magnesium carbonate. Such geologic settings are ideal for active karst processes, as downward-percolating, naturally acidic rain water is not buffered until it has dissolved some of the underlying carbonate bedrock. Other significant karst features of the Niagara Escarpment include small caves in escarpment re-entrants created by the valleys of the Great Miami and Stillwater Rivers in Miami County.

BELLEFONTAINE OUTLIER

The Bellefontaine Outlier in Logan and northern Champaign Counties is an erosionally resistant "island" of Devonian carbonates capped by Ohio Shale and surrounded by a "sea" of Silurian strata. Though completely glaciated, the outlier was such an impediment to Ice Age glaciers that it repeatedly separated advancing ice sheets into two glacial lobes—the Miami Lobe on the west and the Scioto Lobe on the east. Most Ohioans recognize the outlier as the location of Campbell Hill—the highest point in the state at an elevation of 1,549 feet above mean sea level.

Although it is not known for having an especially well-developed karst terrain, the outlier is the location of Ohio's largest known cave, Ohio Caverns. The greatest sinkhole concentrations are present in McArthur and Rushcreek Townships of Logan County, where the density of sinkholes in some areas approaches 30 per square mile. Sinkholes here typically occur in upland areas of Devonian Lucas Dolomite or Columbus Limestone that are 30 to 50 feet or more above surrounding drainage and are covered by less than 20 feet of glacial drift and/or Ohio Shale.

SCIOTO AND OLENTANGY RIVER GORGES

The uplands adjacent to the gorges of the Scioto and Olentangy Rivers in northern Franklin and southern Delaware Counties include areas of well-developed, active karst terrain. These uplands also are among the most rapidly developing areas of the state, which means karst should be a consideration in site assessments for commercial and residential construction projects.

The Scioto River in this area has been incised to a depth of 50 to 100 feet into underlying bedrock, creating a shallow gorge. The floor, walls, and adjacent uplands of the gorge consist of Devonian Delaware and Columbus Limestones mantled by up to 20 feet of Wisconsin till. Sinkhole concentrations up to 1 sinkhole per acre are not uncommon in Concord, Scioto, and Radnor Townships of Delaware County. The sinkholes range in diameter from about 10 to 100 feet and commonly are aligned linearly along major joint systems.

The Olentangy River is approximately 5 miles east of the Scioto River in southern Delaware County and occupies a gorge that is narrower and up to 50 feet deeper than the Scioto River gorge. The floor and the lower half of the walls along the Olentangy gorge are composed of Delaware and Columbus Limestones, the upper half of the walls is composed of Devonian Ohio and Olentangy Shales mantled by a thin veneer of glacial drift. Karst terrain has developed along portions of the gorge in a manner similar to karst terrain along the Scioto River.

ORDOVICIAN UPLANDS

The Ordovician uplands of southwestern Ohio are the location of surprisingly well-developed karst terrain despite the large component of shale in local bedrock. Numerous sinkholes are present in Ordovician rocks of Adams, Brown, Clermont, and Hamilton Counties.

The carbonate-rich members of the Grant Lake Formation (Bellevue and Mount Auburn), Grant Lake Limestone (Bellevue and Straight Creek), and the upper portion of the Arnheim formation are the Ordovician units most prone to karstification; however, the shale-rich (70 percent shale, 30 percent limestone) Waynesville Formation also has been subjected to a surprising amount of karst development in southeastern Brown and southwestern Adams Counties, just north of the Ohio River.

ACKNOWLEDGMENT

The Division of Geological Survey gratefully acknowledges the Ohio Low-Level Radioactive-Waste Facility Development Authority for its financial support for mapping Ohio karst terrain.

Soil Map—Licking County, Ohio
(Mink Street Bridge)



Soil Map—Licking County, Ohio
(Mink Street Bridge)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Unit Polygons

 Soil Map Unit Lines

 Soil Map Unit Points

Special Point Features



Blowout



Borrow Pit



Clay Spot



Closed Depression



Gravel Pit



Gravelly Spot



Landfill



Lava Flow



Marsh or swamp



Mine or Quarry



Miscellaneous Water



Perennial Water



Rock Outcrop



Saline Spot



Sandy Spot



Severely Eroded Spot



Sinkhole



Slide or Slip



Sodic Spot



Spoil Area



Stony Spot



Very Stony Spot



Wet Spot



Other



Special Line Features

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: Licking County, Ohio

Survey Area Data: Version 21, Sep 7, 2023

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

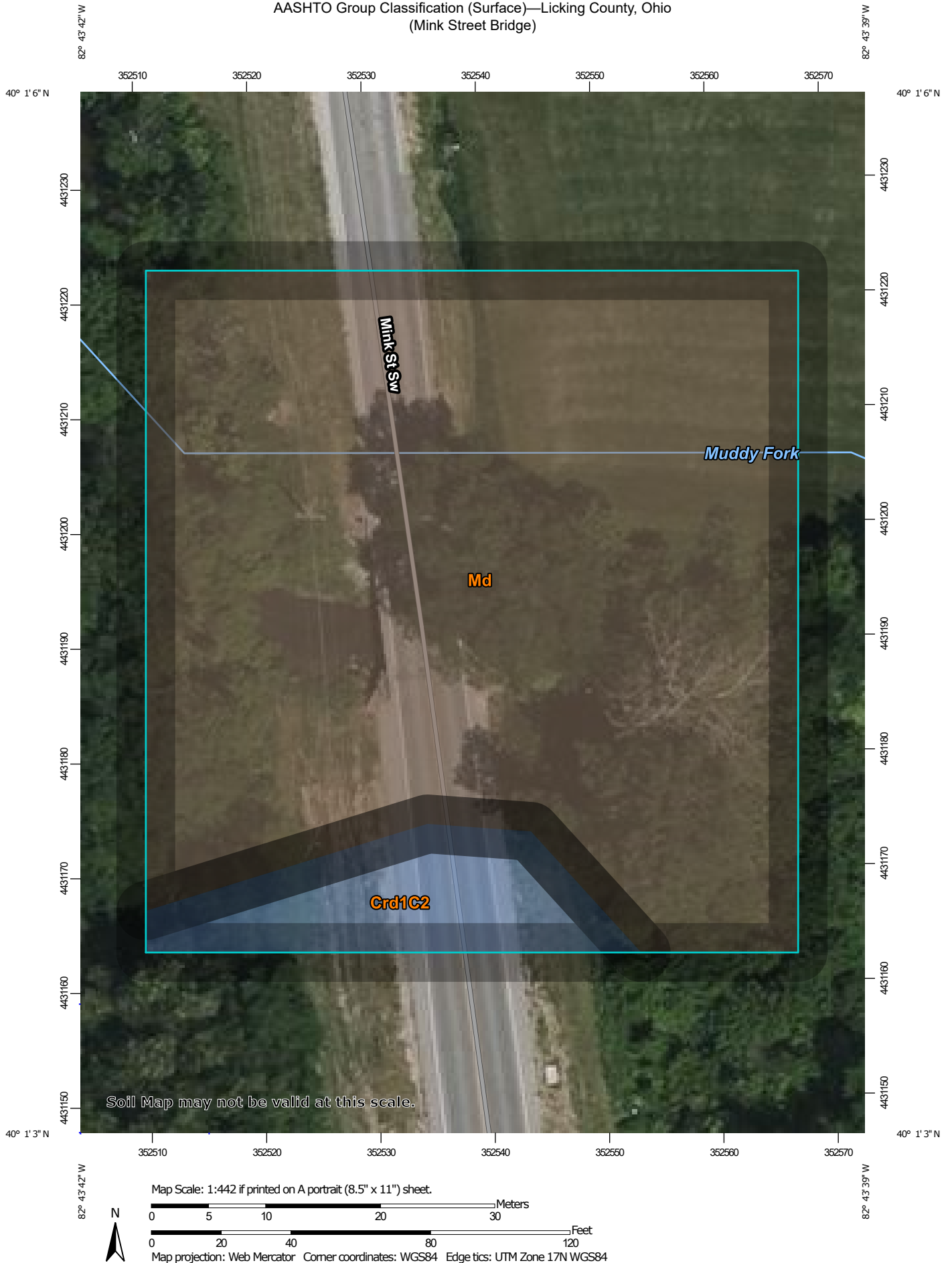
Date(s) aerial images were photographed: May 21, 2023—Aug 8, 2023

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	Percent of AOI
Crd1C2	Cardington silt loam, 6 to 12 percent slopes, eroded	0.1	9.8%
Md	Medway silt loam, occasionally flooded	0.8	90.2%
Totals for Area of Interest		0.8	100.0%

AASHTO Group Classification (Surface)—Licking County, Ohio
(Mink Street Bridge)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

Soil Rating Polygons

 A-1
 A-1-a
 A-1-b
 A-2
 A-2-4
 A-2-5
 A-2-6
 A-2-7
 A-3
 A-4
 A-5
 A-6
 A-7
 A-7-5
 A-7-6
 A-8
 Not rated or not available

Soil Rating Lines

 A-1
 A-1-a
 A-1-b
 A-2

 A-2-4
 A-2-5
 A-2-6
 A-2-7
 A-3
 A-4
 A-5
 A-6
 A-7
 A-7-5
 A-7-6
 A-8
 Not rated or not available

Soil Rating Points

 A-1
 A-1-a
 A-1-b
 A-2
 A-2-4
 A-2-5
 A-2-6
 A-2-7
 A-3
 A-4
 A-5
 A-6

 A-7
 A-7-5
 A-7-6
 A-8
 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: Licking County, Ohio
Survey Area Data: Version 21, Sep 7, 2023

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

Date(s) aerial images were photographed: May 21, 2023—Aug 8, 2023

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.

AASHTO Group Classification (Surface)

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Crd1C2	Cardington silt loam, 6 to 12 percent slopes, eroded	A-6	0.1	9.8%
Md	Medway silt loam, occasionally flooded	A-4	0.8	90.2%
Totals for Area of Interest			0.8	100.0%

Description

AASHTO group classification is a system that classifies soils specifically for geotechnical engineering purposes that are related to highway and airfield construction. It is based on particle-size distribution and Atterberg limits, such as liquid limit and plasticity index. This classification system is covered in AASHTO Standard No. M 145-82. The classification is based on that portion of the soil that is smaller than 3 inches in diameter.

The AASHTO classification system has two general classifications: (i) granular materials having 35 percent or less, by weight, particles smaller than 0.074 mm in diameter and (ii) silt-clay materials having more than 35 percent, by weight, particles smaller than 0.074 mm in diameter. These two divisions are further subdivided into seven main group classifications, plus eight subgroups, for a total of fifteen for mineral soils. Another class for organic soils is used.

For each soil horizon in the database one or more AASHTO Group Classifications may be listed. One is marked as the representative or most commonly occurring. The representative classification is shown here for the surface layer of the soil.

Rating Options

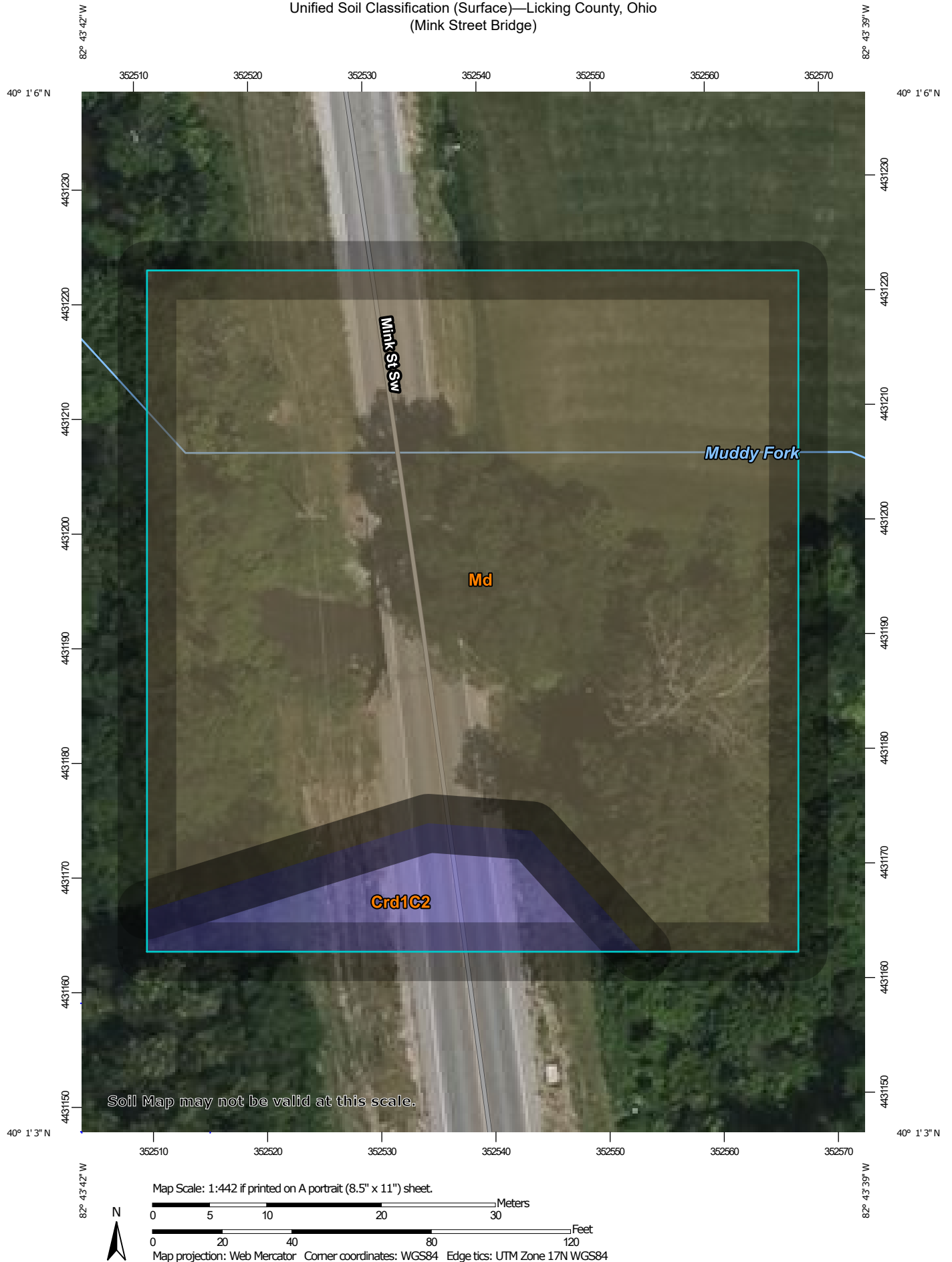
Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Layer Options (Horizon Aggregation Method): Surface Layer (Not applicable)

Unified Soil Classification (Surface)—Licking County, Ohio
(Mink Street Bridge)



Unified Soil Classification (Surface)—Licking County, Ohio
(Mink Street Bridge)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

Soil Rating Polygons

 CH
 CL
 CL-A (proposed)
 CL-K (proposed)
 CL-ML
 CL-O (proposed)
 CL-T (proposed)
 GC
 GC-GM
 GM
 GP
 GP-GC
 GP-GM
 GW
 GW-GC
 GW-GM
 MH
 MH-A (proposed)
 MH-K (proposed)
 MH-O (proposed)
 MH-T (proposed)
 ML

 ML-A (proposed)
 ML-K (proposed)
 ML-O (proposed)
 ML-T (proposed)
 OH
 OH-T (proposed)
 OL
 PT
 SC
 SC-SM
 SM
 SP
 SP-SC
 SP-SM
 SW
 SW-SC
 SW-SM
 Not rated or not available

Soil Rating Lines

 CH
 CL
 CL-A (proposed)
 CL-K (proposed)
 CL-ML
 CL-O (proposed)
 CL-T (proposed)
 GC
 GC-GM
 GM
 GP
 GP-GC
 GP-GM
 GW
 GW-GC
 GW-GM
 MH
 MH-A (proposed)
 MH-K (proposed)
 MH-O (proposed)
 MH-T (proposed)
 ML
 ML-A (proposed)
 ML-K (proposed)
 ML-O (proposed)
 ML-T (proposed)
 OH
 OH-T (proposed)
 OL
 PT
 SC
 SC-SM
 SM

 SP
 SP-SC
 SP-SM
 SW
 SW-SC
 SW-SM
 Not rated or not available

Soil Rating Points

 CH
 CL
 CL-A (proposed)
 CL-K (proposed)
 CL-ML
 CL-O (proposed)
 CL-T (proposed)
 GC
 GC-GM
 GM
 GP
 GP-GC
 GP-GM
 GW
 GW-GC
 GW-GM
 MH
 MH-A (proposed)
 MH-K (proposed)
 MH-O (proposed)
 MH-T (proposed)
 ML
 ML-A (proposed)
 ML-K (proposed)
 ML-O (proposed)
 ML-T (proposed)
 OH
 OH-T (proposed)
 OL
 PT
 SC
 SC-SM
 SM
 SP
 SP-SC
 SP-SM
 SW
 SW-SC
 SW-SM
 Not rated or not available

Water Features

 Streams and Canals

Transportation

 Rails

Unified Soil Classification (Surface)—Licking County, Ohio
(Mink Street Bridge)

MAP INFORMATION

-  Interstate Highways
-  US Routes
-  Major Roads
-  Local Roads

Background

-  Aerial Photography

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: Licking County, Ohio

Survey Area Data: Version 21, Sep 7, 2023

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

Date(s) aerial images were photographed: May 21, 2023—Aug 8, 2023

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.

Unified Soil Classification (Surface)

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Crd1C2	Cardington silt loam, 6 to 12 percent slopes, eroded	CL	0.1	9.8%
Md	Medway silt loam, occasionally flooded	ML	0.8	90.2%
Totals for Area of Interest			0.8	100.0%

Description

The Unified soil classification system classifies mineral and organic mineral soils for engineering purposes on the basis of particle-size characteristics, liquid limit, and plasticity index. It identifies three major soil divisions: (i) coarse-grained soils having less than 50 percent, by weight, particles smaller than 0.074 mm in diameter; (ii) fine-grained soils having 50 percent or more, by weight, particles smaller than 0.074 mm in diameter; and (iii) highly organic soils that demonstrate certain organic characteristics. These divisions are further subdivided into a total of 15 basic soil groups. The major soil divisions and basic soil groups are determined on the basis of estimated or measured values for grain-size distribution and Atterberg limits. ASTM D 2487 shows the criteria chart used for classifying soil in the Unified system and the 15 basic soil groups of the system and the plasticity chart for the Unified system.

The various groupings of this classification correlate in a general way with the engineering behavior of soils. This correlation provides a useful first step in any field or laboratory investigation for engineering purposes. It can serve to make some general interpretations relating to probable performance of the soil for engineering uses.

For each soil horizon in the database one or more Unified soil classifications may be listed. One is marked as the representative or most commonly occurring. The representative classification is shown here for the surface layer of the soil.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

Layer Options (Horizon Aggregation Method): Surface Layer (Not applicable)

Engineering Properties

This table gives the engineering classifications and the range of engineering properties for the layers of each soil in the survey area.

Hydrologic soil group is a group of soils having similar runoff potential under similar storm and cover conditions. The criteria for determining Hydrologic soil group is found in the National Engineering Handbook, Chapter 7 issued May 2007(<http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba>). Listing HSGs by soil map unit component and not by soil series is a new concept for the engineers. Past engineering references contained lists of HSGs by soil series. Soil series are continually being defined and redefined, and the list of soil series names changes so frequently as to make the task of maintaining a single national list virtually impossible. Therefore, the criteria is now used to calculate the HSG using the component soil properties and no such national series lists will be maintained. All such references are obsolete and their use should be discontinued. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonal high water table, saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. Changes in soil properties caused by land management or climate changes also cause the hydrologic soil group to change. The influence of ground cover is treated independently. There are four hydrologic soil groups, A, B, C, and D, and three dual groups, A/D, B/D, and C/D. In the dual groups, the first letter is for drained areas and the second letter is for undrained areas.

The four hydrologic soil groups are described in the following paragraphs:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Depth to the upper and lower boundaries of each layer is indicated.

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly."

Classification of the soils is determined according to the Unified soil classification system (ASTM, 2005) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO, 2004).

The Unified system classifies soils according to properties that affect their use as construction material. Soils are classified according to particle-size distribution of the fraction less than 3 inches in diameter and according to plasticity index, liquid limit, and organic matter content. Sandy and gravelly soils are identified as GW, GP, GM, GC, SW, SP, SM, and SC; silty and clayey soils as ML, CL, OL, MH, CH, and OH; and highly organic soils as PT. Soils exhibiting engineering properties of two groups can have a dual classification, for example, CL-ML.

The AASHTO system classifies soils according to those properties that affect roadway construction and maintenance. In this system, the fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of particle-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in content of fines (silt and clay). At the other extreme, soils in group A-7 are fine grained. Highly organic soils are classified in group A-8 on the basis of visual inspection.

If laboratory data are available, the A-1, A-2, and A-7 groups are further classified as A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, or A-7-6. As an additional refinement, the suitability of a soil as subgrade material can be indicated by a group index number. Group index numbers range from 0 for the best subgrade material to 20 or higher for the poorest.

Percentage of rock fragments larger than 10 inches in diameter and 3 to 10 inches in diameter are indicated as a percentage of the total soil on a dry-weight basis. The percentages are estimates determined mainly by converting volume percentage in the field to weight percentage. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Percentage (of soil particles) passing designated sieves is the percentage of the soil fraction less than 3 inches in diameter based on an oven-dry weight. The sieves, numbers 4, 10, 40, and 200 (USA Standard Series), have openings of 4.76, 2.00, 0.420, and 0.074 millimeters, respectively. Estimates are based on laboratory tests of soils sampled in the survey area and in nearby areas and on estimates made in the field. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Liquid limit and plasticity index (Atterberg limits) indicate the plasticity characteristics of a soil. The estimates are based on test data from the survey area or from nearby areas and on field examination. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

References:

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Report—Engineering Properties

Absence of an entry indicates that the data were not estimated. The asterisk "*" denotes the representative texture; other possible textures follow the dash. The criteria for determining the hydrologic soil group for individual soil components is found in the National Engineering Handbook, Chapter 7 issued May 2007 (<http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba>). Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Engineering Properties—Licking County, Ohio														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			<i>In</i>				<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>
Crd1C2—Cardington silt loam, 6 to 12 percent slopes, eroded														
Cardington, eroded	85	C/D	0-7	Silt loam	CL-ML, CL, ML	A-4, A-6	0- 0- 0	0- 0- 1	95-98-100	88-95-100	74-89-99	63-77-87	20-30-40	6-12-15
			7-27	Silty clay loam, clay loam, silty clay	CH, CL	A-6, A-7	0- 0- 1	0- 0- 1	86-95-98	68-90-97	61-87-97	53-77-88	30-40-50	10-15-30
			27-32	Silty clay loam, clay loam, silty clay	CL	A-6, A-7	0- 0- 1	0- 1- 3	86-95-99	72-89-97	67-85-97	59-76-90	25-35-45	10-15-25
			32-79	Clay loam, silty clay loam, silt loam	CL-ML, CL, ML	A-4, A-6	0- 0- 1	0- 1- 4	86-94-99	72-87-97	63-80-94	53-67-80	22-31-40	3-12-20

Engineering Properties--Licking County, Ohio														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			<i>In</i>				<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>	<i>L-R-H</i>
Md--Medway silt loam, occasionally flooded														
Medway	95	C	0-16	Silt loam	CL-ML, CL, ML	A-4, A-6	0- 0- 0	0- 0- 0	100-100-100	95-98-100	90-95-100	70-75-80	20-30-40	3-9 -15
			16-30	Loam, silt loam, silty clay loam	CL-ML, CL, ML	A-4, A-6, A-7	0- 0- 0	0- 0- 0	95-98-100	80-88-95	75-83-90	70-80-90	20-33-45	4-12-20
			30-47	Silty clay loam, silt loam, loam	SC-SM, CL, ML, SM	A-2, A-4, A-6	0- 0- 0	0- 0- 0	90-95-100	75-88-100	45-70-95	25-50-75	15-23-30	NP-8 -15
			47-60	Silty clay loam, loam, gravelly sandy loam	CL, ML, SC, SM	A-1-b, A-2, A-4, A-6	0- 0- 0	0- 3- 5	65-83-100	50-75-100	30-63-95	15-45-75	15-23-30	NP-8 -15

Data Source Information

Soil Survey Area: Licking County, Ohio
 Survey Area Data: Version 21, Sep 7, 2023

Corrosion of Concrete—Licking County, Ohio
(Mink Street Bridge)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Background

 Aerial Photography

Soils

Soil Rating Polygons

-  High
-  Moderate
-  Low
-  Not rated or not available

Soil Rating Lines

-  High
-  Moderate
-  Low
-  Not rated or not available

Soil Rating Points

-  High
-  Moderate
-  Low
-  Not rated or not available

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.

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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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Soil Survey Area: Licking County, Ohio
Survey Area Data: Version 21, Sep 7, 2023

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Date(s) aerial images were photographed: May 21, 2023—Aug 8, 2023

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Corrosion of Concrete

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Crd1C2	Cardington silt loam, 6 to 12 percent slopes, eroded	Moderate	0.1	9.8%
Md	Medway silt loam, occasionally flooded	Low	0.8	90.2%
Totals for Area of Interest			0.8	100.0%

Description

ENG

Engineering

AGR

Agronomy

"Risk of corrosion" pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens concrete. The rate of corrosion of concrete is based mainly on the sulfate and sodium content, texture, moisture content, and acidity of the soil. Special site examination and design may be needed if the combination of factors results in a severe hazard of corrosion. The concrete in installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the concrete in installations that are entirely within one kind of soil or within one soil layer.

The risk of corrosion is expressed as "low," "moderate," or "high."

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Corrosion of Steel—Licking County, Ohio
(Mink Street Bridge)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Background

 Aerial Photography

Soils

Soil Rating Polygons

-  High
-  Moderate
-  Low
-  Not rated or not available

Soil Rating Lines

-  High
-  Moderate
-  Low
-  Not rated or not available

Soil Rating Points

-  High
-  Moderate
-  Low
-  Not rated or not available

Water Features

 Streams and Canals

Transportation

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

MAP INFORMATION

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Corrosion of Steel

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Crd1C2	Cardington silt loam, 6 to 12 percent slopes, eroded	High	0.1	9.8%
Md	Medway silt loam, occasionally flooded	High	0.8	90.2%
Totals for Area of Interest			0.8	100.0%

Description

ENG

Engineering

AGR

Agronomy

"Risk of corrosion" pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens uncoated steel. The rate of corrosion of uncoated steel is related to such factors as soil moisture, particle-size distribution, acidity, and electrical conductivity of the soil. Special site examination and design may be needed if the combination of factors results in a severe hazard of corrosion. The steel in installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the steel in installations that are entirely within one kind of soil or within one soil layer.

The risk of corrosion is expressed as "low," "moderate," or "high."

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Shallow Excavations (OH)—Licking County, Ohio
(Mink Street Bridge)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Background

 Aerial Photography

Soils

Soil Rating Polygons

-  Very limited
-  Somewhat limited
-  Not limited
-  Not rated or not available

Soil Rating Lines

-  Very limited
-  Somewhat limited
-  Not limited
-  Not rated or not available

Soil Rating Points

-  Very limited
-  Somewhat limited
-  Not limited
-  Not rated or not available

Water Features

 Streams and Canals

Transportation

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

MAP INFORMATION

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Shallow Excavations (OH)

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Crd1C2	Cardington silt loam, 6 to 12 percent slopes, eroded	Very limited	Cardington, eroded (85%)	Depth to saturated zone (1.00)	0.1	9.8%
				Slope (0.04)		
			Bennington (5%)	Depth to saturated zone (1.00)		
			Condit (4%)	Ponding (1.00)		
				Depth to saturated zone (1.00)		
Md	Medway silt loam, occasionally flooded	Very limited	Medway (95%)	Depth to saturated zone (1.00)	0.8	90.2%
				Flooding (0.60)		
Totals for Area of Interest					0.8	100.0%

Rating	Acres in AOI	Percent of AOI
Very limited	0.8	100.0%
Totals for Area of Interest	0.8	100.0%

Description

Shallow excavations are trenches or holes dug to a maximum depth of 5 or 6 feet for graves, utility lines, open ditches, or other purposes. The ratings are based on the soil properties that influence the ease of digging and the resistance to sloughing. Depth to bedrock, hardness of bedrock, the amount of large stones, and dense layers influence the ease of digging, filling, and compacting. Depth to the seasonal high water table, flooding, and ponding may restrict the period when excavations can be made. Slope influences the ease of using machinery. Soil texture, depth to the water table, and linear extensibility (shrink-swell potential) influence the resistance to sloughing.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as the one shown for the map unit. The percent composition of each component in a particular map unit is given to help the user better understand the extent to which the rating applies to the map unit.

Other components with different ratings may occur in each map unit. The ratings for all components, regardless the aggregated rating of the map unit, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Differences between this interpretation for Ohio and the national interpretation: The Ohio interpretation does not consider cemented pans in the ratings and uses different rules for dense layer, too clayey, and cutbanks cave. It also considers soil slippage potential in the ratings.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Roadfill Source (OH)—Licking County, Ohio
(Mink Street Bridge)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Background

 Aerial Photography

Soils

Soil Rating Polygons

-  Poor
-  Fair
-  Good
-  Not rated or not available

Soil Rating Lines

-  Poor
-  Fair
-  Good
-  Not rated or not available

Soil Rating Points

-  Poor
-  Fair
-  Good
-  Not rated or not available

Water Features

 Streams and Canals

Transportation

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

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

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Roadfill Source (OH)

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Crd1C2	Cardington silt loam, 6 to 12 percent slopes, eroded	Fair	Cardington, eroded (85%)	Wetness (0.14)	0.1	9.8%
			Alexandria, severely eroded (6%)	Low strength (0.78)		
Md	Medway silt loam, occasionally flooded	Fair	Medway (95%)	Wetness (0.76)	0.8	90.2%
Totals for Area of Interest					0.8	100.0%

Rating	Acres in AOI	Percent of AOI
Fair	0.8	100.0%
Totals for Area of Interest	0.8	100.0%

Description

Roadfill is soil material that is excavated in one place and used in road embankments in another place. The soils are rated as a source of roadfill for low embankments, generally less than 6 feet high and less exacting in design than higher embankments. The ratings are for the whole soil, from the surface to a depth of about 5 feet. It is assumed that soil layers will be mixed when the soil material is excavated and spread.

The soils are rated "good," "fair," or "poor" as potential sources of roadfill. The ratings are based on the amount of suitable material and on soil properties that affect the ease of excavation and the performance of the material after it is in place. The thickness of the suitable material is a major consideration. The ease of excavation is affected by large stones, depth to a water table, and slope. How well the soil performs in place after it has been compacted and drained is determined by its strength (as inferred from the AASHTO classification of the soil) and linear extensibility (shrink-swell potential). Normal compaction, minor processing, and other standard construction practices are assumed.

Numerical ratings between 0.00 and 0.99 are given after the specified features. These numbers indicate the degree to which the features limit the soils as sources of roadfill. The lower the number, the greater the limitation.

The components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as the one shown for the map unit. The percent composition of each component in a particular map unit is given to help the user better understand the extent to which the rating applies to the map unit.

Other components with different ratings may occur in each map unit. The ratings for all components, regardless the aggregated rating of the map unit, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Differences between this interpretation for Ohio and the national interpretation: The Ohio interpretation does not consider cemented pans in the ratings.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Lower

APPENDIX B

Subsurface Exploration and Lab Testing Results

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: USED .5 BAG ASPHALT PATCH; MIXED WITH 8 BAGS BENTONITE CHIPS

APPENDIX C

Structure Foundation Exploration Sheets

PROJECT DESCRIPTION

GANNETT FLEMING WAS HIRED BY THE CITY OF PATASKALA DEVELOP THE BRIDGE FOUNDATION DESIGNS AND TO GENERATE THE SOIL PROFILE AND STRUCTURE FOUNDATION EXPLORATION REPORT FOR LIC-CR41-5.60 (PID NO. 119707) PROJECT IN LICKING COUNTY, WITH AN ESTIMATED PROJECT LENGTH OF 87 FEET.

HISTORIC RECORDS

BASED ON THE ODOT TRANSPORTATION INFORMATION MAPPING SYSTEM (TIMS), NO HISTORICAL SUBSURFACE DATA WAS AVAILABLE WITHIN OR NEAR THE PROJECT SITE.

GEOLOGY

ACCORDING TO THE OHIO DEPARTMENT OF NATURAL RESOURCES’ (ODNR) PHYSIOGRAPHIC REGIONS OF OHIO, THE SITE LIES WITHIN THE GALION GLACIATED LOW PLATEAU PHYSIOGRAPHIC REGION, WITHIN THE GLACIAL MARGIN WHICH CONSISTS OF GROUND MORAIN E VARYING IN DRIFT THICKNESS OF 211 TO 330 FEET. THE BEDROCK BELOW THE SITE CONSISTS OF THE MISSISSIPPIAN-AGE SHALES AND SANDSTONES WITH SILTSTONE AND CONGLOMERATE AND MINOR LIMESTONE OF MARINE TO MARGINAL MARINE ORIGIN.

RECONNAISSANCE

THE SITE RECONNAISSANCE WAS PERFORMED BY GANNETT FLEMING ENGINEERS AND ARCHITECTS, P.C. (GF) PERSONNEL THROUGH DESKTOP RESEARCH AND A FIELD VISIT BY CHRISTOPHER HALLAHAN, PE ON MAY 13, 2024, PRIOR TO THE SUBSURFACE EXPLORATION. SCOUR WAS OBSERVED ALONG THE SOUTH ABUTMENT TO SEVERAL INCHES BELOW THE CURRENT WATER LEVEL (WEST SIDE). NO OR LITTLE SCOUR WAS OBSERVED ALONG THE NORTH ABUTMENT. THE STREAM FLOWS IS FROM WEST TO EAST. IT WAS OBSERVED THAT A MIX OF TIMBER AND STEEL H PILES WITH WOOD LAGGING SUPPORT THE ABUTMENTS AND WING WALLS. SEVERAL MEMBERS COMBINED TIMBER PILES WITH H-PILE EXTENSIONS TO THE SUPERSTRUCTURE. SUPERSTRUCTURE I-BEAMS ARE IN GENERAL GOOD CONDITION WITH SOME SPOT RUST AREAS. THE CORRUGATED BRIDGE DECK UNDERLAY IS HIGHLY WEATHERED AND RUSTED. OVERHEAD ELECTRIC LINES RUN ALONG THE WEST SIDE OF THE ROADWAY, WELL OFF THE ROAD. A SANITARY SEWER RUNS ALONG THE WEST SIDE OF THE ROADWAY CLOSELY ALONG THE ELECTRIC ALIGNMENT. A SANITARY LIFT STATION APPEARS TO BE LOCATED NORTH OF THE BRIDGE ALONG THE SEWER ALIGNMENT. FIBER OPTIC LINES RUN ALONG THE EAST SIDE OF THE ROADWAY SHOULDER AND UNDER THE STREAM. ANOTHER TELECOM LINE RUNS UNDERGROUND ALONG THE EAST SIDE AT THE BOTTOM OF THE ROADWAY EMBANKMENT AND THEN BECOMES OVERHEAD AS IT PASSES BY THE BRIDGE AND OVER THE STREAM. BOTH TELECOM LINES ARE BURIED WELL BEYOND THE NORTH AND SOUTH LIMITS OF THE BRIDGE AND STREAM. WATER LINES RUN ALONG THE WEST SIDE OF THE ROAD, SOUTH OF THE BRIDGE, AND ALONG THE EAST SIDE OF THE ROAD, NORTH OF THE BRIDGE (AS INDICATED BY OBSERVED VALVE COVERS AND FIRE HYDRANTS). THE WATER LINES APPEAR TO BE SEVERAL FEET OFF THE PAVED ROADWAY IN THE OBSERVED LOCATIONS. NO MANHOLES, VALVE COVER, OR UTILITY MARKERS FOR THE WATER LINE WERE OBSERVED NEAR THE BRIDGE. GAS LINE MARKERS WERE OBSERVED NEAR HOUSES LOCATED SOUTH OF THE BRIDGE; HOWEVER, NO GAS LINE MARKERS WERE OBSERVED NEAR THE BRIDGE.

THE BORING LOCATIONS WERE PROPOSED AND LAID OUT BY GF. BOTH BORINGS WERE MARKED WITH WHITE SURVEY PAINT IN THE NORTHBOUND (NB) LANE OF MINK STREET (CR-41). B-001 WAS STAKED APPROXIMATELY SIX FEET SOUTH OF THE SOUTH ABUTMENT JOINT AND APPROXIMATELY 4 FEET WEST OF THE EDGE OF ROADWAY NB. B-002 WAS STAKED APPROXIMATELY SIX FEET NORTH OF THE NORTH ABUTMENT JOINT AND APPROXIMATELY 4 FEET WEST OF THE EDGE OF ROADWAY NB.

SUBSURFACE EXPLORATION

BETWEEN MAY 21 AND MAY 22, 2024, TWO EXPLORATORY BORINGS WERE ADVANCED. THE BORINGS WERE DESIGNATED B-001-0-24 AND B-002-0-24.

A MOBILE B-57 TRACK-MOUNTED RIG WAS USED TO ADVANCE BOTH THE BORINGS, UTILIZING A 3.25-INCH DIAMETER HOLLOW STEM AUGERS AND 2.0-INCH OUTSIDE DIAMETER SPLIT SPOON SAMPLERS. DISTURBED SAMPLES WERE COLLECTED IN ACCORDANCE WITH THE STANDARD PENETRATION TEST (AASHTO T206) THROUGH THE SOIL AT EITHER CONTINUOUS OR 2.5-INTERVALS TO A DEPTH OF 26.5 FEET AND 5-FOOT AFTERWARDS. THE ENERGY RATIO OF THE HAMMER WAS 76.8% AND WAS LAST CALIBRATED ON MAY 1, 2023. CTL ENGINEERING, INC. PERFORMED THE SOIL SAMPLING OF THE BORINGS. ALL FIELD SAMPLES WERE SEALED IN GLASS JARS AND TRANSPORTED TO CTL’S LABORATORY IN COLUMBUS, OHIO FOR TESTING. THE BORINGS WERE BACKFILLED OR SEALED ACCORDING TO ODOT’S SGE.

EXPLORATION FINDINGS

THE SITE CONSISTS OF MOSTLY LOOSE TO MEDIUM DENSE STONE FRAGMENTS OR GRAVEL WITH SAND AND SILT WITH MINOR LAYERS OF MEDIUM STIFF ELASTIC CLAY, STIFF SILTY CLAY OR SANDY SILT, OVERLYING VERY STIFF SANDY SILT AND VERY DENSE SANDY SILT WITH BOULDERS.

STRATUM 1 CONSISTS OF SHALLOW, MINOR BROWN ELASTIC CLAY, MEDIUM STIFF ELASTIC CLAY (ODOT A-7-5) “AND” SILT, LITTLE SAND, TRACE GRAVEL FILL PRESENT ONLY IN BORING B-001-0-24. STRATUM 2 CONSISTS OF VERY LOOSE TO MEDIUM DENSE GRAVEL WITH SAND AND SILT, TRACE CLAY OR MEDIUM DENSE (ODOT A-2-4). STRATUM 3 IS STIFF BROWN TO GRAY, DAMP TO WET SANDY SILT (ODOT A-4A), LITTLE GRAVEL, SOME CLAY IN B-001-0-24 AND STIFF BROWN TO BLACK MOIST SILTY CLAY (ODOT A-6B), LITTLE GRAVEL, SOME SAND IN B-002-0-24. STRATUM 4 CONSISTS OF DENSE GRAY, MOIST TO WET GRAVEL WITH SAND, LITTLE SILT, TRACE CLAY (ODOT A-1-B) TWELVE TO THIRTEEN FEET THICK. IT WAS NOTED THAT THERE WAS A PETROLEUM ODOR AND UNCONTROLLED FILL TO A DEPTH OF 21 FEET BGE IN BORING B-001-0-24. STRATUM 5 CONSISTS OF VERY STIFF, DARK GRAY, DAMP SANDY SILT (ODOT A-4A) WITH LITTLE TO SOME GRAVEL AND SOME CLAY. AFTER THE BOULDER ZONE IN BORING B-002-0-24, THE BORING TRANSITIONS BACK TO COHESIVE, VERY STIFF TO HARD SANDY SILT UNTIL TERMINATION. STRATUM 5A IS VERY DENSE SANDY SILT WITH LIMITED RECOVERY (ODOT A-4A) CONTAINING BOULDERS WAS ENCOUNTERED AT THE SAME ELEVATION (EL 986.0) IN BOTH BORINGS. THIS LAYER TRANSITIONS INTO VISUALLY CLASSIFIED, VERY DENSE GRAVEL WITH SAND (ODOT A-2-4) AND SILT UNTIL BORING B-001-0-24 WAS TERMINATED.

SPECIFICATIONS

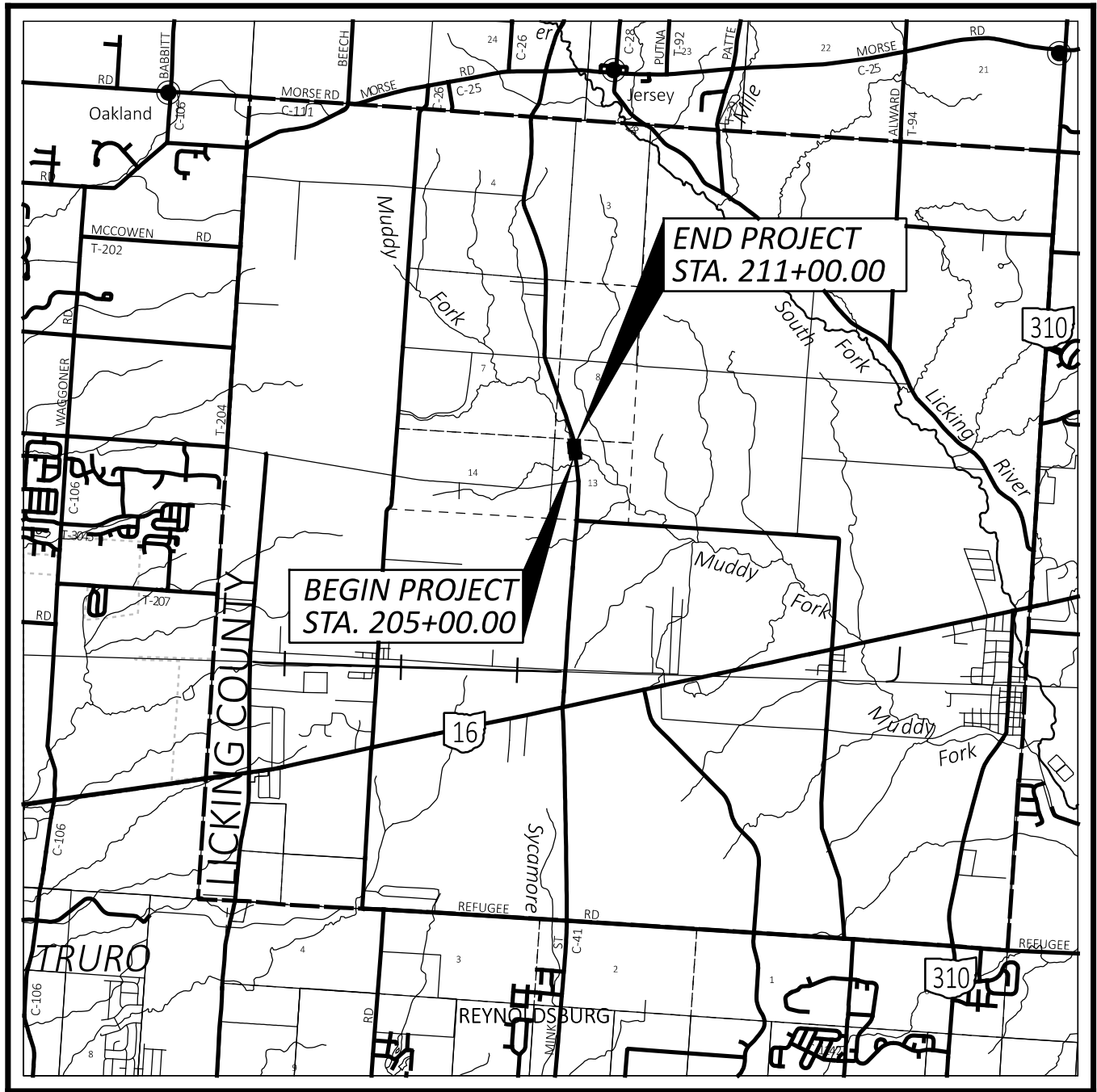
THIS GEOTECHNICAL EXPLORATION WAS PERFORMED IN ACCORDANCE WITH THE STATE OF OHIO, DEPARTMENT OF TRANSPORTATION, OFFICE OF GEOTECHNICAL ENGINEERING, SPECIFICATIONS FOR GEOTECHNICAL EXPLORATIONS, DATED JULY 2025.

LEGEND		ODOT CLASS	CLASSIFIED MECH./VISUAL	
DESCRIPTION				
	GRAVEL WITH SAND	A-1-b	2	8
	GRAVEL WITH SAND AND SILT	A-2-4	2	6
	SANDY SILT	A-4a	8	16
	SILTY CLAY	A-6b	1	1
	ELASTIC CLAY	A-7-5	1	1
	BOULDERS	TOTAL	14	32
	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.			
W	INDICATES FREE WATER ELEVATION.			
	INDICATES A NON-PLASTIC MATERIAL WITH A MOISTURE CONTENT GREATER THAN 25 % OR GREATER THAN 19 % WITH A WET APPEARANCE.			
SS	INDICATES A SPLIT SPOON SAMPLE.			
NP	INDICATES A NON-PLASTIC SAMPLE.			

AVAILABLE INFORMATION

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

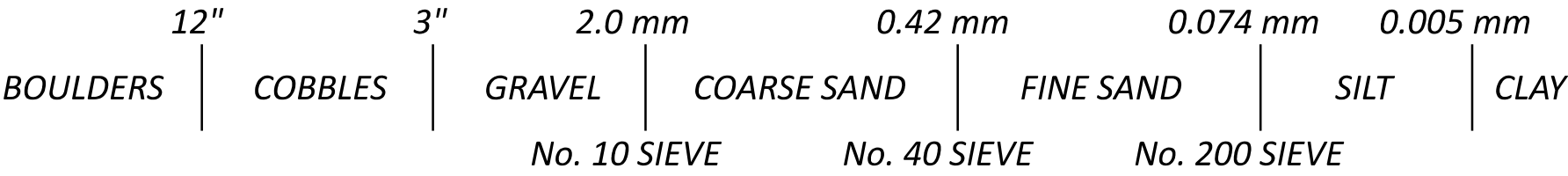
SCOUR SAMPLES						
BORING ID	SAMPLE ID	SAMPLE ELEVATION	D ₅₀ VALUE (mm)	T _c VALUE (psf)	D ₅₀ EQUIV (mm)	EROSION CATEGORY (EC)
B-001-0-24	SS-1	1038.1' to 1036.6'	0.0081	0.5073	24.2857	3.947
	SS-2	1035.6' to 1034.1'	-	0.1122	5.3691	3.947
	SS-3	1033.1' to 1031.6'	0.1302	0.1288	6.1663	3.168
	SS-4	1030.6' to 1029.1'	0.0390	0.1993	9.5415	2.868
	SS-5	1028.6' to 1027.1'	0.8834	0.0185	0.8834	2.135
	SS-6	1027.1' to 1025.6'	1.7437	0.0364	1.7437	2.490
	SS-7	1025.6' to 1024.1'	1.7437	0.0364	1.7437	2.490
B-002-0-24	SS-1	1038.1' to 1036.6'	1.6353	0.0342	1.6353	2.456
	SS-2	1035.6' to 1034.1'	1.4235	0.0297	1.4235	2.384
	SS-3	1031.6' to 1030.1'	0.1866	0.0019	0.0896	1.325
	SS-4	1030.1' to 1028.6'	-	0.2433	11.6457	3.612
	SS-5	1028.6' to 1027.1'	0.0672	0.1490	7.1327	3.612
	SS-6	1027.1' to 1025.6'	1.1388	0.0238	1.1388	2.268
	SS-7	1025.6' to 1024.1'	1.1388	0.0238	1.1388	2.268
	SS-8	1024.1' to 1022.6'	1.1388	0.0238	1.1388	2.268



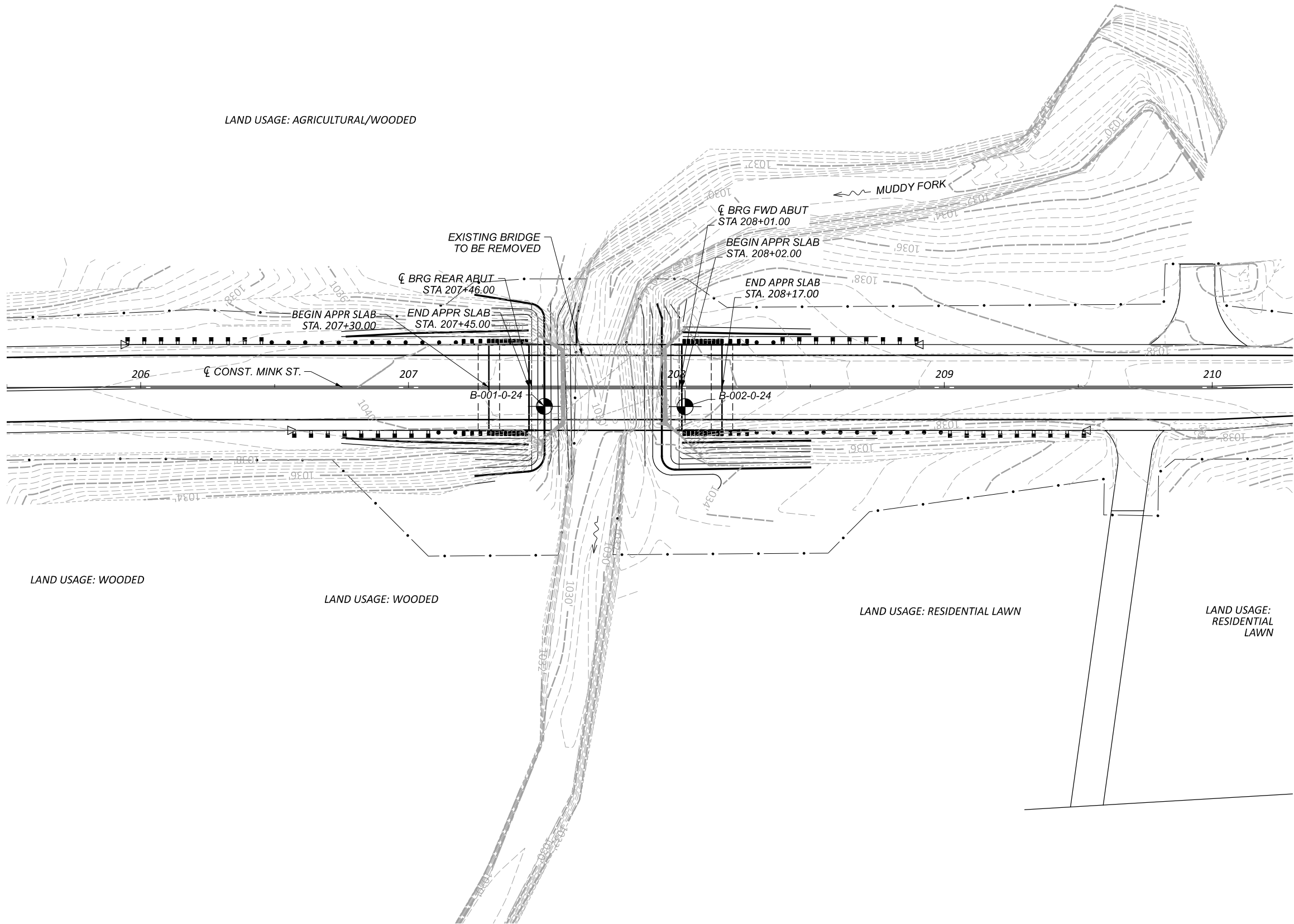
LOCATION MAP
LATITUDE: 40°01'05" LONGITUDE: -82°43'41"



PARTICLE SIZE DEFINITIONS



RECON. - CMH 5/13/24
DRILLING - EE 5/21/24 - 5/22/24
DRAWN - JAY 11/22/24
REVIEWED - TLM 11/26/24
UPDATED - JAY 06/25/25
REVIEWED - YLZ 06/25/25



BEGIN PROJECT STA. 205+00
END PROJECT STA. 211+00



GEOTECHNICAL PROFILE - BRIDGE
BRIDGE NO. LIC-CR41-05.600 OVER MUDDY FORK

DESIGN AGENCY

GFT

DESIGNER

JAY

REVIEWER

TLM 11/26/24

PROJECT ID

119707

SUBSET

2

TOTAL

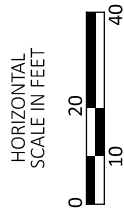
7

SHEET

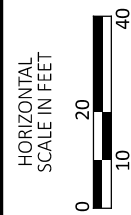
P.31

TOTAL

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DESIGN AGENCY

DESIGNER

JAY

REVIEWER

TIM 11/26/2

PROJECT ID:

110707

119707

SUBSET	TOTAL
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3	7
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SHEET	TOTAL
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P.32 | 36

LIC-CR41-5.60

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PROJECT: LIC-41-05.60				DRILLING FIRM / OPERATOR: CTL / H. BROWN				DRILL RIG: MOBILE B-57 TRACK				STATION / OFFSET: 207+50.8 RT.				EXPLORATION B-001-0-24			
TYPE: STRUCTURE FOUNDATION				SAMPLING FIRM / LOGGER: GF / E. ENGEL				HAMMER: MOBILE AUTOMATIC				ALIGNMENT: LIC-CR41							
PID: 119707 SFN: 4563743				DRILLING METHOD: 3.25" HSA				CALIBRATION DATE: 5/1/23				ELEVATION: 1040.6 (MSL) EOB: 81.5 ft.				PAGE 1 OF 2			
START: 5/22/24 END: 5/22/24				SPT				ENERGY RATIO (%): 76.8				LAT / LONG: 40.017998 -82.727941				1 OF 2			
MATERIAL DESCRIPTION AND NOTES				ELEV.		SPT/ RQD		REC SAMPLE ID (%)		HP (tsf)		GRADATION (%)		ATTERBERG		HOLE SEALED			
				1040.6		DEPTHS		N ₆₀				GR CS FS SI CL LL PL WC		ODOT CLASS (GI)					
ASPHALT = 7" BASE = 23"				1040.0		1													
						2													
MEDIUM STIFF, BROWN, ELASTIC CLAY "AND" SILT, LITTLE SAND, TRACE GRAVEL, [FILL], DAMP TO MOIST				1038.1		3		10		SS-1		5 6 7 36 46 190 35 155 20		A-7-5 (20)					
						4													
STIFF, BROWN, CLAY, "AND" SILT, LITTLE SAND, TRACE GRAVEL				1035.6		5													
						6													
BROWN, DAMP @ 6.3 FT: 1.6-INCH COBBLE				1033.1		7		9		17		0 3 6 36 55 244 25 219 50		A-7-6 (20)					
						8													
MEDIUM STIFF, BROWN, SILT AND CLAY "AND" SAND, LITTLE GRAVEL, DAMP						9		6		17		17 19 20 25 19 29 17 12 14		A-6a (2)					
						10													
STIFF, BROWN, SANDY SILT, LITTLE GRAVEL, SOME CLAY, DAMP				1030.6		11		9		44		12 11 18 36 23 25 16 9 14		A-4a (5)					
						12													
MEDIUM DENSE, GRAY, GRAVEL WITH SAND AND SILT TRACE CLAY, DAMP				1028.6		13		29		44		38 23 15 14 10 21 14 7 8		A-2-4 (0)					
						14													
MEDIUM DENSE TO DENSE, GRAY, GRAVEL WITH SAND, LITTLE SILT, TRACE CLAY, WET				1027.1		15		35		44		- - - - - - - - - -		A-1-b (V)					
						16													
@ 17.5 TO 21.0 FT: PETROLEUM ODOR AND UNCONTROLLED FILL						17		38		56		48 20 11 15 6 NP NP NP 15		A-1-b (0)					
						18													
@ 20.0 FT: LITTLE SAND, LITTLE SILT						19		67		SS-8		- - - - - - - - - -		A-1-b (V)					
						20													
@ 21.0 FT: 3-INCH CLAY SEAM						21		20		56		- - - - - - - - - -		A-1-b (V)					
						22													
VERY STIFF, DARK GRAY, SANDY SILT, LITTLE GRAVEL, SOME CLAY, DAMP				1015.6		23		40		33		- - - - - - - - - -		A-1-b (V)					
						24													
						25													
						26													
						27													
						28													
						29													
						30													
						31		40		SS-11		4.00 14 11 14 38 23 25 15 10 13		A-4a (5)					
						32													
						33													
						34													
						35		12		56		SS-13		2.50 18 12 16 33 21 23 14 9 14		A-4a (4)			
						36													
						37													
						38													
						39													
						40													
						41		13		33		SS-14		2.50 - - - - - - - - - -		A-4a (V)			
						42													
						43													
						44													
						45		17		22		SS-15		2.50 - - - - - - - - - -		A-4a (V)			
						46													
						47													
						48													
						49													
						50													
						51		41		100		SS-16		4.00 - - - - - - - - - -		A-4a (V)			
						52													
						53													
						54													
						55													
						56													
@ 55 FT to 75 FT: BOULDERS AND COBBLES ENCOUNTERED						57		77		67		SS-17		- 20 16 18 28 18 21 13 8 9		A-4a (2)			
						58													
						59													

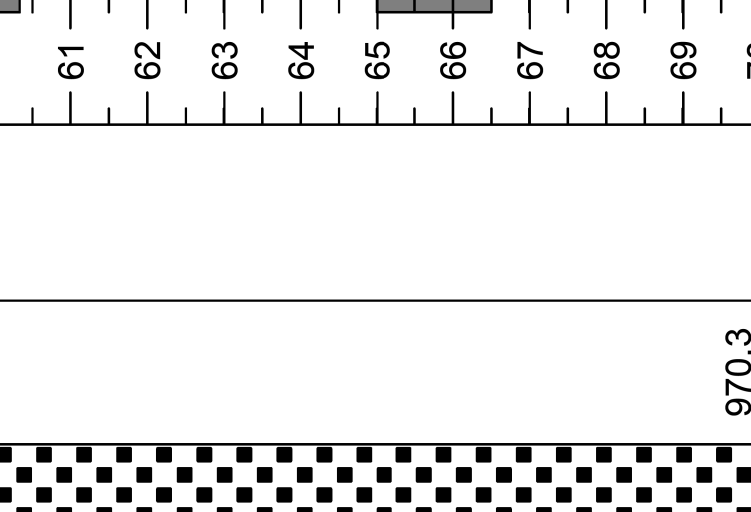
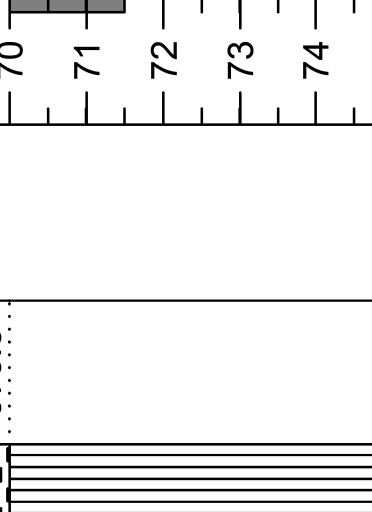
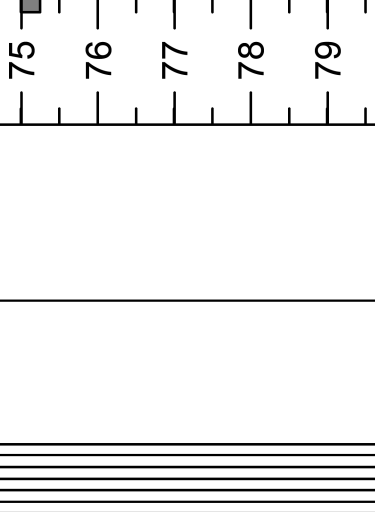
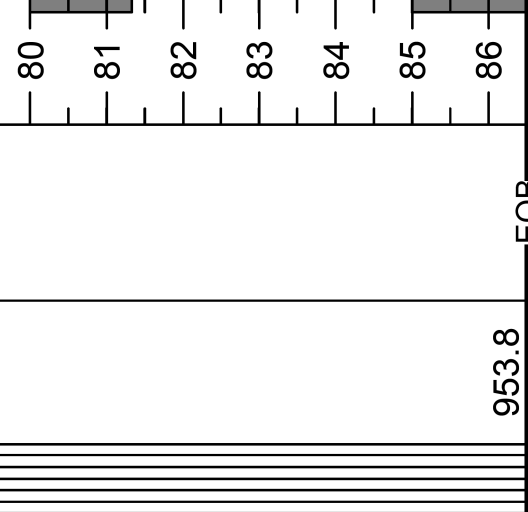
PID: 119707		SFN: 4563743		PROJECT: LIC-41-05.60		STATION / OFFSET:		207+50.8' RT.		START: 5/22/24		END: 5/22/24		PG 2 OF 2		B-001-0-24																	
MATERIAL DESCRIPTION AND NOTES						ELEV.		DEPTHS		SPT/ RQD		N ₆₀		REC SAMPLE (%)		HP (tsf)		GRADATION (%)				ATTERBERG			HOLE SEALED								
@ 55 FT to 75 FT: BOULDERS AND COBBLES ENCOUNTERED (continued)						980.6		50/3"		-		100		SS-18		-		-		-		-		-		A-4a (V)							
								-		-		-		-		-		-		-		-		-		-		-		-			
								61		-		-		-		-		-		-		-		-		-		-		-		-	
								62		-		-		-		-		-		-		-		-		-		-		-		-	
								63		-		-		-		-		-		-		-		-		-		-		-		-	
								64		-		-		-		-		-		-		-		-		-		-		-		-	
								65		49		-		-		-		-		-		-		-		-		-		-		-	
								66		50/3"		-		-		-		-		-		-		-		-		-		-		-	
								67		-		-		-		-		-		-		-		-		-		-		-		-	
								68		-		-		-		-		-		-		-		-		-		-		-		-	
								69		-		-		-		-		-		-		-		-		-		-		-		-	
								70		50/3"		-		-		-		-		-		-		-		-		-		-		-	
								71		-		-		-		-		-		-		-		-		-		-		-		-	
								72		-		-		-		-		-		-		-		-		-		-		-		-	
								73		-		-		-		-		-		-		-		-		-		-		-		-	
								74		-		-		-		-		-		-		-		-		-		-		-		-	
								75		24		-		-		-		-		-		-		-		-		-		-		-	
								76		29		77		33		SS-21		-		-		-		-		-		-		-		9 A-2-4 (V)	
								77		31		-		-		-		-		-		-		-		-		-		-		-	
								78		-		-		-		-		-		-		-		-		-		-		-		-	
								79		-		-		-		-		-		-		-		-		-		-		-		-	
								80		19		21		65		89		SS-22		-		-		-		-		-		-		-	
								81		30		-		-		-		-		-		-		-		-		-		-		11 A-2-4 (V)	
FOR		959.1		-		-		-		-		-		-		-		-		-		-		-									

STANDARD ODOT SOIL BORING LOG (11 X 17) - OH DOT.GDT - 7/8/26 14:03 - C:\USERS\YZIMMERMAN\ONEDRIVE - GANNETT FLEMING INC\G - 078318-MINK STREET BRIDGE REPLACEMENT\5 WORKING\01 DATA\SUBSURFACE EXPLORATION\BORING LOGS\LIC-CR41-5.6.GPJ

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: USED .5 BAG ASPHALT PATCH; MIXED WITH 1 BAG BENTONITE CHIPS; TREMIED 1 BAG CEMENT

PROJECT: LIC-41-05.60				DRILLING FIRM / OPERATOR: CTL / H. BROWN				DRILL RIG: MOBILE B-57 TRACK				STATION / OFFSET: 208+03.8' RT.				EXPLORATION ID	
TYPE: STRUCTURE FOUNDATION				SAMPLING FIRM / LOGGER: GF / E. ENGEL				HAMMER: MOBILE AUTOMATIC				ALIGNMENT: LIC-CR41				B-002-0-24	
PID: 119707 SFN: 4563743				DRILLING METHOD: 3.25" HSA				CALIBRATION DATE: 5/1/23				ELEVATION: 1040.3 (MSL) EOB: 86.5 ft.				PAGE	
START: 5/21/24 END: 5/21/24				SAMPLING METHOD: SPT				ENERGY RATIO (%): 76.8				LAT / LONG: 40.018141, -82.727963				1 OF 2	
MATERIAL DESCRIPTION AND NOTES				ELEV.		REC SAMPLE		GRADATION (%)		ATTERBERG		ODOT					
				1040.3		(%)		(tsf)		GR CS FS SI CL LL PL PI WC		CLASS (G)					
DRY ASPHALT = 7"				1039.7		SPT/ RQD		N ₆₀		ID		HP		HOLE			
DRY BASE = 23"														SEALED			
MEDIUM DENSE BROWN, STONE FRAGMENTS WITH SAND, LITTLE SILT, TRACE CLAY, CONTAINS ROOTS, DAMP				DEPTHS													
				1													
				2													
				3		7		5		12		33		SS-1		NP NP NP 7 A-1-b (0)	
				4													
				5													
				6		5		4		10		22		SS-2		NP NP NP 5 A-1-b (0)	
				7													
				8		2		1		3		-		SS-3		-	
				9													
VERY LOOSE, BROWN, STONE FRAGMENTS WITH SAND AND SILT LITTLE CLAY, WET @ 7.5 FT: NO RECOVERY				10		0		1		5		2.00		20 15 32 22 11 NP NP NP 49 A-2-4 (0)			
				11		1		10		23		56		SS-5		2.00 - - - - - 18 A-6b (V)	
				12													
				13		3		15		41		100		SS-6		2.00 14 8 26 34 18 28 10 18 23 A-6b (6)	
				14		10		13		36		89		SS-7		-	
				15													
				16		15		18		46		100		SS-8		-	
				17		14		14		38		67		SS-9		-	
				18													
				19													
STIFF, BROWN TO BLACK, SILTY CLAY LITTLE GRAVEL, SOME SAND, MOIST				20		19		20		46		17		SS-10		-	
				21													
				22													
				23		14		16		46		33		SS-11		-	
				24													
				25													
				26		10		11		27		67		SS-12		3.50	
				27													
				28													
				29													
DENSE, GRAY, GRAVEL WITH SAND LITTLE SILT, TRACE CLAY, MOIST TO WET				30		7		30		52		56		SS-13		3.50	
				31													
				32													
				33													
				34													
				35		4		6		17		67		SS-14		3.00	
				36													
				37													
				38													
				39													
@ 45.5 FT: CONTAINS ROOTS				40		7		6		15		67		SS-15		2.75	
				41													
				42													
				43													
				44													
				45		4		18		54		67		SS-16		3.00	
				46													
				47													
				48													
				49													
VERY DENSE, GRAY, SANDY SILT, TRACE GRAVEL, MOIST				50		16		24		63		67		SS-17		-	
				51													
				52													
				53													
				54													
				55													
				56		27		24		84		67		SS-18		-	
				57													
				58													
				59													
VERY DENSE, GRAY, SANDY SILT LITTLE GRAVEL, SOME CLAY, [BOULDER ZONE], DAMP				60													
				61													
				62													
				63													
				64													
				65													
				66													
				67													
				68													
				69													
@ 55.0 FT: PETROLEUM ODOR				70													
				71													
				72													
				73													
				74													
				75													
				76													
				77													
				78													
				79													

PID: 119707		SFN: 4563743		PROJECT: LIC-41-05.60		STATION / OFFSET:		208+03.8' RT.		START: 5/21/24		END: 5/21/24		PG 2 OF 2		B-002-0-24																
MATERIAL DESCRIPTION AND NOTES						ELEV.	DEPTHS	SPT/ RQD	N ₆₀	REC SAMPLE (%)	HP (tsf)	GRADATION (%)			ATTERBERG			WC	PI	LL	PL	DOT CLASS (G)	HOLE SEALED									
VERY DENSE GRAY SANDY SILT LITTLE GRAVEL, SOME CLAY, [BOULDER ZONE], DAMP (continued)						980.3		50/4"	-	100	SS-19	-	-	-	-	-	-	-	-	-	-	-	-	-	A-4a (V)	> 1/2"						
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								31	24	65	11	SS-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"								
VERY STIFF TO HARD, GRAY SANDY SILT LITTLE GRAVEL, SOME CLAY, DAMP TO WET						970.3		24	88	100	SS-21	3.25	12	13	19	33	23	21	12	9	10	A-4a (4)	> 1/2"									
								30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
@ 75.0 FT: POSSIBLE BOULDER								50/3"	-	100	SS-22	-	-	-	-	-	-	-	-	-	-	-	-	-	A-4a (V)	> 1/2"						
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
@ 85.0 FT: TRACE GRAVEL								25	-	25	SS-23	-	-	-	-	-	-	-	-	-	-	-	-	-	A-4a (V)	> 1/2"						
								34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								50/4"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"	
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
								-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"
13	50	100	SS-24	4.5+	9	11	17	37	26	22	13	9	9	A-4a (6)	> 1/2"																	
18	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	> 1/2"								

STANDARD ODOT SOIL BORING LOG (11 X 17) - OH DOT.GDT - 7/8/26 14:21 - C:\USERS\YZIMMERMAN\ONE DRIVE - GANNETT FLEMING INC\GF - 078318-MINK STREET BRIDGE REPLACEMENTS WORKING\01 DATA\SUBSURFACE EXPLORATION\BORING LOGS\LIC-CR41-5.6.GPJ

NOTES: NONE
ABANDONMENT METHODS, MATERIALS, QUANTITIES: USED .5 BAG ASPHALT PATCH, MIXED WITH 8 BAGS BENTONITE CHIPS

GEOTECHNICAL PROFILE - BRIDGE
BRIDGE NO. LIC-CR41-05.600 OVER MUDDY FORK
BORING LOG B-001-0-24 (CONT.)

DESIGN AGENCY



DESIGNER

JAY

REVIEWER

TLM 11/26/24

PROJECT ID

119707

SUBSET

7

TOTAL

7

SHEET

P.49

TOTAL

49

APPENDIX D

Calculations

APPENDIX D.1

Scour Analysis



SUBJECT LIC-CR41-05.600
Scour Analysis
FHWA Toolbox Input
Contraction Scour - Main Channel

BY TRS
CHKD BY MTO
SHEET NO.
JOB NO.

DATE 4/7/2026
DATE 4/10/2026
OF
78318

SCOUR DEPTH SUMMARY

Procedure:

- Scour depths were calculated using FHWA Toolbox, using guidance from HEC-18: Evaluating Scour at Bridges, Fifth Edition and ODOT LD-2 Chapter 1008.10.
- Contraction scour is calculated through main channel using a layer-by-layer scour analysis. Should the calculated scour depth exceed the depth of soil, calculate scour using parameters of the subsequent soil layer. Continue until scour depth does not exceed the cumulative depth of soil at a given layer.
- Scour depth was analyzed using geotechnical parameters from borings B-001-0-24 (behind existing rear abutment) and B-002-0-24 (behind existing forward abutment). Analyze given layers of soil for using methods for either cohesive or granular (clear water and/or live bed) scour.

Contraction Scour

Flood Event	Scour Depth (ft)		Scour Elevations	
	B-001	B-002	B-001	B-002
50-Year	4.18	0.47	1029.52	1033.63
100-Year	4.34	0.46	1029.36	1033.64

NOTE: Exact soil makeup through stream channel is unknown. Conservatively report maximum scour depth between borings B-001-0-24 and B-002-0-24 as contraction scour through channel.

Abutment Scour

Flood Event	Scour Depth (ft)		Use for Forward Abut (See Note)	Scour Elevations	
	Rear Abut	Forward Abut		B-001	B-002
50-Year	5.90	0.00	0.47	1027.80	1034.10
100-Year	7.37	0.29	0.46	1026.33	1033.81

NOTE: Due to differences in computation methods used, NCHRP Scour calculation methods may underestimate scour depth for forward abutment. Conservatively apply contraction scour depths to forward abutment.



SUBJECT LIC-CR41-05.600
Scour Analysis
FHWA Toolbox Input - Contraction
Main Channel - B-001-0-24

BY TRS
CHKD BY MTO
SHEET NO.
JOB NO. 78318
DATE 4/7/2026
DATE 4/10/2026
OF

Contraction Scour Analysis Procedure:

Use soil parameters from boring B-001-0-24 to estimate scour depths through main channel. Upon inspection, overbank flow is minimal and scour can be ignored.

Per ODOT LD2 Sec 1008.10.4, given the variability of soil layer D50, perform layer-by-layer scour analysis. If scour depth exceeds the layer thickness, use the next layer D50 in the analysis, keeping the same velocity and depth as the first layer. Use 657450 hours for duration of flow in FHWA input to represent the 75-year service life of the bridge.

Per the Stage 2 Review comments from the ODOT Office of Geotechnical Engineering, begin the analysis at Elev. 1033.7 feet.

NOTE: Soil from layers 1033.7 - 1028.6 are cohesive. Soil layers from 1028.6 - 1024.1 are granular. For granular soils, select "Clear-Water or Live Bed Scour" to evaluate contraction scour.

FHWA Toolbox Input, Contraction Scour Computation Method

= Granular Soil Cohesive Soil

Layer	Sample ID	D50 (mm)	Depth (ft)	Start Elevation (ft)	End Elevation (ft)	τ_c (Pa)	τ_c (psf)	ODOT Soil Class
1	SS-3	0.2	3.1	1033.7	1030.6	6.163	0.129	A-6a
2	SS-4	0.2	2	1030.6	1028.6	9.536	0.199	A-4a
3	SS-5	0.8834	1.5	1028.6	1027.1	0.885	0.0185	A-2-4
4	SS-6/7	1.7437	11.5	1027.1	1015.6	1.742	0.0364	A-1-b

NOTES

1. "Start Elevation" for layer 1 is set to elevation of soil layer in front of rear abutment. Soil layers above this elevation are discounted.
2. For cohesive layers 1-2, assume end elevation of soil layer is equal to the start elevation of the subsequent soil layer.



SUBJECT LIC-CR41-05.600
Scour Analysis
FHWA Toolbox Input - Contraction
Main Channel - B-001-0-24

BY TRS
CHKD BY MTO
SHEET NO. OF
JOB NO. 78318

DATE 4/7/2026
DATE 4/10/2026

Input Parameters

NOTE: Input parameters below are applicable for cohesive and granular soils. Not all inputs are used for both methods of scour evaluation. See FHWA input.

Flood Event	y (ft)	Manning's n	V (ft/s)	V ₂ (ft/s)
50-Yr	6.42	0.03	5.09	7.13
100-Yr	7.02	0.03	5.41	7.11

Flood Event	S ₁ (ft/ft)	Q ₂ (cfs)	Q ₁ (cfs)	W ₂ (ft)	W ₁ (ft)	y _o (ft)
50-Yr	0.000995	950.00	917.09	47.76	28.10	4.24
100-Yr	0.000996	1120.00	1067.07	50.63	28.10	4.56

y = y₁ = average depth in upstream main channel (XS 540)

Manning's n = manning's n value through channel

V = Channel velocity in upstream main channel (XS 540)

V₂ = average velocity in contracted section (XS 501)

y_o = average existing depth in the contracted section (XS 501)

W₁ = top or bottom width of upstream main channel that is transporting bed material (XS 540)

W = W₂ = top or bottom width of main channel in the contracted section less pier width(s) (XS 501)

Q₁ = flow in the upstream channel transporting sediment (XS 540)

S₁ = slope of energy grade line of main channel (XS 540)

Q₂ = Discharge in Contracted Section (XS 501)

Unit Weight of Water = 62.40lb/ft³ = 1.94 slug/ft³

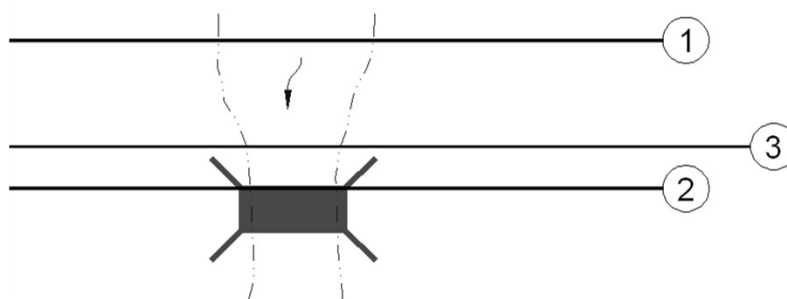
Unit Weight of Sediment = 165.00 lb/ft³

Duration of flow = 657450 hours, ODOT LD2 1008.10.4

XS # 540

XS # 527

XS # 501





SUBJECT LIC-CR41-05.600
Scour Analysis
FHWA Toolbox Input - Contraction
Main Channel - B-001-0-24

BY TRS
CHKD BY MTO
SHEET NO. OF
JOB NO. 78318

DATE 4/7/2026

DATE 4/10/2026

FHWA Toolbox Analysis

50-Year

Layer	Scour Condition	D50 (mm)	Layer Depth (ft)	τ_c (psf)	Cumulative Depth (ft)	Scour Depth (ft)
1	Cohesive	0.20	3.10	0.13	3.10	4.18
2	Cohesive	0.20	2.00	0.20	5.10	3.87

Scour depth using controlling shear stress does not exceed cumulative soil depth. Analysis complete.

Use scour depth = 4.18 ft from beginning soil data Elev. 1033.7

Use scour elevation = 1029.52 ft

100-Year

Layer	Scour Condition	D50 (mm)	Layer Depth (ft)	τ_c (psf)	Cumulative Depth (ft)	Scour Depth (ft)
1	Cohesive	0.20	3.10	0.13	3.10	4.34
1	Cohesive	0.20	2.00	0.20	5.10	4.01

Scour depth using controlling shear stress does not exceed cumulative soil depth. Analysis complete.

Use scour depth = 4.34 ft from beginning soil data Elev. 1033.7

Use scour elevation = 1029.36 ft

Conclusion: For the two design storms, soil in layer 1 will be scoured through the lifetime of the bridge.
Soil in layer 2 will remain partially intact.



SUBJECT	LIC-CR41-05.600	BY	TRS	DATE	4/7/2026
	Scour Analysis	CHKD BY	MTO	DATE	4/10/2026
	FHWA Toolbox Input - Abutment	SHEET NO.		OF	
	Rear Abut - Boring B-001-0-24	JOB NO.		78318	

Abutment Scour Analysis Procedure:

Use soil parameters from boring B-001-0-24 to estimate scour depth for rear abutment.

- Notes:**
- Soil layers 1 and 2 (SS-2 and SS-3, respectively) are cohesive soil. FHWA Toolbox does not distinguish between cohesive and granular soils to determine scour depth using the NCHRP method. Instead, the program will determine whether the scour condition is clear-water or live-bed using HEC 18 Equation 6.1.
 - Considering the results of HEC 18 Eq. 6.1, the NCHRP method uses one of three equations to estimate scour depth at the abutment. HEC 18 equations 8.5 (live-bed), 8.6 (clear water, based on particle size), and 8.7 (clear water, based on critical shear stress).
 - By inspection, it is more likely that the cohesive materials will fall into a clear-water scour condition where there is no transport of bed material through the downstream reach. Additionally, to maintain consistency with channel contraction scour calculations using soil parameters from boring B-001-0-24, the cohesive soils method should be used to determine local abutment scour.
 - In order to use the most appropriate equations, a D50 greater than what's listed in the geotechnical parameters is entered into FHWA toolbox to force the program to use the Tc shear stress value and clear-water scour calculations for cohesive soils.
 - External validation of HEC 18 Equation 8.7 is provided after scour depth summaries in this calculation.

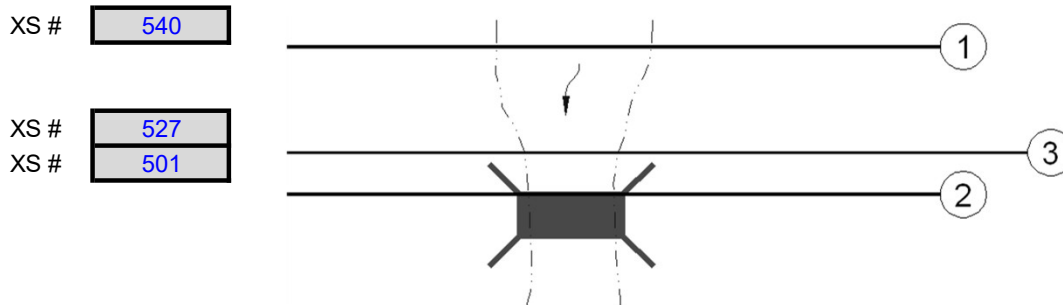
FHWA Toolbox Input, Abutment Scour

Computation Method	=	NCHRP
Scour Condition	=	Compute
Scour Condition Location	=	Type A (Main Channel)
Abutment Type	=	Spill-through
Angle of Embankment to Flow	=	90 degrees
Manning's n	=	0.03

Soil Layer	ID	Depth	Start Elev	End Elev	D50 *	τ_c **
1	SS-3	3.1	1033.7	1030.6	0.1302	0.1288
2	SS-4	2	1030.6	1028.6	0.039	0.1993
3	SS-5	1.5	1028.6	1027.1	0.8834	-
4	SS-6	11.5	1027.1	1015.6	1.7437	-

* Note: For cohesive soils, D50 input in FHWA toolbox is greater than D50 listed in soil parameters. See notes above.

** Note: Critical shear stress only included for cohesive soils





SUBJECT LIC-CR41-05.600
 Scour Analysis
 FHWA Toolbox Input - Abutment
 Rear Abut - Boring B-001-0-24

BY TRS
 CHKD BY MTO
 SHEET NO.
 JOB NO. 78318
 DATE 4/7/2026
 DATE 4/10/2026
 OF

Event	W	q1	q2	y	y0
50-Year	28.10	32.637	19.891	6.42	4.24

W = Width of Flood Plain through main channel (XS 540)
 q1 = Main Channel flow / (W), active flow area (XS 540)
 q2 = Main Channel flow / Main Channel Width, contracted section (XS 501)
 y = upstream flow depth (XS 501)
 y0 = flow depth prior to scour (XS 501)
 ys = scour hole depth (XS 501)
 Note: Negative ys values imply zero scour depth. (Computed by FHWA toolbox)

Flood Event	$\tau_c / D50$	Scour Depth (ft)	Soil Depth (ft)	Cumulative Soil Depth (ft)	Comment
50-Year, L1	0.1288	3.53	3.10	3.10	Scour depth exceeds soil depth. Proceed to next layer.
50-Year, L2	0.1993	2.20	2.00	5.10	Scour depth exceeds soil depth. Proceed to next layer.
50-Year, L3	0.8834	0.80	1.50	6.60	Analysis complete.

Scour depth extends into soil layer 3. Maximum scour depth is equal to total depth of soil layers 1 and 2 plus scour depth of layer 3.

Use for max scour depth 5.90 ft

Use scour elevation = 1027.80 ft

Event	W	q1	q2	y	y0
100-Year	25.81	37.974	22.121	7.02	4.56

Flood Event	$\tau_c / D50$	Scour Depth (ft)	Soil Depth (ft)	Cumulative Soil Depth (ft)	Comment
100-Year, L1	0.1288	4.09	3.10	3.10	Scour depth exceeds soil depth. Proceed to next layer.
100-Year, L2	0.1993	2.50	2.00	5.10	Scour depth exceeds soil depth. Proceed to next layer.
100-Year, L3	0.8834	0.74	1.50	6.60	Scour depth exceeds soil depth. Proceed to next layer.
100-Year, L4	1.7437	0.77	1.50	8.10	Analysis complete.

Scour depth extends into soil layer 4. Maximum scour depth is equal to total depth of soil layers 1, 2, and 3 plus scour depth of layer 4.

Use for max scour depth 7.37 ft

Use scour elevation = 1026.33 ft



SUBJECT	LIC-CR41-05.600	BY	TRS	DATE	4/7/2026
	Scour Analysis	CHKD BY	MTO	DATE	4/10/2026
	FHWA Toolbox Input - Abutment	SHEET NO.		OF	
	Rear Abut - Boring B-001-0-24	JOB NO.		78318	

Model Validation:

- For cohesive soils, the NCHRP input can under-estimate the potential scour depth by applying live-bed scour conditions to computation. Scour should be clear-water and HEC-18 Equation 8.7 should be applied to assume a clear-water scour condition and to incorporate known critical shear stress provided in the geotechnical parameters.
- A higher D50 must be input in FHWA toolbox in order for the correct equations to be used.
- The following example calculation is used to check the calculation being used by FHWA toolbox when higher D50 is input.

Example 1. 50-Year Storm, Layer 1. Abutment scour using clear-water scour equation with critical shear stress:

HEC 18 8.7:

If the critical shear stress is known for a floodplain soil, then the alternative clear-water scour equation can be used:

$$y_c = \left(\frac{\gamma}{\tau_c} \right)^{\frac{3}{7}} * \left(\frac{nq_{2f}}{K_u} \right)^{\frac{6}{7}} \quad (\text{HEC 18 Eqn 8.7})$$

y_c	=	Flow depth including scour
γ	62.4	Unit weight of water
τ_c	0.1288	Critical shear stress for floodplain material
n	0.03	manning's n of the floodplain material under bridge
q_{2f}	19.891	Unit Discharge
K_u	1.486	Constant

y_c	6.474	
Amplification factor, A	1.2	(HEC 18 Figure 8.10)
$y_c * A$	7.77	
Scour depth = $y_c - y_0$		
Scour Depth =	3.53	Calculation matches FHWA output. Say OK



SUBJECT	LIC-CR41-05.600	BY	TRS	DATE	4/7/2026
	Scour Analysis	CHKD BY	MTO	DATE	4/10/2026
	FHWA Toolbox Input - Contraction	SHEET NO.		OF	
	Main Channel - B-002-0-24	JOB NO.		78318	

Contraction Scour Analysis Procedure:

Use soil parameters from boring B-002-0-24 to estimate scour depths through main channel. Upon inspection, overbank flow is minimal and scour can be ignored.

Per ODOT LD2 Sec 1008.10.4, given the variability of soil layer D50, perform layer-by-layer scour analysis. If scour depth exceeds the layer thickness, use the next layer D50 in the analysis, keeping the same velocity and depth as the first layer. Use 657450 hours for duration of flow in FHWA input to represent the 75-year service life of the bridge.

Per the Stage 2 Review comments from the ODOT Office of Geotechnical Engineering, begin the analysis at Elev. 1034.1 feet.

NOTE: Soil is granular between elevations 1034.1-ft - 1032.8-ft and 1027.3-ft - 1015.3-ft. For granular soils, select "Clear-Water or Live Bed Scour" to evaluate contraction scour. Soil is cohesive between elevations 1032.8-ft - 1027.3-ft.

FHWA Toolbox Input, Contraction Scour Computation Method

=

Granular Soil Cohesive Soil

Critical Shear Stress

ODOT GDM 1302.1.1

W	=	water content	See geotechnical parameters
qu, L1-L3	=	2000 psi	See geotechnical parameters
	=	13789520 Pa	
qu, L4	=	9000 psi	See geotechnical parameters
	=	62052840 Pa	
f	=	% Finer than 0.075 mm, see geotechnical parameters	
PI	=	Plasticity Index, see geotechnical parameters	
tc (Pa)	=	Critical Shear Stress	See geotechnical parameters

Layer	Sample ID	D50 (mm)	Depth (ft)	Start Elevation (ft)	End Elevation (ft)	tc (Pa)	tc (psf)	ODOT Soil Class
1	SS-2	1.4235	1.3	1034.1	1032.8	1.421	0.030	A-1-b
2	SS-3	0.2	5.5	1032.8	1027.3	0.091	0.002	A-6b
3	SS-6	0.8834	12	1027.3	1015.3	0.885	0.0185	A-2-4

NOTES:

1. "Start Elevation" for layer 1 is set to elevation of soil layer in front of forward abutment. Soil layers above this elevation are discounted.



SUBJECT LIC-CR41-05.600
 Scour Analysis
 FHWA Toolbox Input - Contraction
 Main Channel - B-002-0-24

BY TRS
 CHKD BY MTO
 SHEET NO.
 JOB NO.

DATE 4/7/2026
 DATE 4/10/2026
 OF
 78318

Input Parameters

NOTE: Input parameters below are applicable for cohesive and granular soils. Not all inputs are used for both methods of scour evaluation. See FHWA input.

Flood Event	y (ft)	Manning's n	V (ft/s)	V ₂ (ft/s)
50-Yr	6.42	0.03	5.09	7.13
100-Yr	7.02	0.03	5.41	7.11

Flood Event	S ₁ (ft/ft)	Q ₂ (cfs)	Q ₁ (cfs)	W ₂ (ft)	W ₁ (ft)	y _o (ft)
50-Yr	0.000995	950.00	917.09	47.76	28.10	4.24
100-Yr	0.000996	1120.00	1067.07	50.63	28.10	4.56

y = y₁ = average depth in upstream main channel (XS 540)
 Manning's n = manning's n value through channel
 V = Channel velocity in upstream main channel (XS 540)
 V₂ = average velocity in contracted section (XS 501)
 y_o = average existing depth in the contracted section (XS 501)
 W₁ = top or bottom width of upstream main channel that is transporting bed material (XS 540)
 W = W₂ = top or bottom width of main channel in the contracted section less pier width(s) (XS 501)
 V = Channel velocity in upstream main channel (XS 540)
 Q₁ = flow in the upstream channel transporting sediment (XS 540)
 S₁ = slope of energy grade line of main channel (XS 540)
 Q₂ = Discharge in Contracted Section (XS 501)

Unit Weight of Water = 62.40lb/ft³

Unit Weight of Sediment = 165.00 lb/ft³

Duration of flow = 657450 hours, ODOT LD2 1008.10.4



FHWA Toolbox Analysis

SUBJECT LIC-CR41-05.600
Scour Analysis
FHWA Toolbox Input - Contraction
Main Channel - B-002-0-24

BY TRS
CHKD BY MTO
SHEET NO.
JOB NO. 78318
DATE 4/7/2026
DATE 4/10/2026
OF

50-Year

Layer	Scour Condition	D50 (mm)	Layer Depth (ft)	Scour Depth (ft)
1	Live Bed	1.42	1.30	0.47

Scour Depth does not exceed layer depth. Analysis complete.

Use scour depth = 0.47 ft from beginning soil data Elev. 1034.1

Use scour elevation = 1033.63 ft

100-Year

Layer	Scour Condition	D50 (mm)	Layer Depth (ft)	Scour Depth (ft)
1	Live Bed	1.42	1.30	0.46

Scour Depth does not exceed layer depth. Analysis complete.

Use scour depth = 0.46 ft from beginning soil data Elev. 1034.1

Use scour elevation = 1033.64 ft

Conclusion: For the two design storms, scour will remain within soil layer 1.



SUBJECT LIC-CR41-05.600
Scour Analysis
FHWA Toolbox Input - Abutment
Forward Abut - Boring B-002-0-24

BY TRS
CHKD BY MTO
SHEET NO.
JOB NO. 78318
DATE 4/7/2026
DATE 4/10/2026
OF

Abutment Scour Analysis Procedure:

Use soil parameters from boring B-002-0-24 to estimate scour depth for forward abutment.

FHWA Toolbox Input, Abutment Scour

Computation Method = NCHRP
Scour Condition = Compute
Scour Condition Location = Type A (Main Channel)
Abutment Type = Spill-through
Angle of Embankment to Flow = 90 degrees
Manning's n = 0.03
D50, Soil Layer 1 = 1.4235 mm *
Critical Shear Stress, Layer 1 = 0.0297 psf *

* Note: Only layer 1 geotechnical information shown. For information on subsequent layers, see contraction scour input.

Event	W	q1	q2	y	y0	ys
50-Year	28.10	32.637	19.891	6.42	4.24	-0.13
100-Year	25.81	37.974	22.121	7.02	4.56	0.29

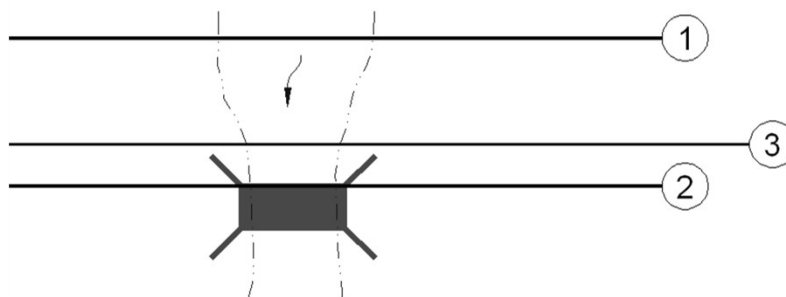
Flood Event	Scour Depth (ft)	Scour Elevation =
50-Year	0.00	1034.10
100-Year	0.29	1033.81

W = Width of Flood Plain through main channel (XS 540)
q1 = Main Channel flow / (W), active flow area (XS 540)
q2 = Main Channel flow / Main Channel Width, contracted section (XS 501)
y = upstream flow depth (XS 540)
y0 = flow depth prior to scour (XS 501)
ys = scour hole depth (Computed by FHWA toolbox)
Note: Negative ys values imply zero scour depth.

XS # 540

XS # 527

XS # 501





HEC-RAS Scour Output

Project Mink St
By TRS
Date 4/7/2026
Checked By MTO
Date 4/10/2026

Uncontracted Section Output - Cross Section 1 (XS 540)

Plan: PropFinal_n=030 Muddy Fork Reach 1 RS: 540 Profile: 50-yr					
E.G. Elev (ft)	1036.58	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.39	Wt. n-Val.	0.1	0.03	0.1
W.S. Elev (ft)	1036.19	Reach Len. (ft)	12.8	13.6	14.9
Crit W.S. (ft)		Flow Area (sq ft)	12.82	180.29	36.14
E.G. Slope (ft/ft)	0.000995	Area (sq ft)	12.82	180.29	111.67
Q Total (cfs)	950	Flow (cfs)	7.1	917.09	25.81
Top Width (ft)	125.7	Top Width (ft)	9.45	28.1	88.14
Vel Total (ft/s)	4.14	Avg. Vel. (ft/s)	0.55	5.09	0.71
Max Chl Dpth (ft)	8.24	Hydr. Depth (ft)	1.36	6.42	1.9
Conv. Total (cfs)	30124.4	Conv. (cfs)	225	29080.9	818.5
Length Wtd. (ft)	13.62	Wetted Per. (ft)	9.99	30.68	19.21
Min Ch El (ft)	1027.95	Shear (lb/sq ft)	0.08	0.36	0.12
Alpha	1.46	Stream Power (lb/ft s)	0.04	1.86	0.08
Frctn Loss (ft)	0.02	Cum Volume (acre-ft)	0.87	1.17	2.48
C & E Loss (ft)	0.04	Cum SA (acres)	0.63	0.24	1.65

Plan: PropFinal_n=030 Muddy Fork Reach 1 RS: 540 Profile: 100-yr					
E.G. Elev (ft)	1037.23	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.43	Wt. n-Val.	0.1	0.03	0.1
W.S. Elev (ft)	1036.8	Reach Len. (ft)	12.8	13.6	14.9
Crit W.S. (ft)		Flow Area (sq ft)	19.51	197.36	47.72
E.G. Slope (ft/ft)	0.000996	Area (sq ft)	19.51	197.36	167.72
Q Total (cfs)	1120	Flow (cfs)	11.89	1067.07	41.04
Top Width (ft)	136.93	Top Width (ft)	12.57	28.1	96.26
Vel Total (ft/s)	4.23	Avg. Vel. (ft/s)	0.61	5.41	0.86
Max Chl Dpth (ft)	8.85	Hydr. Depth (ft)	1.55	7.02	2.51
Conv. Total (cfs)	35493.2	Conv. (cfs)	376.9	33815.9	1300.4
Length Wtd. (ft)	13.62	Wetted Per. (ft)	13.17	30.68	19.21
Min Ch El (ft)	1027.95	Shear (lb/sq ft)	0.09	0.4	0.15
Alpha	1.56	Stream Power (lb/ft s)	0.06	2.16	0.13
Frctn Loss (ft)	0.02	Cum Volume (acre-ft)	1.03	1.24	2.88
C & E Loss (ft)	0.04	Cum SA (acres)	0.69	0.24	1.72



HEC-RAS Scour Output

Project Mink St
By TRS
Date 4/7/2026
Checked By MTO
Date 4/10/2026

Contracted Section Output - Cross Section 2 (XS 501)

Plan: PropFinal_n=030 Muddy Fork Reach 1 RS: 501 Profile: 50-yr

E.G. US. (ft)	1036.53	Element	Inside BR	Inside BR
W.S. US. (ft)	1036.02	E.G. Elev (ft)	1036.51	1036.21
Q Total (cfs)	950	W.S. Elev (ft)	1036	1034.93
Q Bridge (cfs)	950	Crit W.S. (ft)	1033.33	1034.32
Q Weir (cfs)		Max Chl Dpth (ft)	7.6	5.37
Weir Sta Lft (ft)		Vel Total (ft/s)	4.69	7.13
Weir Sta Rgt (ft)		Flow Area (sq ft)	202.59	133.27
Weir Submerg		Froude # Chl	0.41	0.76
Weir Max Depth (ft)		Specif Force (cu ft)	729.81	532.98
Min El Weir Flow (ft)	1040.57	Hydr Depth (ft)	4.24	3.15
Min El Prs (ft)	1037.95	W.P. Total (ft)	50.9	44.94
Delta EG (ft)	0.35	Conv. Total (cfs)	26150.3	13468.3
Delta WS (ft)	1.15	Top Width (ft)	47.76	42.28
BR Open Area (sq ft)	279.94	Frctn Loss (ft)	0.07	0.03
BR Open Vel (ft/s)	7.13	C & E Loss (ft)	0.23	0.01
BR Sluice Coef		Shear Total (lb/sq ft)	0.33	0.92
BR Sel Method	Energy only	Power Total (lb/ft s)	1.54	6.57

Plan: PropFinal_n=030 Muddy Fork Reach 1 RS: 501 Profile: 100-yr

E.G. US. (ft)	1037.17	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1036.59	E.G. Elev (ft)	1037.16	1036.85
Q Total (cfs)	1120	W.S. Elev (ft)	1036.57	1035.48
Q Bridge (cfs)	1120	Crit W.S. (ft)	1033.77	1034.77
Q Weir (cfs)		Max Chl Dpth (ft)	8.17	5.92
Weir Sta Lft (ft)		Vel Total (ft/s)	4.85	7.11
Weir Sta Rgt (ft)		Flow Area (sq ft)	230.92	157.62
Weir Submerg		Froude # Chl	0.42	0.74
Weir Max Depth (ft)		Specif Force (cu ft)	896.61	669.46
Min El Weir Flow (ft)	1040.57	Hydr Depth (ft)	4.56	3.49
Min El Prs (ft)	1037.95	W.P. Total (ft)	54.01	48.01
Delta EG (ft)	0.48	Conv. Total (cfs)	30532.2	16445.7
Delta WS (ft)	1.63	Top Width (ft)	50.63	45.13
BR Open Area (sq ft)	279.94	Frctn Loss (ft)	0.07	0.04
BR Open Vel (ft/s)	7.11	C & E Loss (ft)	0.23	0.11
BR Sluice Coef		Shear Total (lb/sq ft)	0.36	0.95
BR Sel Method	Energy only	Power Total (lb/ft s)	1.74	6.75



HEC-RAS Scour Output

Project Mink St
By TRS
Date 4/7/2026
Checked By MTO
Date 4/10/2026

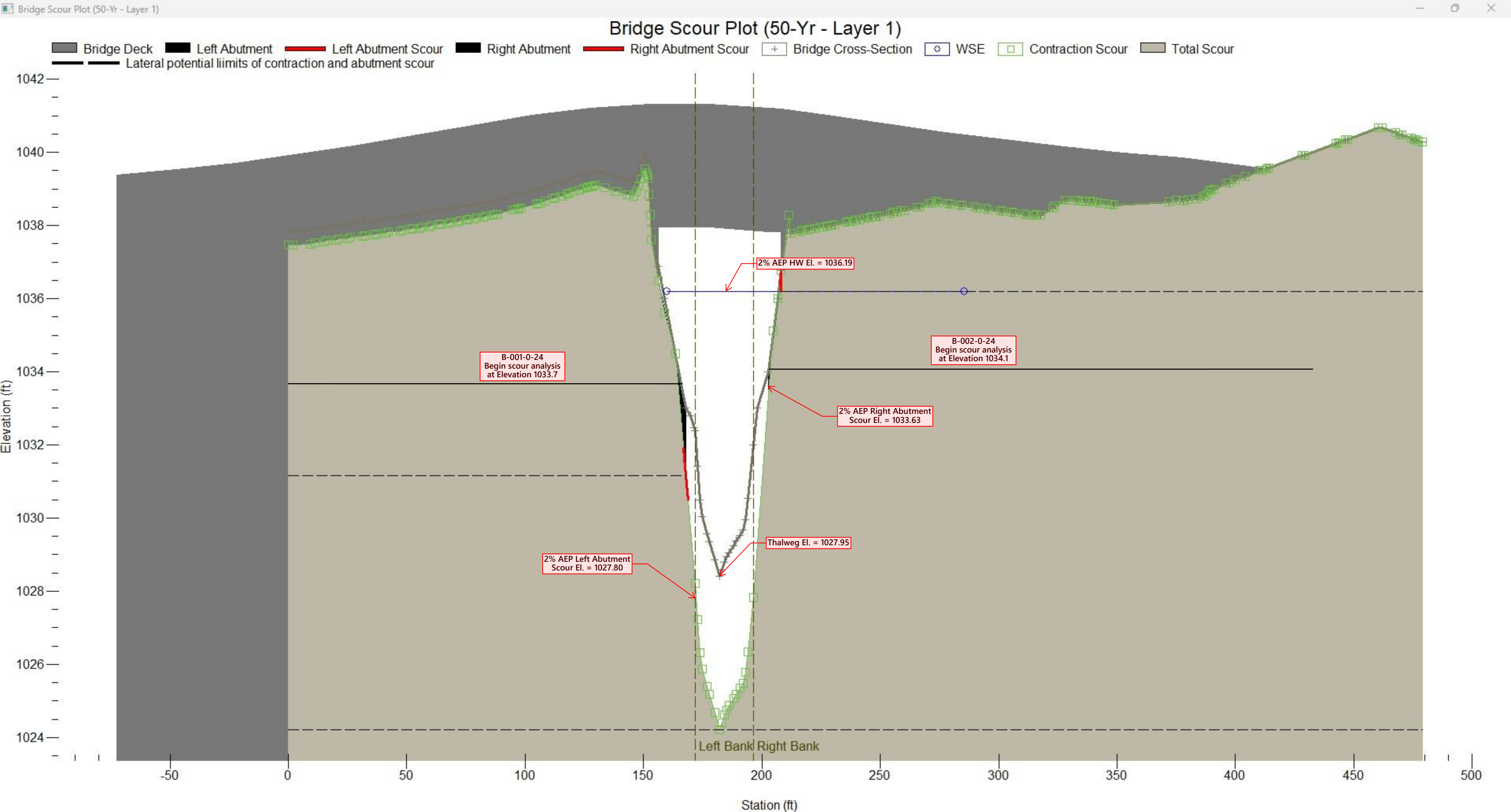
Uncontracted Section Output - Cross Section 3 (XS 527)

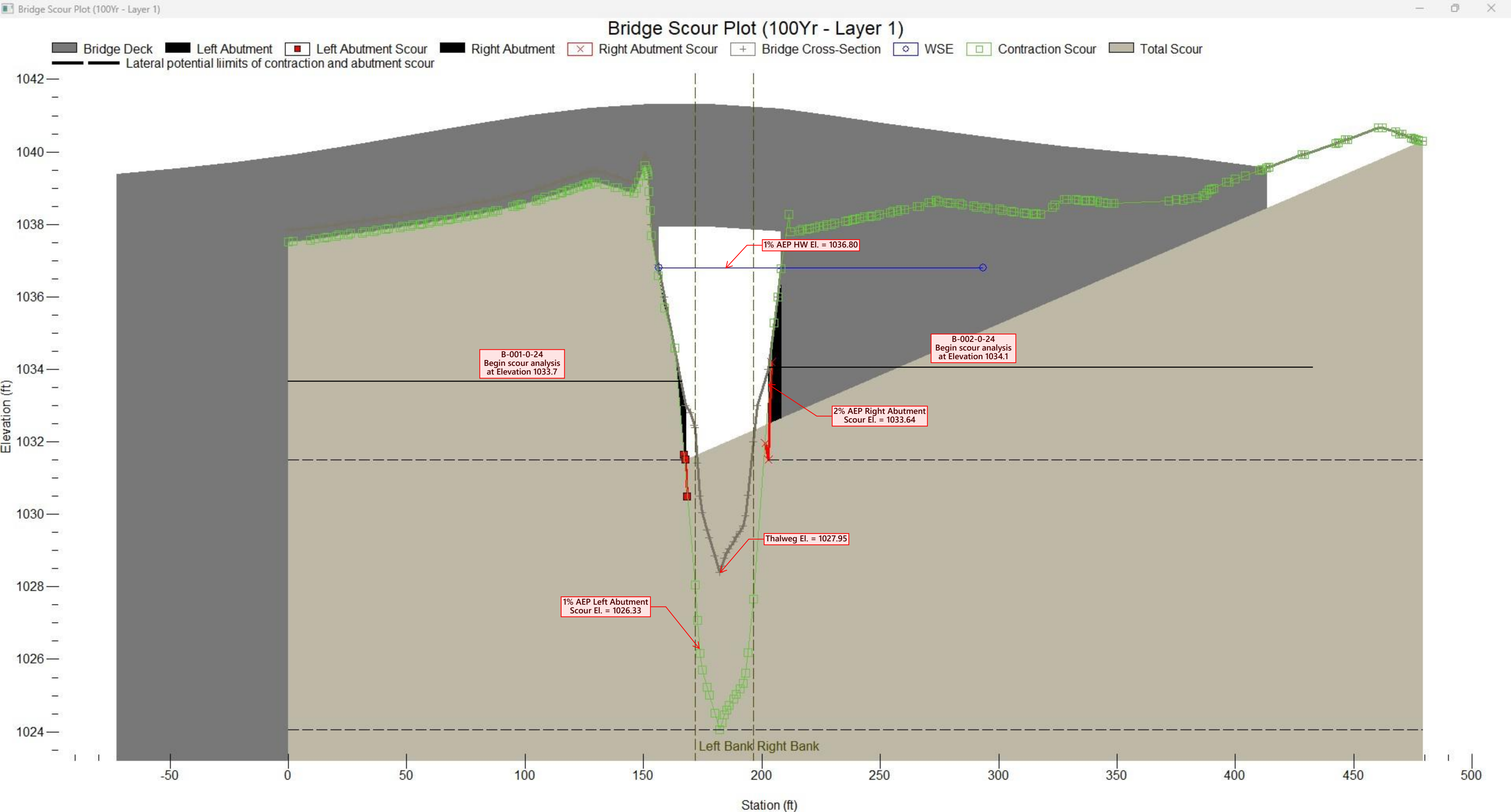
Plan: PropFinal_n=030 Muddy Fork Reach 1 RS: 527 Profile: 50-yr

E.G. Elev (ft)	1036.53	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.51	Wt. n-Val.	0.1	0.03	0.1
W.S. Elev (ft)	1036.02	Reach Len. (ft)	10	10	10
Crit W.S. (ft)	1033.33	Flow Area (sq ft)	26.91	155.13	21.44
E.G. Slope (ft/ft)	0.001306	Area (sq ft)	26.91	155.13	21.44
Q Total (cfs)	950	Flow (cfs)	22.72	909.51	17.77
Top Width (ft)	47.85	Top Width (ft)	13.11	24.43	10.31
Vel Total (ft/s)	4.67	Avg. Vel. (ft/s)	0.84	5.86	0.83
Max Chl Dpth (ft)	7.62	Hydr. Depth (ft)	2.05	6.35	2.08
Conv. Total (cfs)	26287.4	Conv. (cfs)	628.6	25167	491.8
Length Wtd. (ft)	10	Wetted Per. (ft)	13.65	26.17	11.18
Min Ch El (ft)	1028.4	Shear (lb/sq ft)	0.16	0.48	0.16
Alpha	1.51	Stream Power (lb/ft s)	0.14	2.83	0.13
Frctn Loss (ft)	0.01	Cum Volume (acre-ft)	0.86	1.12	2.45
C & E Loss (ft)	0	Cum SA (acres)	0.63	0.23	1.63

Plan: PropFinal_n=030 Muddy Fork Reach 1 RS: 527 Profile: 100-yr

E.G. Elev (ft)	1037.17	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.58	Wt. n-Val.	0.1	0.03	0.1
W.S. Elev (ft)	1036.59	Reach Len. (ft)	10	10	10
Crit W.S. (ft)	1033.77	Flow Area (sq ft)	34.96	169.21	27.72
E.G. Slope (ft/ft)	0.001332	Area (sq ft)	34.96	169.21	27.72
Q Total (cfs)	1120	Flow (cfs)	32.65	1061.75	25.6
Top Width (ft)	50.73	Top Width (ft)	14.84	24.43	11.46
Vel Total (ft/s)	4.83	Avg. Vel. (ft/s)	0.93	6.27	0.92
Max Chl Dpth (ft)	8.19	Hydr. Depth (ft)	2.36	6.93	2.42
Conv. Total (cfs)	30683.6	Conv. (cfs)	894.5	29087.6	701.4
Length Wtd. (ft)	10	Wetted Per. (ft)	15.47	26.17	12.47
Min Ch El (ft)	1028.4	Shear (lb/sq ft)	0.19	0.54	0.18
Alpha	1.6	Stream Power (lb/ft s)	0.18	3.37	0.17
Frctn Loss (ft)	0.01	Cum Volume (acre-ft)	1.03	1.18	2.84
C & E Loss (ft)	0	Cum SA (acres)	0.68	0.23	1.71





Hydraulic Analysis Report

Project Data

Project Title: Mink Street Bridge Scour

Designer: TRS / MTO

Project Date: April 10, 2026

Project Units: U.S. Customary Units

Notes:

Bridge Scour Analysis: Bridge Scour Analysis - B1

Notes:

Scenario: 50-Yr - Layer 1

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 4.18 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 4.18 ft

Applied Contraction Scour Elevation with LTD 0.00 ft

Local Scour at Abutments Summary

Left Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.80 ft

Total Scour at Abutment 0.80 ft

Total Scour Elevation at Abutment 1031.15 ft

Right Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.00 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 1036.19 ft

Main Channel Contraction Scour

Computation Type: Cohesive Soil

Input Parameters

Input Parameters for Cohesive Scour

Average Depth Upstream (y): 6.42 ft

Average Velocity in Contracted Section (V2): 7.13 ft/s

Critical Shear Stress (τ_c): 0.1300 lb/ft²

Density of Water (Δ): 1.94 lb/ft³

Manning's n (n): 0.0300

Depth Prior to Scour in Contracted Section (y0): 6.33 ft

Time Rate of Scour

Unit Weight of Water (γ_w): 62.40 lb/ft³

Duration of Flow (t): 657450.00 hr

Results

Results for Cohesive Scour

Scour Depth: 4.18 ft

Recommendations

Recommended Scour Condition: Cohesive

Recommended Scour Depth: 4.18 ft

Results of Flow Event

Scour Depth from Flow Event (y(t)): 4.18 ft

Left Bank Contraction Scour

Computation Type: Cohesive Soil

Input Parameters

Input Parameters for Cohesive Scour

Average Depth Upstream (y): 1.36 ft

Average Velocity in Contracted Section (V2): 1.48 ft/s

Critical Shear Stress (τ_c): 0.1300 lb/ft²

Density of Water (Δ): 1.94 lb/ft³

Manning's n (n): 0.1000

Depth Prior to Scour in Contracted Section (y_0): 1.73 ft

Time Rate of Scour

Unit Weight of Water (γ_w): 62.40 lb/ft³

Duration of Flow (t): 657450.00 hr

Results

Results for Cohesive Scour

Scour Depth: 0.39 ft

Recommendations

Recommended Scour Condition: Cohesive

Recommended Scour Depth: 0.39 ft

Results of Flow Event

Scour Depth from Flow Event ($y(t)$): 0.39 ft

Right Bank Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y_1): 0.00 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 0.00 ft/s

Results

More input is required for complete calculations

Left Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q_1): 32.64 cfs

Unit Discharge in the Constricted Area (q_2): 19.89 cfs/ft

D50: 0.199949 mm

Upstream Flow Depth: 6.42 ft

User Defined Shear Stress of floodplain

Critical Shear Stress of Floodplain Material: 0.1288 lb/ft³

Unit Weight of Water: 62.40 lb/ft³

Manning's n: 0.0300

Flow Depth Prior to Scour: 4.24 ft

Result Parameters

q_2/q_1 : 0.61

Average Velocity Upstream: 5.08 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 1.32 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 4.20 ft

Maximum Flow Depth including Abutment Scour: 5.04 ft

Scour Hole Depth from NCHRP Method: 0.80 ft

Right Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q_1): 0.00 cfs

Unit Discharge in the Constricted Area (q_2): 0.00 cfs/ft

D50: 0.199949 mm

Upstream Flow Depth: 0.00 ft

Flow Depth Prior to Scour: 0.00 ft

Result Parameters

q_2/q_1 : 0.00

Average Velocity Upstream: 0.00 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 0.00 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: -nan(ind)

Scour Condition: b (overbank)

Amplification Factor: 0.00

Flow Depth including Contraction Scour: 0.00 ft

Maximum Flow Depth including Abutment Scour: 0.00 ft

Scour Hole Depth from NCHRP Method: 0.00 ft

Scenario: 100Yr - Layer 1

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 4.18 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 4.18 ft

Applied Contraction Scour Elevation with LTD 0.00 ft

Local Scour at Abutments Summary

Left Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.80 ft

Total Scour at Abutment 0.80 ft

Total Scour Elevation at Abutment 1031.15 ft

Right Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.00 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 1036.19 ft

Main Channel Contraction Scour

Computation Type: Cohesive Soil

Input Parameters

Input Parameters for Cohesive Scour

Average Depth Upstream (y): 6.42 ft

Average Velocity in Contracted Section (V2): 7.13 ft/s

Critical Shear Stress (τ_c): 0.1300 lb/ft²

Density of Water (Δ): 1.94 lb/ft³

Manning's n (n): 0.0300

Depth Prior to Scour in Contracted Section (y0): 6.33 ft

Time Rate of Scour

Unit Weight of Water (γ_w): 62.40 lb/ft³

Duration of Flow (t): 657450.00 hr

Results

Results for Cohesive Scour

Scour Depth: 4.18 ft

Recommendations

Recommended Scour Condition: Cohesive

Recommended Scour Depth: 4.18 ft

Results of Flow Event

Scour Depth from Flow Event ($y(t)$): 4.18 ft

Left Bank Contraction Scour

Computation Type: Cohesive Soil

Input Parameters

Input Parameters for Cohesive Scour

Average Depth Upstream (y): 1.36 ft

Average Velocity in Contracted Section (V_2): 1.48 ft/s

Critical Shear Stress (τ_c): 0.1300 lb/ft²

Density of Water (Δ): 1.94 lb/ft³

Manning's n (n): 0.1000

Depth Prior to Scour in Contracted Section (y_0): 1.73 ft

Time Rate of Scour

Unit Weight of Water (γ_w): 62.40 lb/ft³

Duration of Flow (t): 657450.00 hr

Results

Results for Cohesive Scour

Scour Depth: 0.39 ft

Recommendations

Recommended Scour Condition: Cohesive

Recommended Scour Depth: 0.39 ft

Results of Flow Event

Scour Depth from Flow Event ($y(t)$): 0.39 ft

Right Bank Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y_1): 0.00 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 0.00 ft/s

Results

More input is required for complete calculations

Left Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q_1): 32.64 cfs

Unit Discharge in the Constricted Area (q_2): 19.89 cfs/ft

D50: 0.199949 mm

Upstream Flow Depth: 6.42 ft

User Defined Shear Stress of floodplain

Critical Shear Stress of Floodplain Material: 0.1288 lb/ft³

Unit Weight of Water: 62.40 lb/ft³

Manning's n: 0.0300

Flow Depth Prior to Scour: 4.24 ft

Result Parameters

q₂/q₁: 0.61

Average Velocity Upstream: 5.08 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 1.32 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 4.20 ft

Maximum Flow Depth including Abutment Scour: 5.04 ft

Scour Hole Depth from NCHRP Method: 0.80 ft

Right Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q₁): 0.00 cfs

Unit Discharge in the Constricted Area (q₂): 0.00 cfs/ft

D₅₀: 0.199949 mm

Upstream Flow Depth: 0.00 ft

Flow Depth Prior to Scour: 0.00 ft

Result Parameters

q_2/q_1 : 0.00

Average Velocity Upstream: 0.00 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 0.00 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: -nan(ind)

Scour Condition: b (overbank)

Amplification Factor: 0.00

Flow Depth including Contraction Scour: 0.00 ft

Maximum Flow Depth including Abutment Scour: 0.00 ft

Scour Hole Depth from NCHRP Method: 0.00 ft

Scenario: 50-Yr - Layer 2

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 4.18 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 4.18 ft

Applied Contraction Scour Elevation with LTD 0.00 ft

Local Scour at Abutments Summary

Left Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.80 ft

Total Scour at Abutment 0.80 ft

Total Scour Elevation at Abutment 1031.15 ft

Right Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.00 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 1036.19 ft

Main Channel Contraction Scour

Computation Type: Cohesive Soil

Input Parameters

Input Parameters for Cohesive Scour

Average Depth Upstream (y): 6.42 ft

Average Velocity in Contracted Section (V2): 7.13 ft/s

Critical Shear Stress (τ_c): 0.1300 lb/ft²

Density of Water (Δ): 1.94 lb/ft³

Manning's n (n): 0.0300

Depth Prior to Scour in Contracted Section (y0): 6.33 ft

Time Rate of Scour

Unit Weight of Water (γ_w): 62.40 lb/ft³

Duration of Flow (t): 657450.00 hr

Results

Results for Cohesive Scour

Scour Depth: 4.18 ft

Recommendations

Recommended Scour Condition: Cohesive

Recommended Scour Depth: 4.18 ft

Results of Flow Event

Scour Depth from Flow Event (y(t)): 4.18 ft

Left Bank Contraction Scour

Computation Type: Cohesive Soil

Input Parameters

Input Parameters for Cohesive Scour

Average Depth Upstream (y): 1.36 ft

Average Velocity in Contracted Section (V2): 1.48 ft/s

Critical Shear Stress (τ_c): 0.1300 lb/ft²

Density of Water (Δ): 1.94 lb/ft³

Manning's n (n): 0.1000

Depth Prior to Scour in Contracted Section (y0): 1.73 ft

Time Rate of Scour

Unit Weight of Water (γ_w): 62.40 lb/ft³

Duration of Flow (t): 657450.00 hr

Results

Results for Cohesive Scour

Scour Depth: 0.39 ft

Recommendations

Recommended Scour Condition: Cohesive

Recommended Scour Depth: 0.39 ft

Results of Flow Event

Scour Depth from Flow Event (y(t)): 0.39 ft

Right Bank Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 0.00 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 0.00 ft/s

Results

More input is required for complete calculations

Left Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q_1): 32.64 cfs

Unit Discharge in the Constricted Area (q_2): 19.89 cfs/ft

D50: 0.199949 mm

Upstream Flow Depth: 6.42 ft

User Defined Shear Stress of floodplain

Critical Shear Stress of Floodplain Material: 0.1288 lb/ft³

Unit Weight of Water: 62.40 lb/ft³

Manning's n: 0.0300

Flow Depth Prior to Scour: 4.24 ft

Result Parameters

q_2/q_1 : 0.61

Average Velocity Upstream: 5.08 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 1.32 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 4.20 ft

Maximum Flow Depth including Abutment Scour: 5.04 ft

Scour Hole Depth from NCHRP Method: 0.80 ft

Right Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q_1): 0.00 cfs

Unit Discharge in the Constricted Area (q_2): 0.00 cfs/ft

D50: 0.199949 mm

Upstream Flow Depth: 0.00 ft

Flow Depth Prior to Scour: 0.00 ft

Result Parameters

q_2/q_1 : 0.00

Average Velocity Upstream: 0.00 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 0.00 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: -nan(ind)

Scour Condition: b (overbank)

Amplification Factor: 0.00

Flow Depth including Contraction Scour: 0.00 ft

Maximum Flow Depth including Abutment Scour: 0.00 ft

Scour Hole Depth from NCHRP Method: 0.00 ft

Scenario: 100Yr - Layer 2

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 4.18 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 4.18 ft

Applied Contraction Scour Elevation with LTD 0.00 ft

Local Scour at Abutments Summary

Left Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.80 ft

Total Scour at Abutment 0.80 ft

Total Scour Elevation at Abutment 1031.15 ft

Right Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.00 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 1036.19 ft

Main Channel Contraction Scour

Computation Type: Cohesive Soil

Input Parameters

Input Parameters for Cohesive Scour

Average Depth Upstream (y): 6.42 ft

Average Velocity in Contracted Section (V2): 7.13 ft/s

Critical Shear Stress (τ_c): 0.1300 lb/ft²

Density of Water (Δ): 1.94 lb/ft³

Manning's n (n): 0.0300

Depth Prior to Scour in Contracted Section (y_0): 6.33 ft

Time Rate of Scour

Unit Weight of Water (γ_w): 62.40 lb/ft³

Duration of Flow (t): 657450.00 hr

Results

Results for Cohesive Scour

Scour Depth: 4.18 ft

Recommendations

Recommended Scour Condition: Cohesive

Recommended Scour Depth: 4.18 ft

Results of Flow Event

Scour Depth from Flow Event ($y(t)$): 4.18 ft

Left Bank Contraction Scour

Computation Type: Cohesive Soil

Input Parameters

Input Parameters for Cohesive Scour

Average Depth Upstream (y): 1.36 ft

Average Velocity in Contracted Section (V_2): 1.48 ft/s

Critical Shear Stress (τ_c): 0.1300 lb/ft²

Density of Water (Δ): 1.94 lb/ft³

Manning's n (n): 0.1000

Depth Prior to Scour in Contracted Section (y_0): 1.73 ft

Time Rate of Scour

Unit Weight of Water (γ_w): 62.40 lb/ft³

Duration of Flow (t): 657450.00 hr

Results

Results for Cohesive Scour

Scour Depth: 0.39 ft

Recommendations

Recommended Scour Condition: Cohesive

Recommended Scour Depth: 0.39 ft

Results of Flow Event

Scour Depth from Flow Event ($y(t)$): 0.39 ft

Right Bank Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y_1): 0.00 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 0.00 ft/s

Results

More input is required for complete calculations

Left Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q_1): 32.64 cfs

Unit Discharge in the Constricted Area (q_2): 19.89 cfs/ft

D50: 0.199949 mm

Upstream Flow Depth: 6.42 ft

User Defined Shear Stress of floodplain

Critical Shear Stress of Floodplain Material: 0.1288 lb/ft³

Unit Weight of Water: 62.40 lb/ft³

Manning's n: 0.0300

Flow Depth Prior to Scour: 4.24 ft

Result Parameters

q₂/q₁: 0.61

Average Velocity Upstream: 5.08 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 1.32 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 4.20 ft

Maximum Flow Depth including Abutment Scour: 5.04 ft

Scour Hole Depth from NCHRP Method: 0.80 ft

Right Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q1): 0.00 cfs

Unit Discharge in the Constricted Area (q2): 0.00 cfs/ft

D50: 0.199949 mm

Upstream Flow Depth: 0.00 ft

Flow Depth Prior to Scour: 0.00 ft

Result Parameters

q2/q1: 0.00

Average Velocity Upstream: 0.00 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 0.00 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: -nan(ind)

Scour Condition: b (overbank)

Amplification Factor: 0.00

Flow Depth including Contraction Scour: 0.00 ft

Maximum Flow Depth including Abutment Scour: 0.00 ft

Scour Hole Depth from NCHRP Method: 0.00 ft

Scour Summary Table

Long Term Degradation

Contraction Scour

Parameter	50-Yr - Layer 1	100Yr - Layer 1	50-Yr - Layer 2	100Yr - Layer 2	Units	Notes
Selected Contraction Computation Method	Cohesive Soil	Cohesive Soil	Cohesive Soil	Cohesive Soil		
Applied Contraction Scour Depth	4.18	4.34	3.87	4.01	ft	Cohesive
Cohesive Material	4.18	4.34	3.87	4.01	ft	

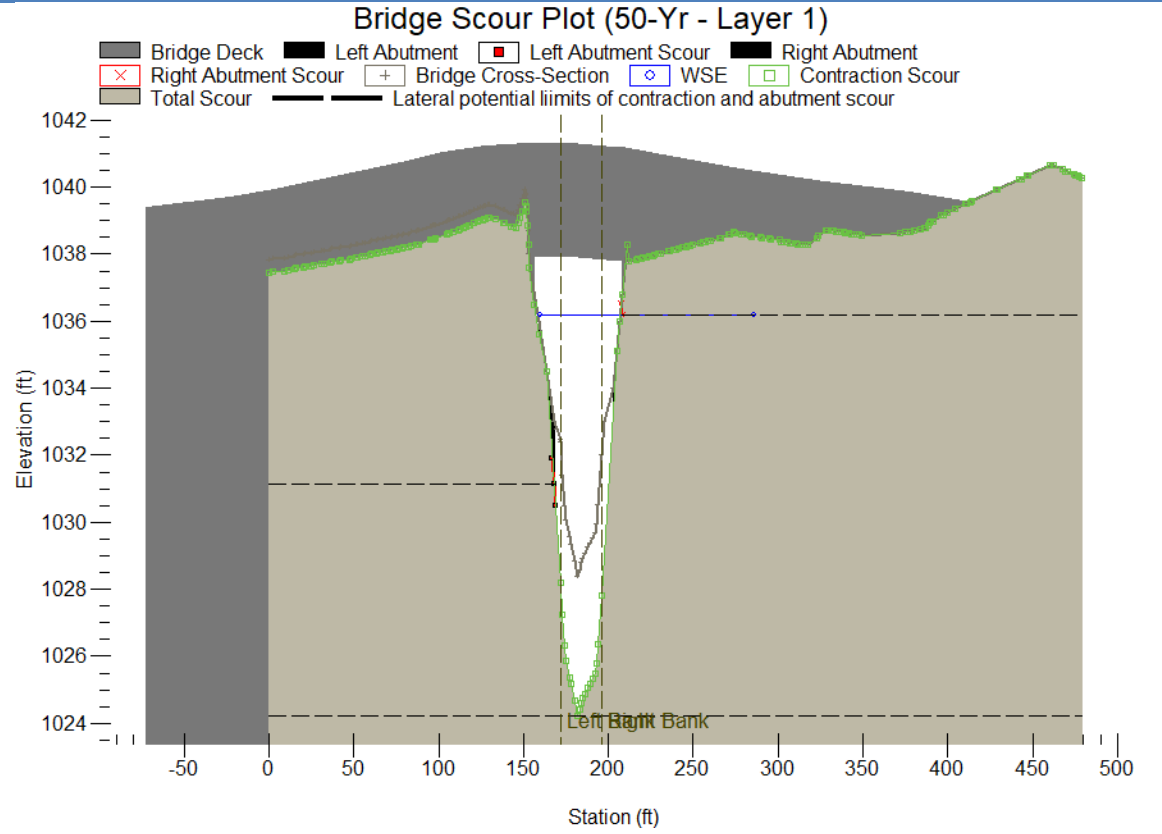
Scour Depth						
Streambed Thalweg Elevation	1028.40	1028.40	1028.40	1028.40	ft	prior to any scour
Applied Contraction Scour Elevation with LTD	1024.22	1024.06	1024.53	1024.39	ft	

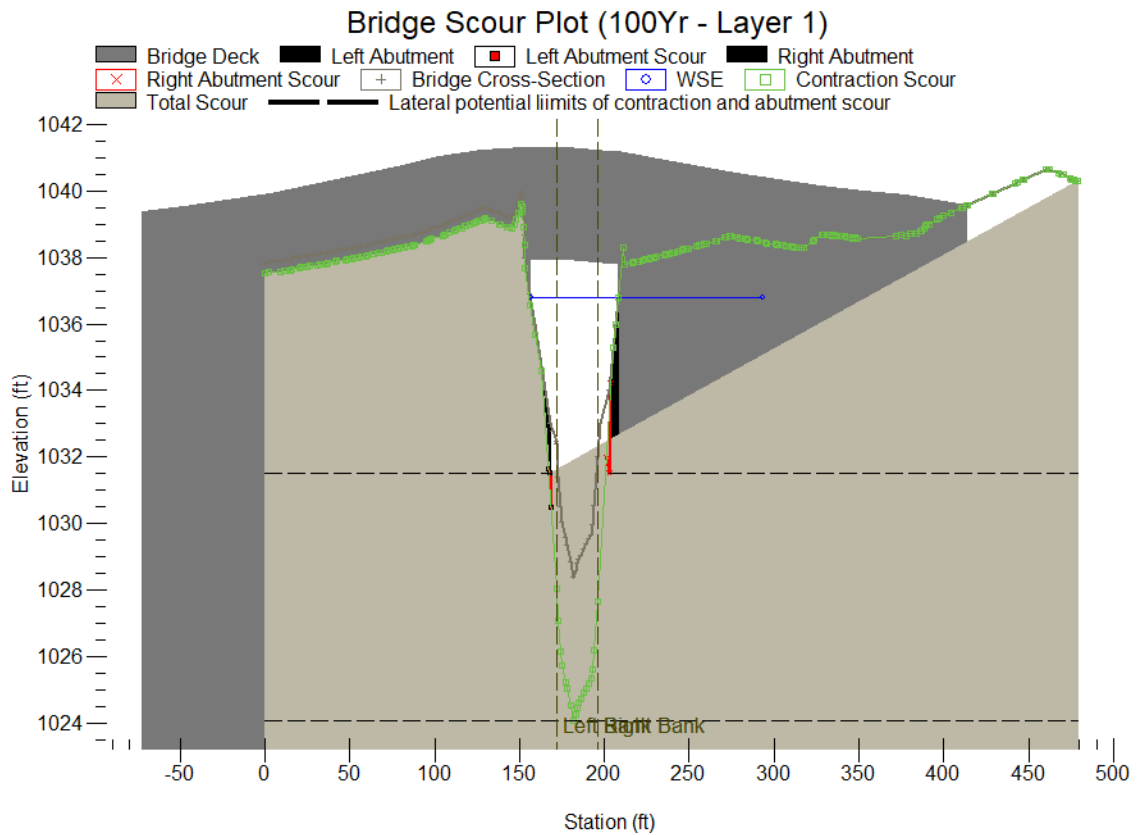
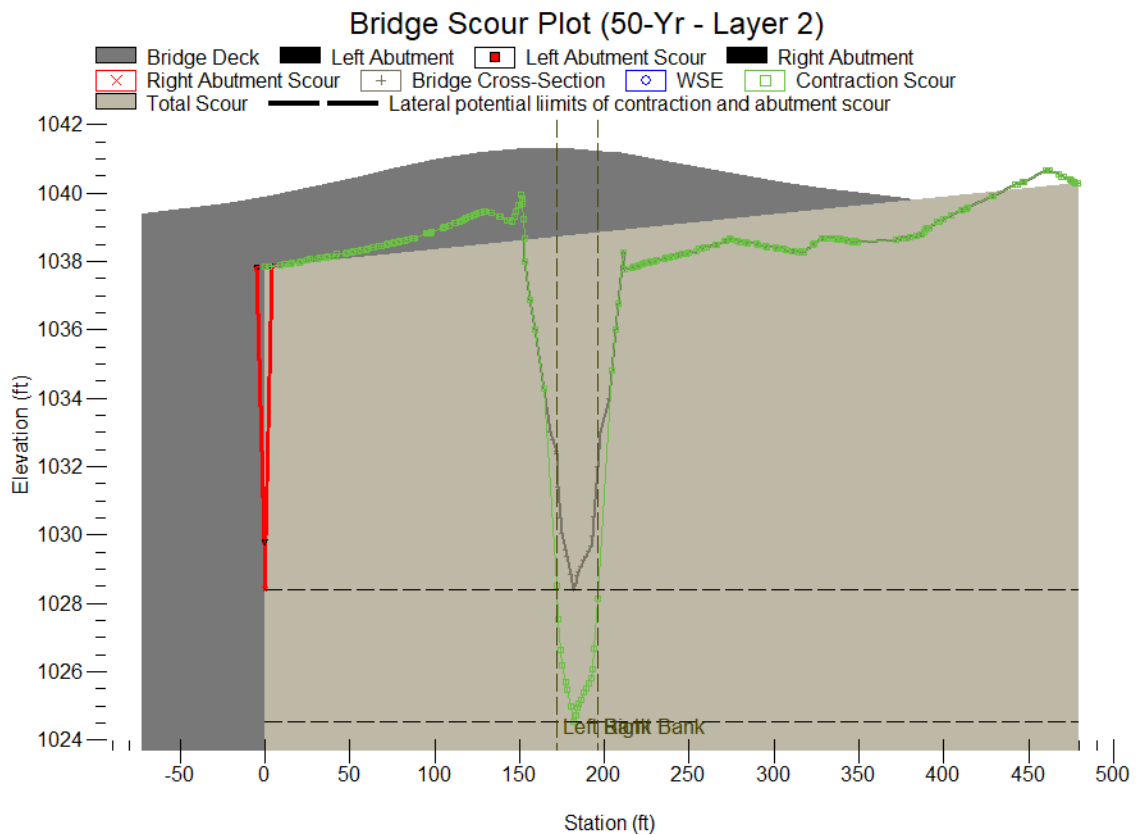
Local Scour at Piers

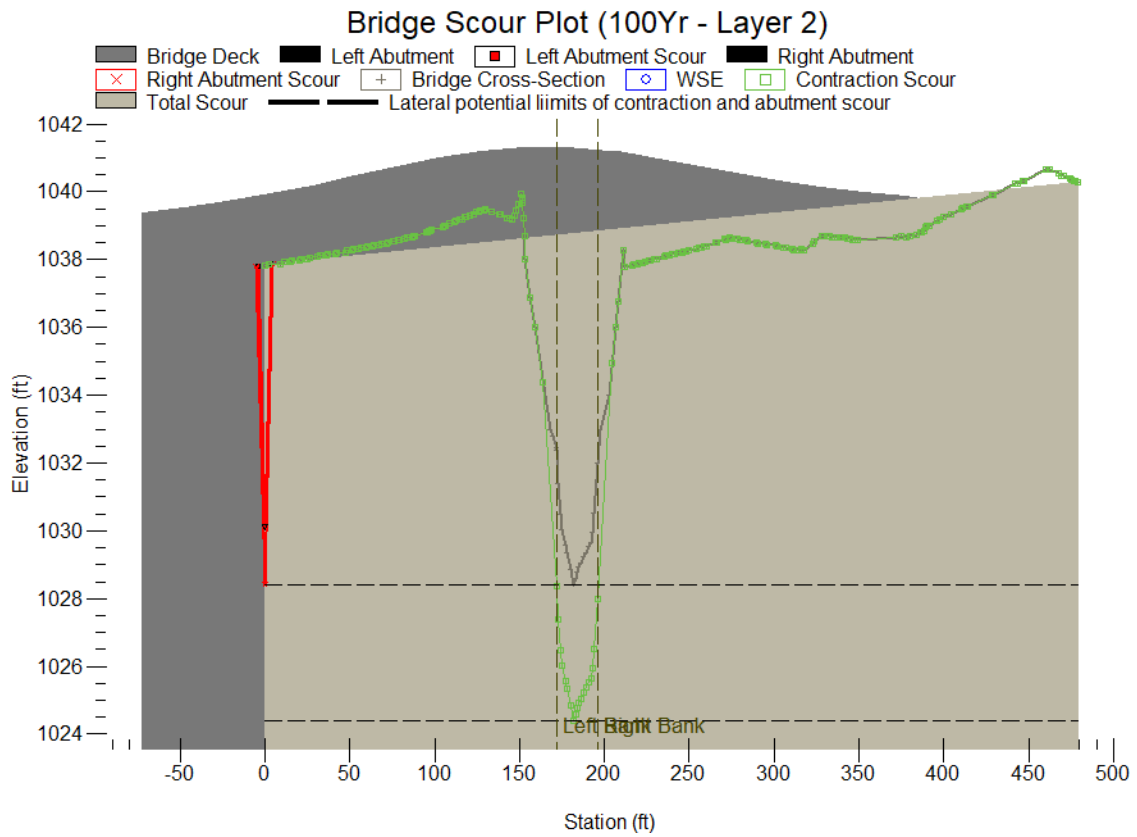
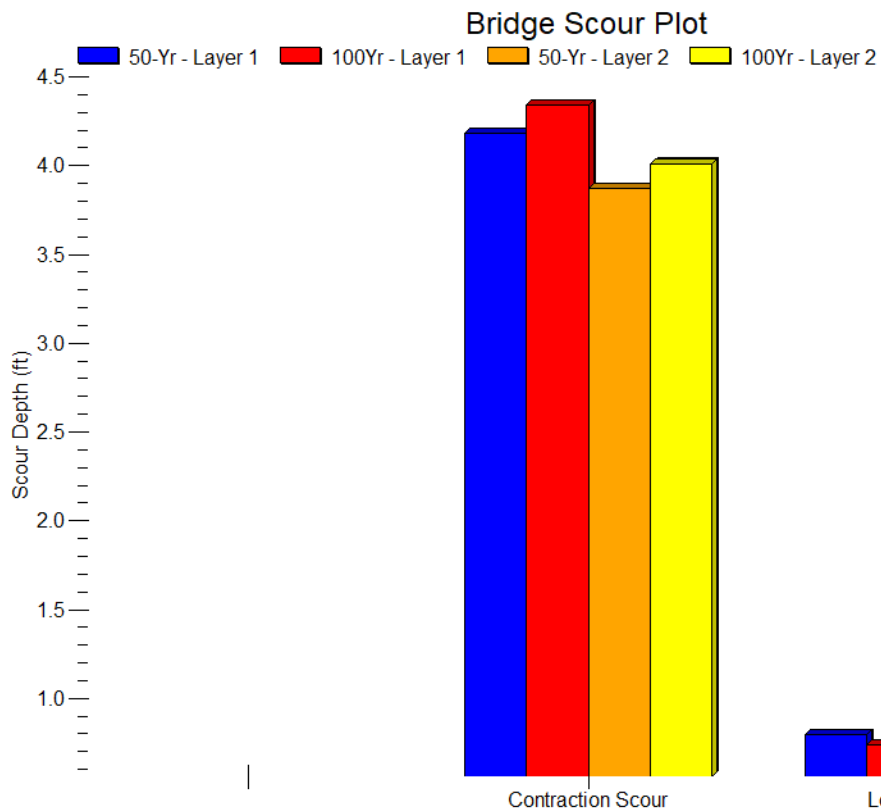
Local Scour at Abutments

Parameter	50-Yr - Layer 1	100Yr - Layer 1	50-Yr - Layer 2	100Yr - Layer 2	Units	Notes
Left Abutment						
Abutment Scour Depth	0.80	0.74	0.80	0.74	ft	NCHRP Method: Scour Condition A (includes LTD)
Max Flow Depth including Abutment Scour	5.04	5.30	5.04	5.30	ft	Including the long-term scour depth
Total Scour at Abutment	0.80	0.74	0.80	0.74	ft	
Local Streambed Elevation at Abutment	1033.00	1033.00	1037.84	1037.84	ft	prior to any scour
Total Scour Elevation at Abutment	1031.15	1031.50	1029.78	1030.12	ft	
Right Abutment						
Abutment Scour Depth	0.00	0.74	0.00	0.00	ft	NCHRP Method: Scour Condition B

Max Flow Depth including Abutment Scour	0.00	5.30	0.00	0.00	ft	
Total Scour at Abutment	0.00	0.74	0.00	0.00	ft	
Local Streambed Elevation at Abutment	1036.63	1034.00	1037.84	1037.84	ft	prior to any scour
Total Scour Elevation at Abutment	1036.19	1031.50	1028.40	1028.40	ft	







Bridge Scour Analysis: Bridge Scour Analysis - B2

Notes:

Scenario: 50-Yr - Layer 1

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 0.47 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 0.47 ft

Clear Water Contraction Scour Depth 2.77 ft

Live Bed Contraction Scour Depth 0.47 ft

Applied Contraction Scour Elevation with LTD 0.47 ft

Local Scour at Abutments Summary

Left Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.00 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 0.00 ft

Right Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth -0.13 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 1032.08 ft

Main Channel Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 6.42 ft

D50 (D50): 1.423416 mm

Average Velocity Upstream (V): 5.09 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed

Temperature of Water: 60.00 °F

Slope of Energy Grade Line at Approach Section (S1): 0.000995 ft/ft

Discharge in Contracted Section (Q2): 950.00 cfs

Discharge Upstream that is Transporting Sediment (Q1): 917.09 cfs

Bottom Width in Contracted Section (W2): 47.76 ft

Width Upstream that is Transporting Sediment (W1): 28.10 ft

Depth Prior to Scour in Contracted Section (y0): 4.24 ft

Unit Weight of Water (γ_w): 62.40 lb/ft³

Unit Weight of Sediment (γ_s): 165.00 lb/ft³

Results

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported (Vc): 2.55 ft/s

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material (Dm): 1.779270 mm

Average Depth in Contracted Section after Scour (y2): 7.01 ft

Scour Depth (ys): 2.77 ft

Results of Live Bed Method

k1 (k1): 0.64

Shear Velocity (V*): 0.45 ft/s

Fall Velocity (V*): 0.52 ft/s

Scour Depth (ys): 0.47 ft

Shear Applied to Bed by Live-Bed Scour (θ_0): 0.1631 lb/ft²

Shear Required for Movement of D50 Particle (τ_c): 0.0187 lb/ft²

Recommendations

Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.47 ft

Left Bank Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 0.00 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 0.00 ft/s

Results

More input is required for complete calculations

Right Bank Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 0.00 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 0.00 ft/s

Results

More input is required for complete calculations

Left Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q_1): 0.00 cfs

Unit Discharge in the Constricted Area (q_2): 0.00 cfs/ft

D50: 0.000000 mm

Upstream Flow Depth: 0.00 ft

Flow Depth Prior to Scour: 0.00 ft

Result Parameters

q_2/q_1 : 0.00

Average Velocity Upstream: 0.00 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 0.00 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: -nan(ind)

Scour Condition: b (overbank)

Amplification Factor: 0.00

Flow Depth including Contraction Scour: 0.00 ft

Maximum Flow Depth including Abutment Scour: 0.00 ft

Scour Hole Depth from NCHRP Method: 0.00 ft

Right Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 90.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q_1): 32.64 cfs

Unit Discharge in the Constricted Area (q_2): 17.37 cfs/ft

D50: 1.423416 mm

Upstream Flow Depth: 5.88 ft

User Defined Shear Stress of floodplain

Critical Shear Stress of Floodplain Material: 0.0297 lb/ft²

Unit Weight of Water: 62.40 lb/ft³

Manning's n: 0.0300

Flow Depth Prior to Scour: 4.24 ft

Result Parameters

q_2/q_1 : 0.53

Average Velocity Upstream: 5.55 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 2.51 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 3.42 ft

Maximum Flow Depth including Abutment Scour: 4.11 ft

Scour Hole Depth from NCHRP Method: -0.13 ft

Scenario: 100Yr - Layer 1

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 0.47 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 0.47 ft

Clear Water Contraction Scour Depth 2.77 ft

Live Bed Contraction Scour Depth 0.47 ft

Applied Contraction Scour Elevation with LTD 0.47 ft

Local Scour at Abutments Summary

Left Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.00 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 0.00 ft

Right Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth -0.13 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 1032.08 ft

Main Channel Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 6.42 ft

D50 (D50): 1.423416 mm

Average Velocity Upstream (V): 5.09 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed

Temperature of Water: 60.00 °F

Slope of Energy Grade Line at Approach Section (S1): 0.000995 ft/ft

Discharge in Contracted Section (Q2): 950.00 cfs

Discharge Upstream that is Transporting Sediment (Q1): 917.09 cfs

Bottom Width in Contracted Section (W2): 47.76 ft

Width Upstream that is Transporting Sediment (W1): 28.10 ft

Depth Prior to Scour in Contracted Section (y0): 4.24 ft

Unit Weight of Water (γ_w): 62.40 lb/ft³

Unit Weight of Sediment (γ_s): 165.00 lb/ft³

Results

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported (V_c): 2.55 ft/s

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material (D_m): 1.779270 mm

Average Depth in Contracted Section after Scour (y2): 7.01 ft

Scour Depth (y_s): 2.77 ft

Results of Live Bed Method

k_1 (k_1): 0.64

Shear Velocity (V^*): 0.45 ft/s

Fall Velocity (V^*): 0.52 ft/s

Scour Depth (y_s): 0.47 ft

Shear Applied to Bed by Live-Bed Scour (θ_0): 0.1631 lb/ft²

Shear Required for Movement of D50 Particle (τ_c): 0.0187 lb/ft²

Recommendations

Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.47 ft

Left Bank Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 0.00 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 0.00 ft/s

Results

More input is required for complete calculations

Right Bank Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 0.00 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 0.00 ft/s

Results

More input is required for complete calculations

Left Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 0.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q1): 0.00 cfs

Unit Discharge in the Constricted Area (q2): 0.00 cfs/ft

D50: 0.000000 mm

Upstream Flow Depth: 0.00 ft

Flow Depth Prior to Scour: 0.00 ft

Result Parameters

q2/q1: 0.00

Average Velocity Upstream: 0.00 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 0.00 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: -nan(ind)

Scour Condition: b (overbank)

Amplification Factor: 0.00

Flow Depth including Contraction Scour: 0.00 ft

Maximum Flow Depth including Abutment Scour: 0.00 ft

Scour Hole Depth from NCHRP Method: 0.00 ft

Right Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 90.00 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q1): 32.64 cfs

Unit Discharge in the Constricted Area (q2): 17.37 cfs/ft

D50: 1.423416 mm

Upstream Flow Depth: 5.88 ft

User Defined Shear Stress of floodplain

Critical Shear Stress of Floodplain Material: 0.0297 lb/ft³

Unit Weight of Water: 62.40 lb/ft³

Manning's n: 0.0300

Flow Depth Prior to Scour: 4.24 ft

Result Parameters

q₂/q₁: 0.53

Average Velocity Upstream: 5.55 ft/s

Critical Velocity above which Bed Material of Size D and Smaller will be Transported: 2.51 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 3.42 ft

Maximum Flow Depth including Abutment Scour: 4.11 ft

Scour Hole Depth from NCHRP Method: -0.13 ft

Scour Summary Table

Long Term Degradation

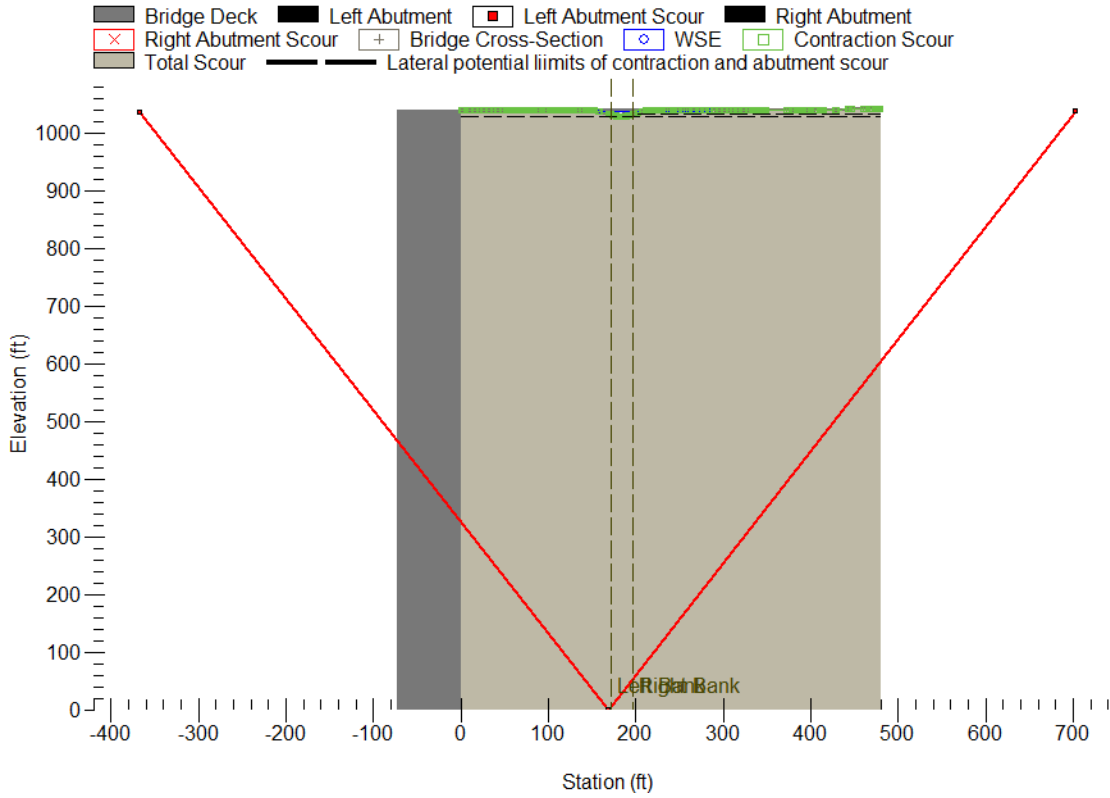
Contraction Scour

Parameter	50-Yr - Layer 1	100Yr - Layer 1	Units	Notes
Selected Contraction Computation Method	Clear-Water and Live-Bed Scour	Clear-Water and Live-Bed Scour		
Applied Contraction Scour Depth	0.47	0.46	ft	Live Bed
Clear Water Contraction Scour Depth	2.77	3.12	ft	
Live Bed Contraction Scour Depth	0.47	0.46	ft	
Streambed Thalweg	1028.40	1028.40	ft	prior to any scour

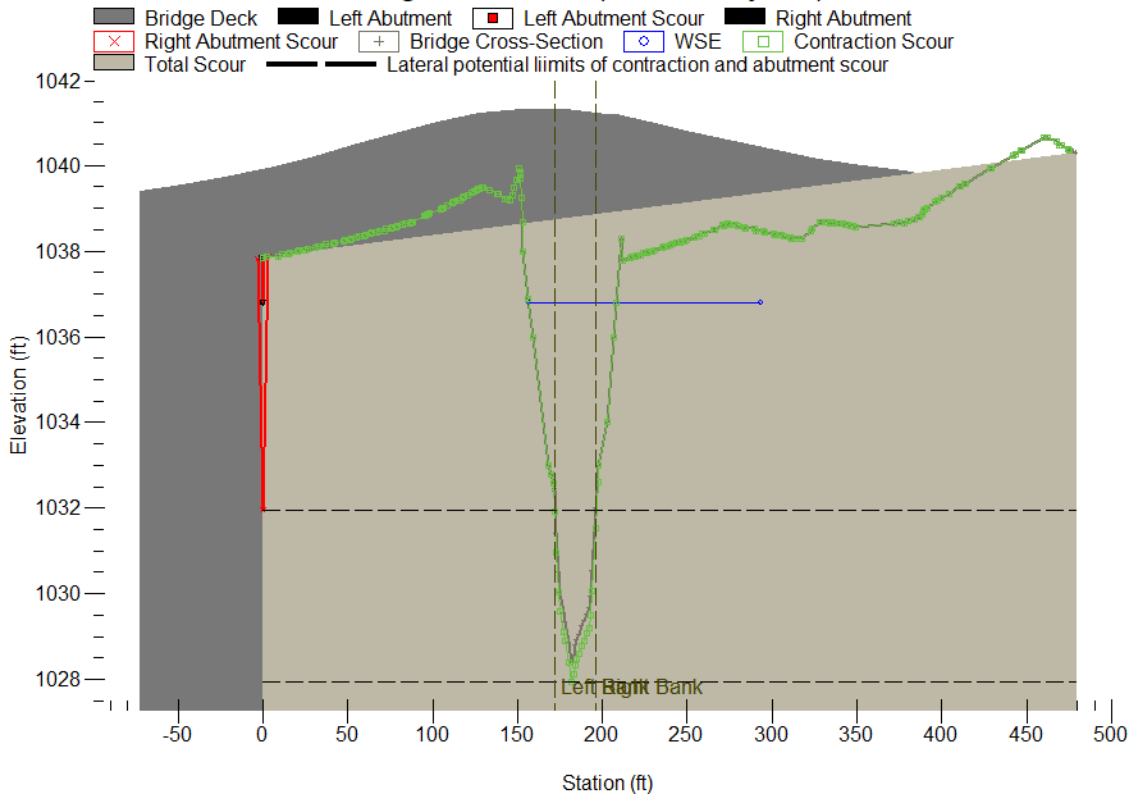
Elevation				
Applied Contraction Scour Elevation with LTD	1027.93	1027.94	ft	
Local Scour at Piers				
Local Scour at Abutments				
Parameter	50-Yr - Layer 1	100Yr - Layer 1	Units	Notes
Left Abutment				
Abutment Scour Depth	0.00	0.00	ft	NCHRP Method: Scour Condition B
Max Flow Depth including Abutment Scour	0.00	0.00	ft	
Total Scour at Abutment	0.00	0.00	ft	
Local Streambed Elevation at Abutment	1033.00	1037.84	ft	prior to any scour
Total Scour Elevation at Abutment	0.00	1036.80	ft	
Right Abutment				
Abutment Scour Depth	-0.13	0.29	ft	NCHRP Method: Scour Condition A (includes LTD)
Max Flow Depth including Abutment Scour	4.11	4.85	ft	Including the long-term scour depth
Total Scour at Abutment	0.00	0.29	ft	
Local Streambed Elevation at Abutment	1034.00	1037.84	ft	prior to any scour
Total Scour Elevation at	1032.08	1031.95	ft	

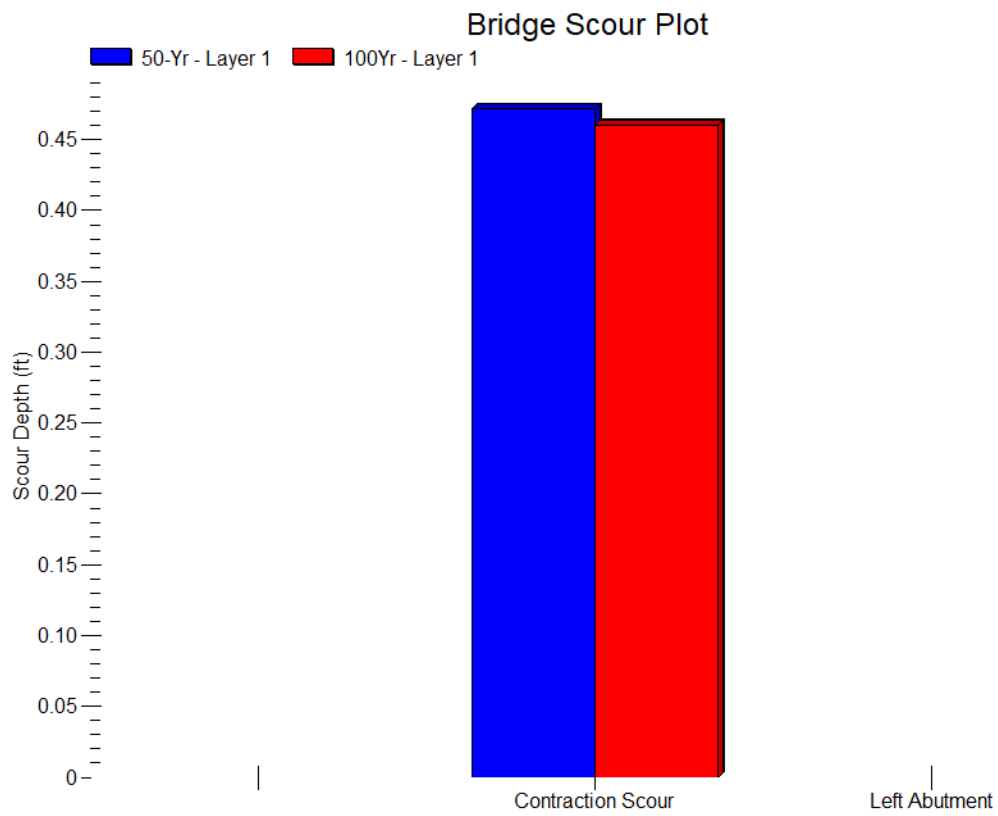
Abutment

Bridge Scour Plot (50-Yr - Layer 1)



Bridge Scour Plot (100Yr - Layer 1)





APPENDIX D.2

Friction Pile Analysis



Project: Mink Street Bridge Pile Foundations		Sheet 1 of 8	
Purpose: Friction Pile Static Analysis		Job No. : 078318	
By: YLZ	Date: 4/16/26	CHKD By: JAY/TLM	Date: 4/17/26

PURPOSE:

The purpose of this calculation is to evaluate the friction piles for the structure foundations at the proposed Mink Street Bridge in Licking County, Ohio. This calculation determines the static analysis per Ohio Department of Transportation (ODOT) Bridge Design Manual (BDM) and AASHTO LRFD. The static analysis is performed with APILE by Ensoft.

CODES/STANDARDS:

LRFD *Bridge Design Specifications Tenth Edition 2024 (LRFD)*

ODOT *Bridge Design Manual, 2020 Edition*, Jan 2026 (BDM)

ODOT *Construction Materials Specification*, Jan 2023 (CMS)

ODOT *Geotechnical Design Manual*, Jan 2026 (GDM)



Project: Mink Street Bridge Pile Foundations				Sheet 2 of 8
Purpose: Friction Pile Static Analysis				Job No. : 078318
By: YLZ	Date: 4/16/26	CHKD By: JAY/TLM	Date: 4/17/26	

ANALYSIS INPUTS AND DATA SOURCES:

- The strength load and footing elevations are provided by structure group. According to the scour analysis, the 50-year and 100-year scour elevation is very close, 100-year scour elevation is used for design and the design contraction scour elevation and the local scour elevation are listed in Table 1 below. Per GDM 1304.1.1, the scour model starts from the channel (contraction) scour elevation with zero-friction length down to the local scour elevation. Table 1 presents the Axial Loads and Structure information. The required minimum UBV is calculated by divided by the resistance factor for driven piles ($\phi_{dyn}=0.7$).

Table 1: Bridge Friction Pile Foundation Information

Sub-structure	Bottom of Footing Elevation	Contraction Scour Elevation	Local Scour Elevation	Zero Friction Length*	Pile Diameter	Maximum UBV	Factored Axial Pile Load	Required Minimum UBV
	(ft.)	(ft.)	(ft.)	(ft.)	(in.)	(kips)	(kips)	(kips)
Rear Abutment	1031.8	1029.4	1026.3	3.1	12	330	213.5	305
Forward Abutment	1032.1	1033.6	1033.8*	NA	12	330	213.5	305

Note: Zero friction length is calculated from the contraction scour elevation to the local scour elevation. The abutment (local) scour calculations include simplified (and therefore, slightly different) scour depth equations per the approved NCHRP method for abutment scour. Since the difference between the contraction scour and local scour is minimum, the calculation is acceptable, and the local scour is ignored for forward abutment for pile design.

- The soil parameters for the analyses were prepared and checked by GF. The values for each substructure are summarized in Table 2 and Table 3.

Table 2: GRLWEAP S1 Soil Parameters

ODOT Classification	Stratum	Elevation (ft)	Depth (ft)	γ_{moist} (pcf)	N ₆₀	N ₁₆₀	Skin Quake (in)	Toe Quake (in)	Skin Damping (s/ft)	Toe Damping (s/ft)	Setup Factor	Limit Distance (ft)	Setup Time (hr)
Rear Abutment (B-1)													
A-4a	1	1029	2.8	118.0	8	11	0.1	0.166	0.15	0.15	1.50	6	72
A-2-4	2	1027.5	4.3	128.0	29	38	0.1	0.131	0.1	0.15	1.20	6	1
A-1-b	3	1022	9.8	128.0	37	45	0.1	0.124	0.05	0.15	1.00	6	1
A-1-b	4	1018.5	13.3	125.0	20	23	0.1	0.153	0.05	0.15	1.00	6	1
A-1-b	5	1016	15.8	128.0	40	43	0.1	0.126	0.05	0.15	1.00	6	1
A-4a	6	1012	19.8	125.0	24	26	0.1	0.128	0.15	0.15	1.50	6	72
A-4a	7	1007.5	24.3	132.0	40	39	0.1	0.117	0.15	0.15	1.50	6	72
A-4a	8	997.5	34.3	120.0	13	12	0.1	0.148	0.15	0.15	1.50	6	72
A-4a	9	993	38.8	122.0	17	15	0.1	0.139	0.15	0.15	1.50	6	72
A-4a	10	986	45.8	132.0	41	33	0.1	0.117	0.15	0.15	1.50	6	72
Forward Abutment (B-2)													



Project: Mink Street Bridge Pile Foundations				Sheet 3 of 8
Purpose: Friction Pile Static Analysis				Job No. : 078318
By: YLZ	Date: 4/16/26	CHKD By: JAY/TLM	Date: 4/17/26	

ODOT Classification	Stratum	Elevation (ft)	Depth (ft)	γ_{moist} (pcf)	N_{60}	N_{160}	Skin Quake (in)	Toe Quake (in)	Skin Damping (s/ft)	Toe Damping (s/ft)	Setup Factor	Limit Distance (ft)	Setup Time (hr)
A-2-4	1	1030.5	1.6	118.0	4	6	0.1	0.233	0.1	0.15	1.20	6	1
A-6b	2	1028	4.1	128.0	32	42	0.1	0.120	0.2	0.15	1.75	6	168
A-1-b	3	1021	11.1	128.0	40	49	0.1	0.121	0.05	0.15	1.00	6	1
A-1-b	4	1016	16.1	132.0	46	51	0.1	0.120	0.05	0.15	1.00	6	1
A-4a	5	1011	21.1	125.0	27	29	0.1	0.125	0.15	0.15	1.50	6	72
A-4a	6	1009	23.1	140.0	52	50	0.1	0.117	0.15	0.15	1.50	6	72
A-4a	7	996	36.1	122.0	16	16	0.1	0.141	0.15	0.15	1.50	6	72
A-4a	8	986	46.1	140.0	59	47	0.1	0.117	0.15	0.15	1.50	6	72

Table 3: APILE Static Analysis Design Parameters

Sub-structure	Boring	Soil Strata	Bottom Elevation	Depth Below Bottom of Footing	Depth after scour	γ_m (pcf)	γ' (pcf)	Φ (deg)	S_u^1 (psf)	APILE Reduction Factor
Rear Abutment	B-001-0-24	Soil 1	1029.0	2.8	0.4	118	55.6	NA	1125	0.75
		Soil 2	1027.5	4.3	1.9	128	65.6	39.2	NA	0.83
		Soil 3	1022.0	9.8	7.4	128	65.6	41.2	NA	1.00
		Soil 4	1018.5	13.3	10.9	125	62.6	37.3	NA	1.00
		Soil 5	1016.0	15.8	13.4	128	65.6	41.0	NA	1.00
		Soil 6	1012.0	19.8	17.4	125	62.6	NA	3000	0.67
		Soil 7	1007.5	24.3	21.9	132	69.6	NA	5000	0.67
		Soil 8	997.5	34.3	31.9	120	57.6	NA	1563	0.67
		Soil 9	993.0	38.8	36.4	122	59.6	NA	2125	0.67
		Soil 10	986.0	45.8	43.4	132	69.6	NA	5125	0.67
Forward Abutment	B-002-0-24	Soil 11 ²	966.0	65.8	63.4	140	77.6	40	NA	0.83
		Soil 1	1030.5	1.6	1.6	118	55.6	30.9	NA	0.83
		Soil 2	1028.0	4.1	4.1	128	65.6	NA	4000	0.57
		Soil 3	1021.0	11.1	11.1	128	65.6	41.5	NA	1.00
		Soil 4	1016.0	16.1	16.1	132	69.6	42.0	NA	1.00
		Soil 5	1011.0	21.1	21.1	125	62.6	NA	3375	0.67
		Soil 6	1009.0	23.1	23.1	140	77.6	NA	6163	0.67
		Soil 7	996.0	36.1	36.1	122	59.6	NA	2000	0.67
		Soil 8	986.0	46.1	46.1	140	77.6	NA	6934	0.67
		Soil 9 ²	971.0	61.1	61.1	140	77.6	40	NA	0.83

Notes:

- For cohesive layers, the undrained shear strength (s_u) of the layer was calculated based on $S_u = f_1 \times N_{60} \times \text{pa}/100$, per Stroud (1974, 1989).
- The very dense bouldery zone layers were modeled as cohesionless soil with high friction angle.



Project: Mink Street Bridge Pile Foundations		Sheet 4 of 8	
Purpose: Friction Pile Static Analysis		Job No. : 078318	
By: YLZ	Date: 4/16/26	CHKD By: JAY/TLM	Date: 4/17/26

3. The Steel Properties in Table 4 are according to ASTM 252.

TABLE 4: Steel Properties

Steel Grade	Tension (PSI)	F'y (PSI)	Max Compression (PSI) $\sigma_{dr} = 0.9\phi_d f'_y$ $\phi_d = 1$
Grade 1	50,000	30,000	27,000
Grade 2	60,000	35,000	31,500
Grade 3	66,000	45,000	40,500



Project: Mink Street Bridge Pile Foundations				Sheet 5 of 8
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By: YLZ	Date: 4/16/26	CHKD By: JAY/TLM	Date: 4/17/26	

ASSUMPTIONS AND ANALYSIS METHODOLOGY:

The abutments for the proposed Bridge are designed to be supported by Cast-in-Place (close-end) piles. Since the subsurface soils profile consists of a very thick cohesive layer, so a pile reduction factor in the APILE analysis were applied for the static analysis to account for the soil setup.

Static analyses were performed for both no scour and scour conditions. For Rear abutment, the "Scour Condition" analysis was used to determine the tip elevations needed to obtain the nominal bearing resistance and the "No Scour Condition" analysis determined the Nominal amount of side resistance (kips) that must be overcome during driving through soil in the scour zone. Since there will be no soil overburden for both abutments at the time of construction. Therefore, the subsurface model starts at the bottom of the footing for No Scour Condition. For Scour Condition, the subsurface model starts from the channel (contraction) scour elevation with zero-friction length down to the local scour elevation. However, scour analysis indicates that the scour at the Forward Abutment is lower the bottom of footing, no Scour Condition is included for Forward Abutment.

The boring logs indicate the static water ranges from El. 1029.0 to El. 1031.0. Since it is very close to the bottom of footing elevation, the water level was modeled at bottom of footing elevation for the static analysis.

Dynamic drivability analyses are performed with ultimate bearing value with setup factors. The energy of the hammer used in the GRLWEAP analysis for all the substructures is 43.240 kip-ft/kw (Delmag D-19-42), which is common in Ohio practice. FHWA soil model was used in the drivability analysis with parameters used in the static models.



Project: Mink Street Bridge Pile Foundations				Sheet 6 of 8
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FORMULAS:

Calculation for UBV

$$UBV = EOID + R_{SSu} \quad (\text{BDM C 305.3.2-3})$$

$$EOID = R_n + R_{SSc} - R_{SSu} \quad (\text{BDM C 305.3.2-2})$$

$$R_n = Q_p / \phi_{dyn} \quad (\text{BDM C 305.3.2-4})$$

$$UBV = R_s + R_p + R_{SSc} \quad (\text{BDM C 305.3.2-6})$$

$$R_s = R_{Sndr} + R_{SSu} \quad (\text{BDM C 305.3.2-6})$$

$$R_{Sndr} = (1 / f_{su}) \times R_s \quad (\text{BDM C 305.2.4-3})$$

$$EOID = R_p + R_{Sndr} + R_{SSc} \quad (\text{BDM C 305.3.4-4})$$

$$\text{Therefore: } EOID = R_p + (1 / f_{su}) \times R_s$$

Computer Programs Used:

APILE 2023.10.5

GRLWEAP 14.1.20.1

Attachments

Attachment A – Rear Abutment analysis Output

Attachment B – Forward Abutment analysis Output

Attachment C – Soil parameter calculation



Project: Mink Street Bridge Pile Foundations				Sheet 7 of 8
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Results and Conclusions:

The pile lengths as linearly interpreted from the static friction pile analyses (APILE) are presented in Table 5. The Pile Length per ODOT BDM are presented in Table 7. The estimated driving resistance indicates driving losses that would increase the length of the pile during driving by less than 10-ft with EOID compared to the UBV for both abutments, therefore pile setup will not be included in the design. Since the drivability analysis indicates a requirement of 0.33" Grade 3 pipe pile for rear abutment, a 0.33" Grade 3 pipe pile was recommended for both abutments.

Table 5: APILE Determined Pile Lengths

Sub-structure	Pile Diameter (in.)	Pile Length including initial loss (ft)	Pile length without initial loss (ft)	UBV (kips)	EOID (kips)	R _{SSC} (kips)	R _{SSU} (kips)	R _n (kips)	Bottom of Footing El. (ft)	Pile Tip Elevation (ft)
Rear Abutment	12	45.9	45.20	343.2	NA	38.2	NA	305	1031.8	986.6
Forward Abutment	12	46.7	40.8	305	NA	NA	NA	305	1032.1	991.3

The results of the Drivability Analysis Are Shown in Table 9.

Table 6: GRLWEAP Results

Substructure	Pile Diameter (in)	Pile Wall Thickness (in)	Total Driving Time (min)	Max Blow Ct (bl/ft)	Max Compressive in Steel (ksi)
Rear Abutment	12	0.28	13	45.5	39.93
Forward Abutment	12	0.28	14	35.3	38.12

Table 7: Pile Lengths Per ODOT BDM

Sub-structure	Pile Diameter (in.)	Pile Embedment Depth (ft)	Pile Cutoff Elevation (ft)	Pile Tip Elevation (ft)	Estimated Pile Length (ft)	Order Length (ft)	Wall Thickness (in)	Grade	UBV (kips)
Rear Abutment	12	1	1032.8	986.6	50	55	0.28	3	343.2
Forward Abutment	12	1	1033.1	991.3	45	50	0.28	3	305



Project: Mink Street Bridge Pile Foundations				Sheet 8 of 8
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Pile Notes

PILE DESIGN LOADS (ULTIMATE BEARING VALUE): The Ultimate Bearing Value (UBV) is 343.2 kips per pile for rear abutment piles, and 305 kips per pile for forward abutment. The UBV for the rear abutment piles includes an additional 38.2 kips per pile due to the possibility of losing 5.5 ft. of frictional resistance due to scour. Drive the rear abutment piles to the UBV or a tip elevation of 986.6 and drive forward abutment to the UBV or a tip elevation of 991.3, whichever is deeper.

Rear Abutment Piles:

12" CIP piles 55 feet long, order length

1 Dynamic load tests

Provide plain Grade 3 cylindrical casings with a minimum pile wall thickness of 0.28 inch for the cast-in place reinforced concrete piles.

Forward Abutment Piles:

12" CIP piles 50 feet long, order length

1 Dynamic load tests

Provide plain Grade 3 cylindrical casings with a minimum pile wall thickness of 0.28 inch for the cast-in-place reinforced concrete piles.

REAR ABUTMENT

RABT With Scour

		0.00
Sand ϕ : [39.2, 39.2]		1.90
Sand ϕ : [41.2, 41.2]		7.40
Sand ϕ : [37.3, 37.3]		10.90
Sand ϕ : [41.0, 41.0]		13.40
Clay c_u : [3000, 3000]		17.40
Clay c_u : [5000, 5000]		21.90
Clay c_u : [1563, 1563]	60.00 ft	31.90
Clay c_u : [2125, 2125]		36.40
Clay c_u : [5125, 5125]		43.40
Sand ϕ : [40.0, 40.0]	60.00	63.40
Sand ϕ : [40.3, 40.3]		

RABT Without Scour

		0.00
Clay c_u : [1125, 1125]		2.80
Sand ϕ : [39.2, 39.2]		4.30
Sand ϕ : [41.2, 41.2]		9.80
Sand ϕ : [37.3, 37.3]		13.30
Sand ϕ : [41.0, 41.0]		15.80
Clay c_u : [3000, 3000]		19.80
Clay c_u : [5000, 5000]		24.30
Clay c_u : [1563, 1563]	60.00 ft	34.30
Clay c_u : [2125, 2125]		38.80
Clay c_u : [5125, 5125]		45.80
Sand ϕ : [40.0, 40.0]		65.80
	60.00	
Sand ϕ : [40.3, 40.3]		

**REAR ABUTMENT
12" PIPE PILE STATIC ANALYSIS**

RABT
12" Pipe Pile

RABT PILE Diam (in) 12
Ult_with Scour

PILE LENGTH FT.	SKIN FRICTION KIP	END BEARING KIP	ULTIMATE CAPACITY KIP
0	0	2	2
1	0	6.7	6.7
2	0	14.7	14.7
3	0	24	24
4	0.3	33.1	33.4
5	1	41.4	42.4
6	1.8	49.7	51.5
7	2.8	51.4	54.2
8	3.9	45.3	49.2
9	5	37.5	42.5
10	6.1	42.9	49
11	7.3	63.8	71.1
12	8.9	86.2	95.1
13	10.7	86.9	97.6
14	12.7	62.6	75.3
15	18.5	35.7	54.1
16	27.9	21.2	49.1
17	37.3	23.6	60.9
18	46.8	28.3	75
19	59.3	33	92.3
20	75	35.3	110.4
21	90.7	31.3	122
22	104.8	23.2	128
23	113.4	15.1	128.5
24	118.3	11	129.3
25	123.2	11	134.2
26	128.1	11	139.1
27	132.9	11	144
28	137.8	11	148.9
29	142.7	11	153.8
30	147.6	11	158.6
31	152.5	11.7	164.2
32	157.3	13	170.3
33	162.6	14.4	177
34	168.5	15	183.6
35	174.5	15	189.5
36	180.4	18.6	198.9
37	185.9	25.6	211.6
38	193.2	32.7	225.9
39	202.4	36.2	238.7
40	211.7	36.2	247.9
41	221	36.2	257.2
42	230.2	36.2	266.4
43	239.5	74.5	313.9
44	247.3	152.8	400.1
45	253.8	233.5	487.4
46	260.5	278.5	539
47	267.4	285.6	552.9
48	274.4	291.1	565.5
49	281.6	294.2	575.8
50	289	295.2	584.2
51	296.6	295.3	591.8
52	304.3	295.3	599.6
53	312.2	295.3	607.5
54	320.3	295.3	615.6
55	328.6	295.3	623.9
56	337.1	295.3	632.3
57	345.7	295.3	640.9
58	354.5	295.3	649.8
59	363.5	295.3	658.7
60	372.6	295.3	667.9

Rn (kip)	305	Length (ft.)	42.8
Rn1	266.4	Length 1	42
Rn2	313.9	Length 2	43

Ground Elevation 1031.8
Ult_No Scour

PILE LENGTH FT.	SKIN FRICTION KIP	END BEARING KIP	ULTIMATE CAPACITY KIP
0	0	4	4
1	0	6.6	6.6
2	1.6	9.1	10.7
3	4.8	12.8	17.5
4	6.6	20.5	27.2
5	7.2	32	39.2
6	7.9	43.8	51.7
7	8.8	54.2	63
8	9.9	62.5	72.4
9	11.1	63	74
10	12.4	54.4	66.8
11	13.8	44.1	57.9
12	15	40	55.1
13	16.4	53.4	69.9
14	17.9	78	96
15	19.8	87.1	106.9
16	22	68.5	90.6
17	27.9	37.6	65.5
18	37.3	21.2	58.5
19	46.7	23.6	70.3
20	56	28.3	84.3
21	68.2	33	101.2
22	83.4	35.3	118.7
23	98.6	35.3	133.9
24	113.8	31.3	145.1
25	127.1	23.2	150.3
26	135.2	15.1	150.3
27	140	11	151.1
28	144.8	11	155.9
29	149.6	11	160.7
30	154.5	11	165.5
31	159.3	11	170.3
32	164.1	11	175.1
33	168.9	11	180
34	173.7	11.7	185.4
35	178.4	13	191.5
36	183.6	14.4	197.9
37	189.2	15	204.2
38	194.8	18.6	213.4
39	200.1	25.6	225.8
40	206.9	32.7	239.5
41	215.3	36.2	251.6
42	223.8	36.2	260
43	232.3	36.2	268.5
44	240.7	36.2	277
45	249.2	76.2	325.4
46	256.7	157.9	414.5
47	263.3	242	505.3
48	270.2	288.1	558.3
49	277.3	292.8	570.1
50	284.6	295	579.6
51	292.1	295.3	587.3
52	299.7	295.3	595
53	307.5	295.3	602.8
54	315.5	295.3	610.8
55	323.7	295.3	618.9
56	332	295.3	627.3
57	340.5	295.3	635.8
58	349.2	295.3	644.5
59	358.1	295.3	653.4
60	367.2	295.3	662.4

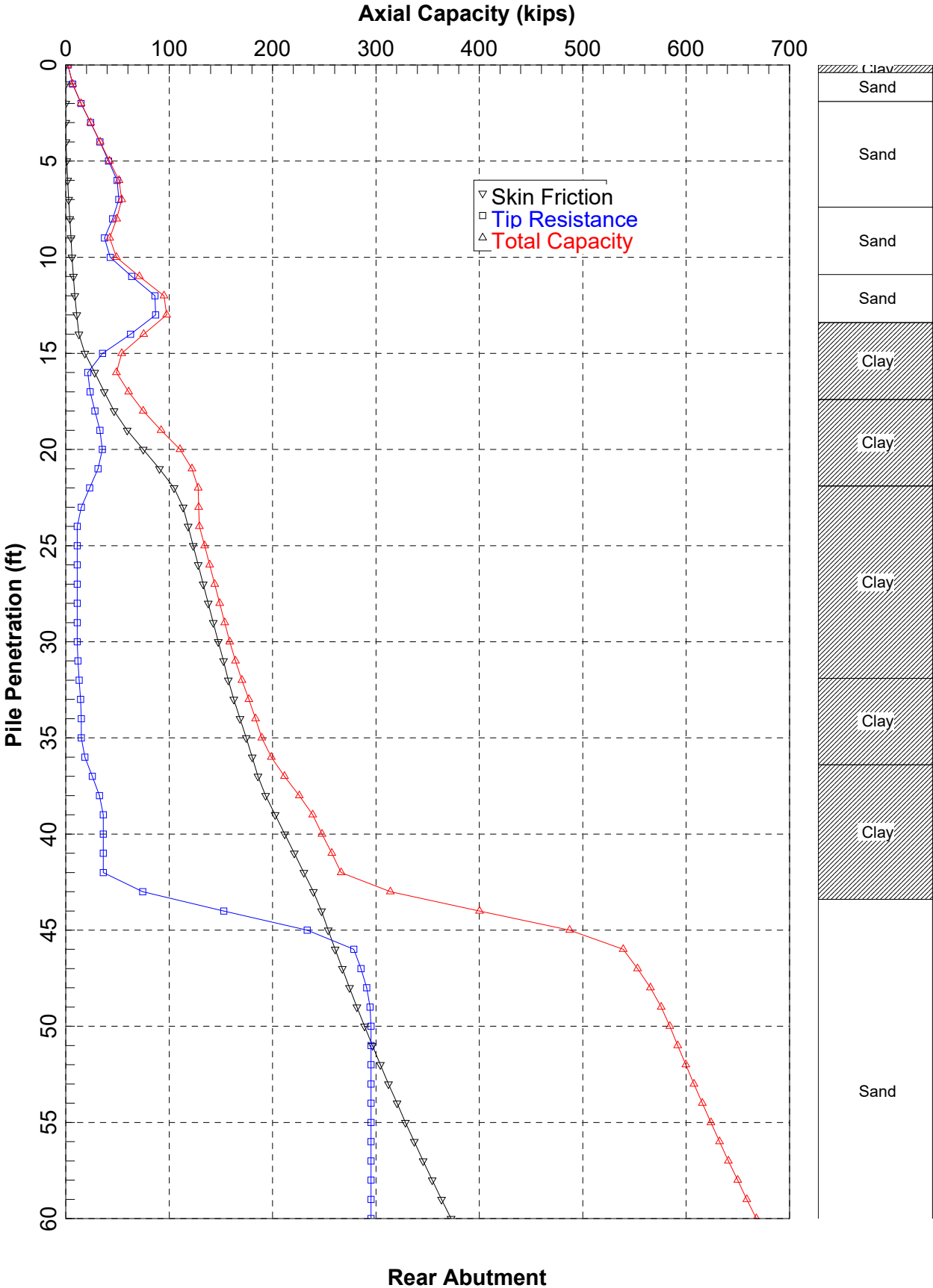
Rn (kip)	343.2	length	45.20
Rn1	325.4	Length 1	45
Rn2	414.5	Length 2	46
Rssc (kip)	38.2	UBV (kips)	343.2

Scour Elevation 1029.4
EOID_No Scour

PILE LENGTH FT.	SKIN FRICTION KIP	END BEARING KIP	ULTIMATE CAPACITY KIP
0	0	4	4
1	0	6.6	6.6
2	1.2	9.1	10.3
3	3.8	12.8	16.6
4	5.4	20.5	25.9
5	5.9	32	38
6	6.7	43.8	50.5
7	7.6	54.2	61.8
8	8.6	62.5	71.1
9	9.8	63	72.8
10	11.2	54.4	65.6
11	12.5	44.1	56.6
12	13.8	40	53.8
13	15.2	53.4	68.6
14	16.7	78	94.7
15	18.5	87.1	105.6
16	20	68.5	88.6
17	24	37.6	61.6
18	30.3	21.2	51.5
19	36.6	23.6	60.2
20	42.8	28.3	71.1
21	51	33	83.9
22	61.1	35.3	96.5
23	71.3	35.3	106.7
24	81.5	31.3	112.8
25	90.4	23.2	113.6
26	95.9	15.1	111
27	99.1	11	110.1
28	102.3	11	113.4
29	105.5	11	116.6
30	108.8	11	119.8
31	112	11	123
32	115.2	11	126.3
33	118.5	11	129.5
34	121.7	11.7	133.4
35	124.8	13	137.9
36	128.3	14.4	142.6
37	132	15	147.1
38	135.8	18.6	154.4
39	139.4	25.6	165
40	143.9	32.7	176.6
41	149.5	36.2	185.8
42	155.2	36.2	191.4
43	160.9	36.2	197.1
44	166.6	36.2	202.8
45	172.2	76.2	248.4
46	178.4	157.9	336.3
47	183.9	242	425.9
48	189.7	288.1	477.8
49	195.6	292.8	488.3
50	201.6	295	496.6
51	207.8	295.3	503.1
52	214.2	295.3	509.4
53	220.6	295.3	515.9
54	227.3	295.3	522.5
55	234	295.3	529.3
56	241	295.3	536.2
57	248	295.3	543.3
58	255.3	295.3	550.5
59	262.6	295.3	557.9
60	270.2	295.3	565.4

UBV (kip)	343.2	Length (ft.)	46.1
UBV1	336.3	Length 1	46
UBV2	425.9	Length 2	47
Rssu (kip)	NA	EOID (kip)	NA
		EOID1	248.4
		EOID2	336.3

RABT
12" Ult with Scour



RABT
12" Ult with Scour

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APILE for Windows, Version 2023.10.5

Serial Number : 546958499

A Program for Analyzing the Axial Capacity
and Short-term Settlement of Driven Piles
under Axial Loading.
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Path to file locations : C:\Users\yzimmerman\OneDrive - Gannett Fleming
Inc\GF - 078318-Mink Street Bridge
Replacement\5_Working\05_Design_Support\Geotech\APILE\RABT\
Name of input data file : RABT_12ULT_S.ap10d
Name of output file : RABT_12ULT_S.ap10o
Name of plot output file : RABT_12ULT_S.ap10p

Time and Date of Analysis

Date: April 16, 2026 Time: 12:10:42

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* INPUT INFORMATION *

PROJECT DESCRIPTION :
Mink Street BG RABT 12"Ult with Scour
DESIGNER : YLZ
JOB NUMBER : 78318

METHOD FOR UNIT LOAD TRANSFERS :
- FHWA (Federal Highway Administration)
Unfactored Unit Side Friction and Unit Side Resistance are used.

COMPUTATION METHOD(S) FOR PILE CAPACITY :

- FHWA (Federal Highway Administration)

TYPE OF LOADING :

- COMPRESSION

PILE TYPE :

Steel pipe pile or non-tapered portion of monotube pile

- Open-Ended Pile

AVERAGE DEPTH TO ESTIMATE TIP RESISTANCE:

- USE 1.5 DIAMETERS ABOVE AND BELOW TIP

DATA FOR AXIAL STIFFNESS :

- MODULUS OF ELASTICITY = 0.290E+08 PSI
- CROSS SECTION AREA = 9.23 IN²

CIRCULAR PILE PROPERTIES :

- OUTSIDE DIAMETER, OD = 12.00 IN.
- INTERNAL DIAMETER, ID = 11.50 IN.
- TOTAL PILE LENGTH, TL = 60.00 FT.
- BATTER ANGLE = 0.00 DEG
- PILE STICKUP LENGTH, PSL = 0.00 FT.
- ZERO FRICTION LENGTH, ZFL = 3.10 FT.
- INCREMENT OF PILE LENGTH
USED IN COMPUTATION = 1.00 FT.
- PRINTING INCREMENT = 1
- LENGTH OF ENHANCED
END SECTION = 60.00 FT.
- INTERNAL DIAMETER OF
ENHANCED END SECTION = 11.50 IN.

PLUGGED/UNPLUGGED CONDITIONS :

Plugged for open-ended pile

SOIL INFORMATIONS :

DEPTH FT.	SOIL TYPE	LATERAL EARTH PRESSURE	EFFECTIVE UNIT WEIGHT LB/FT ³	FRICTION ANGLE DEGREES	Nq FACTOR FHWA
0.00	CLAY	0.80*	55.60	0.00	4.80**
0.40	CLAY	0.80*	55.60	0.00	4.80**
0.40	SAND	0.80*	65.60	39.20	140.16**
1.90	SAND	0.80*	65.60	39.20	140.16**
1.90	SAND	0.80*	65.60	41.20	210.40**
7.40	SAND	0.80*	65.60	41.20	210.40**
7.40	SAND	0.80*	62.60	37.30	95.28**
10.90	SAND	0.80*	62.60	37.30	95.28**

10.90	SAND	0.80*	65.60	41.00	202.00**
13.40	SAND	0.80*	65.60	41.00	202.00**
13.40	CLAY	0.80*	62.60	0.00	4.80**
17.40	CLAY	0.80*	62.60	0.00	4.80**
17.40	CLAY	0.80*	69.60	0.00	4.80**
21.90	CLAY	0.80*	69.60	0.00	4.80**
21.90	CLAY	0.80*	57.60	0.00	4.80**
31.90	CLAY	0.80*	57.60	0.00	4.80**
31.90	CLAY	0.80*	59.60	0.00	4.80**
36.40	CLAY	0.80*	59.60	0.00	4.80**
36.40	CLAY	0.80*	69.60	0.00	4.80**
43.40	CLAY	0.80*	69.60	0.00	4.80**
43.40	SAND	7971.00	77.60	40.00	160.00**
63.40	SAND	7971.00	77.60	40.00	160.00**
63.40	SAND	0.80*	77.60	40.30	172.60**
69.90	SAND	0.80*	77.60	40.30	172.60**

* VALUE ASSUMED BY THE PROGRAM

** VALUE ESTIMATED BY THE PROGRAM BASED ON FRICTION ANGLE

MAXIMUM UNIT FRICTION KSF	MAXIMUM UNIT BEARING KSF	UNDISTURB SHEAR STRENGTH KSF	REMOLDED SHEAR STRENGTH KSF	BLOW COUNT	UNIT SKIN FRICTION KSF	UNIT END BEARING KSF
0.10E+08*	0.10E+08*	1.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	1.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	1.56	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	1.56	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	2.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	2.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING
WERE SET TO LARGE VALUES INDICATING THAT APILE
USES THE LIMITS SPECIFIED BY EACH SELECTED
CRITERIA (IF ANY).

DEPTH FT.	LRFD FACTOR ON UNIT FRICTION	LRFD FACTOR ON UNIT BEARING
0.00	1.000	1.000
0.40	1.000	1.000
0.40	1.000	1.000
1.90	1.000	1.000
1.90	1.000	1.000
7.40	1.000	1.000
7.40	1.000	1.000
10.90	1.000	1.000
10.90	1.000	1.000
13.40	1.000	1.000
13.40	1.000	1.000
17.40	1.000	1.000
17.40	1.000	1.000
21.90	1.000	1.000
21.90	1.000	1.000
31.90	1.000	1.000
31.90	1.000	1.000
36.40	1.000	1.000
36.40	1.000	1.000
43.40	1.000	1.000
43.40	1.000	1.000
63.40	1.000	1.000
63.40	1.000	1.000
69.90	1.000	1.000

DEPTH FT.	Z PEAK IN.	T RESIDUAL
0.00	0.120 *	0.90 **
0.40	0.120 *	0.90 **
0.40	0.120 *	0.00
1.90	0.120 *	0.00
1.90	0.120 *	0.00
7.40	0.120 *	0.00
7.40	0.120 *	0.00
10.90	0.120 *	0.00
10.90	0.120 *	0.00
13.40	0.120 *	0.00

13.40	0.120 *	0.90 **
17.40	0.120 *	0.90 **
17.40	0.120 *	0.90 **
21.90	0.120 *	0.90 **
21.90	0.120 *	0.90 **
31.90	0.120 *	0.90 **
31.90	0.120 *	0.90 **
36.40	0.120 *	0.90 **
36.40	0.120 *	0.90 **
43.40	0.120 *	0.90 **
43.40	0.120 *	0.00
63.40	0.120 *	0.00
63.40	0.120 *	0.00
69.90	0.120 *	0.00

* DEFAULT VALUE = 0.01 D
 ** DEFAULT VALUE = 0.9

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 * COMPUTATION RESULT *

 * FED. HWY. METHOD *

PILE LENGTH BELOW GND. FT.	SKIN FRICTION KIP	END BEARING KIP	ULTIMATE CAPACITY KIP
0.00	0.0	2.0	2.0
1.00	0.0	6.7	6.7
2.00	0.0	14.7	14.7
3.00	0.0	24.0	24.0
4.00	0.3	33.1	33.4
5.00	1.0	41.4	42.4
6.00	1.8	49.7	51.5
7.00	2.8	51.4	54.2
8.00	3.9	45.3	49.2
9.00	5.0	37.5	42.5
10.00	6.1	42.9	49.0
11.00	7.3	63.8	71.1
12.00	8.9	86.2	95.1
13.00	10.7	86.9	97.6

14.00	12.7	62.6	75.3
15.00	18.5	35.7	54.1
16.00	27.9	21.2	49.1
17.00	37.3	23.6	60.9
18.00	46.8	28.3	75.0
19.00	59.3	33.0	92.3
20.00	75.0	35.3	110.4
21.00	90.7	31.3	122.0
22.00	104.8	23.2	128.0
23.00	113.4	15.1	128.5
24.00	118.3	11.0	129.3
25.00	123.2	11.0	134.2
26.00	128.1	11.0	139.1
27.00	132.9	11.0	144.0
28.00	137.8	11.0	148.9
29.00	142.7	11.0	153.8
30.00	147.6	11.0	158.6
31.00	152.5	11.7	164.2
32.00	157.3	13.0	170.3
33.00	162.6	14.4	177.0
34.00	168.5	15.0	183.6
35.00	174.5	15.0	189.5
36.00	180.4	18.6	198.9
37.00	185.9	25.6	211.6
38.00	193.2	32.7	225.9
39.00	202.4	36.2	238.7
40.00	211.7	36.2	247.9
41.00	221.0	36.2	257.2
42.00	230.2	36.2	266.4
43.00	239.5	74.5	313.9
44.00	247.3	152.8	400.1
45.00	253.8	233.5	487.4
46.00	260.5	278.5	539.0
47.00	267.4	285.6	552.9
48.00	274.4	291.1	565.5
49.00	281.6	294.2	575.8
50.00	289.0	295.2	584.2
51.00	296.6	295.3	591.8
52.00	304.3	295.3	599.6
53.00	312.2	295.3	607.5
54.00	320.3	295.3	615.6
55.00	328.6	295.3	623.9
56.00	337.1	295.3	632.3
57.00	345.7	295.3	640.9
58.00	354.5	295.3	649.8
59.00	363.5	295.3	658.7
60.00	372.6	295.3	667.9

NOTES:

- AN ASTERISK IS PLACED IN THE END-BEARING COLUMN
IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION
OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.

* COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
* CURVES FOR AXIAL LOADING *

T-Z CURVE NO.	NO. OF POINTS	DEPTH TO CURVE FT.	LOAD TRANSFER PSI	PILE MOVEMENT IN.
1	10	0.4167E-01	0.0000E+00	0.0000E+00
			0.0000E+00	0.1920E-01
			0.0000E+00	0.3720E-01
			0.0000E+00	0.6840E-01
			0.0000E+00	0.9600E-01
			0.0000E+00	0.1200E+00
			0.0000E+00	0.2400E+00
			0.0000E+00	0.3600E+00
			0.0000E+00	0.6000E+00
			0.0000E+00	0.2400E+01
2	10	0.9500E+00	0.0000E+00	0.0000E+00
			0.0000E+00	0.1920E-01
			0.0000E+00	0.3720E-01
			0.0000E+00	0.6840E-01
			0.0000E+00	0.9600E-01
			0.0000E+00	0.1200E+00
			0.0000E+00	0.2400E+00
			0.0000E+00	0.3600E+00
			0.0000E+00	0.6000E+00
			0.0000E+00	0.2400E+01
3	10	0.1858E+01	0.0000E+00	0.0000E+00
			0.0000E+00	0.1920E-01
			0.0000E+00	0.3720E-01
			0.0000E+00	0.6840E-01
			0.0000E+00	0.9600E-01
			0.0000E+00	0.1200E+00
			0.0000E+00	0.2400E+00
			0.0000E+00	0.3600E+00
			0.0000E+00	0.6000E+00
			0.0000E+00	0.2400E+01
4	10	0.1942E+01	0.0000E+00	0.0000E+00

5	10	0.4650E+01	0.0000E+00	0.1920E-01
			0.0000E+00	0.3720E-01
			0.0000E+00	0.6840E-01
			0.0000E+00	0.9600E-01
			0.0000E+00	0.1200E+00
			0.0000E+00	0.2400E+00
			0.0000E+00	0.3600E+00
			0.0000E+00	0.6000E+00
			0.0000E+00	0.2400E+01
			0.0000E+00	0.0000E+00
			0.4635E+00	0.1920E-01
			0.7725E+00	0.3720E-01
			0.1159E+01	0.6840E-01
			0.1390E+01	0.9600E-01
			0.1545E+01	0.1200E+00
6	10	0.7358E+01	0.1545E+01	0.2400E+00
			0.1545E+01	0.3600E+00
			0.1545E+01	0.6000E+00
			0.1545E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7334E+00	0.1920E-01
			0.1222E+01	0.3720E-01
			0.1834E+01	0.6840E-01
			0.2200E+01	0.9600E-01
			0.2445E+01	0.1200E+00
			0.2445E+01	0.2400E+00
			0.2445E+01	0.3600E+00
			0.2445E+01	0.6000E+00
			0.2445E+01	0.2400E+01
			0.0000E+00	0.0000E+00
7	10	0.7442E+01	0.7417E+00	0.1920E-01
			0.1236E+01	0.3720E-01
			0.1854E+01	0.6840E-01
			0.2225E+01	0.9600E-01
			0.2472E+01	0.1200E+00
			0.2472E+01	0.2400E+00
			0.2472E+01	0.3600E+00
			0.2472E+01	0.6000E+00
			0.2472E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7021E+00	0.1920E-01
			0.1170E+01	0.3720E-01
			0.1755E+01	0.6840E-01
			0.2106E+01	0.9600E-01
			0.2340E+01	0.1200E+00
8	10	0.9150E+01	0.2340E+01	0.2400E+00

9	10	0.1086E+02	0.2340E+01	0.3600E+00
			0.2340E+01	0.6000E+00
			0.2340E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.8279E+00	0.1920E-01
			0.1380E+01	0.3720E-01
			0.2070E+01	0.6840E-01
			0.2484E+01	0.9600E-01
			0.2760E+01	0.1200E+00
			0.2760E+01	0.2400E+00
			0.2760E+01	0.3600E+00
			0.2760E+01	0.6000E+00
			0.2760E+01	0.2400E+01
10	10	0.1094E+02	0.0000E+00	0.0000E+00
			0.8340E+00	0.1920E-01
			0.1390E+01	0.3720E-01
			0.2085E+01	0.6840E-01
			0.2502E+01	0.9600E-01
			0.2780E+01	0.1200E+00
			0.2780E+01	0.2400E+00
			0.2780E+01	0.3600E+00
			0.2780E+01	0.6000E+00
			0.2780E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1197E+01	0.1920E-01
			0.1996E+01	0.3720E-01
11	10	0.1215E+02	0.2993E+01	0.6840E-01
			0.3592E+01	0.9600E-01
			0.3991E+01	0.1200E+00
			0.3991E+01	0.2400E+00
			0.3991E+01	0.3600E+00
			0.3991E+01	0.6000E+00
			0.3991E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1318E+01	0.1920E-01
			0.2196E+01	0.3720E-01
			0.3295E+01	0.6840E-01
			0.3953E+01	0.9600E-01
			0.4393E+01	0.1200E+00
12	10	0.1336E+02	0.4393E+01	0.2400E+00
			0.4393E+01	0.3600E+00
			0.4393E+01	0.6000E+00
			0.4393E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1326E+01	0.1920E-01
13	10	0.1344E+02	0.0000E+00	0.0000E+00
			0.1326E+01	0.1920E-01

14	10	0.1540E+02	0.2210E+01	0.3720E-01
			0.3315E+01	0.6840E-01
			0.3978E+01	0.9600E-01
			0.4420E+01	0.1200E+00
			0.3978E+01	0.2400E+00
			0.3978E+01	0.3600E+00
			0.3978E+01	0.6000E+00
			0.3978E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6250E+01	0.1920E-01
			0.1042E+02	0.3720E-01
			0.1562E+02	0.6840E-01
			0.1875E+02	0.9600E-01
			0.2083E+02	0.1200E+00
15	10	0.1736E+02	0.1875E+02	0.2400E+00
			0.1875E+02	0.3600E+00
			0.1875E+02	0.6000E+00
			0.1875E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6250E+01	0.1920E-01
			0.1042E+02	0.3720E-01
			0.1562E+02	0.6840E-01
			0.1875E+02	0.9600E-01
			0.2083E+02	0.1200E+00
			0.1875E+02	0.2400E+00
			0.1875E+02	0.3600E+00
			0.1875E+02	0.6000E+00
			0.1875E+02	0.2400E+01
16	10	0.1744E+02	0.0000E+00	0.0000E+00
			0.6250E+01	0.1920E-01
			0.1042E+02	0.3720E-01
			0.1562E+02	0.6840E-01
			0.1875E+02	0.9600E-01
			0.2083E+02	0.1200E+00
			0.1875E+02	0.2400E+00
			0.1875E+02	0.3600E+00
			0.1875E+02	0.6000E+00
			0.1875E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6250E+01	0.1920E-01
			0.1042E+02	0.3720E-01
			0.1562E+02	0.6840E-01
17	10	0.1965E+02	0.1875E+02	0.9600E-01
			0.2083E+02	0.1200E+00
			0.1875E+02	0.2400E+00
			0.1875E+02	0.3600E+00
			0.1875E+02	0.6000E+00
			0.1875E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1042E+02	0.1920E-01
			0.1736E+02	0.3720E-01
			0.2604E+02	0.6840E-01
			0.3125E+02	0.9600E-01
			0.3472E+02	0.1200E+00
			0.3125E+02	0.2400E+00
			0.3125E+02	0.3600E+00

18	10	0.2186E+02	0.3125E+02	0.6000E+00
			0.3125E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.8517E+01	0.1920E-01
			0.1419E+02	0.3720E-01
			0.2129E+02	0.6840E-01
			0.2555E+02	0.9600E-01
			0.2839E+02	0.1200E+00
			0.2555E+02	0.2400E+00
			0.2555E+02	0.3600E+00
19	10	0.2194E+02	0.2555E+02	0.6000E+00
			0.2555E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.8332E+01	0.1920E-01
			0.1389E+02	0.3720E-01
			0.2083E+02	0.6840E-01
			0.2500E+02	0.9600E-01
			0.2777E+02	0.1200E+00
			0.2500E+02	0.2400E+00
			0.2500E+02	0.3600E+00
20	10	0.2690E+02	0.2500E+02	0.6000E+00
			0.2500E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3239E+01	0.1920E-01
			0.5398E+01	0.3720E-01
			0.8097E+01	0.6840E-01
			0.9716E+01	0.9600E-01
			0.1080E+02	0.1200E+00
			0.9716E+01	0.2400E+00
			0.9716E+01	0.3600E+00
21	10	0.3186E+02	0.9716E+01	0.6000E+00
			0.9716E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3154E+01	0.1920E-01
			0.5257E+01	0.3720E-01
			0.7885E+01	0.6840E-01
			0.9462E+01	0.9600E-01
			0.1051E+02	0.1200E+00
			0.9462E+01	0.2400E+00
			0.9462E+01	0.3600E+00
22	10	0.3194E+02	0.9462E+01	0.6000E+00
			0.9462E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3146E+01	0.1920E-01
			0.5243E+01	0.3720E-01

23	10	0.3415E+02	0.7865E+01	0.6840E-01
			0.9438E+01	0.9600E-01
			0.1049E+02	0.1200E+00
			0.9438E+01	0.2400E+00
			0.9438E+01	0.3600E+00
			0.9438E+01	0.6000E+00
			0.9438E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3926E+01	0.1920E-01
			0.6543E+01	0.3720E-01
			0.9815E+01	0.6840E-01
			0.1178E+02	0.9600E-01
			0.1309E+02	0.1200E+00
			0.1178E+02	0.2400E+00
24	10	0.3636E+02	0.1178E+02	0.3600E+00
			0.1178E+02	0.6000E+00
			0.1178E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3762E+01	0.1920E-01
			0.6269E+01	0.3720E-01
			0.9404E+01	0.6840E-01
			0.1128E+02	0.9600E-01
			0.1254E+02	0.1200E+00
			0.1128E+02	0.2400E+00
			0.1128E+02	0.3600E+00
			0.1128E+02	0.6000E+00
			0.1128E+02	0.2400E+01
25	10	0.3644E+02	0.0000E+00	0.0000E+00
			0.3723E+01	0.1920E-01
			0.6205E+01	0.3720E-01
			0.9308E+01	0.6840E-01
			0.1117E+02	0.9600E-01
			0.1241E+02	0.1200E+00
			0.1117E+02	0.2400E+00
			0.1117E+02	0.3600E+00
			0.1117E+02	0.6000E+00
			0.1117E+02	0.2400E+01
26	10	0.3990E+02	0.0000E+00	0.0000E+00
			0.6139E+01	0.1920E-01
			0.1023E+02	0.3720E-01
			0.1535E+02	0.6840E-01
			0.1842E+02	0.9600E-01
			0.2046E+02	0.1200E+00
			0.1842E+02	0.2400E+00
			0.1842E+02	0.3600E+00
			0.1842E+02	0.6000E+00

27	10	0.4336E+02	0.1842E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.5470E+01	0.1920E-01
			0.9116E+01	0.3720E-01
			0.1367E+02	0.6840E-01
			0.1641E+02	0.9600E-01
			0.1823E+02	0.1200E+00
			0.1641E+02	0.2400E+00
			0.1641E+02	0.3600E+00
			0.1641E+02	0.6000E+00
28	10	0.4344E+02	0.1641E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.5314E+01	0.1920E-01
			0.8857E+01	0.3720E-01
			0.1329E+02	0.6840E-01
			0.1594E+02	0.9600E-01
			0.1771E+02	0.1200E+00
			0.1771E+02	0.2400E+00
			0.1771E+02	0.3600E+00
			0.1771E+02	0.6000E+00
29	10	0.5340E+02	0.1771E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.5358E+01	0.1920E-01
			0.8930E+01	0.3720E-01
			0.1340E+02	0.6840E-01
			0.1607E+02	0.9600E-01
			0.1786E+02	0.1200E+00
			0.1786E+02	0.2400E+00
			0.1786E+02	0.3600E+00
			0.1786E+02	0.6000E+00
30	10	0.6336E+02	0.1786E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6136E+01	0.1920E-01
			0.1023E+02	0.3720E-01
			0.1534E+02	0.6840E-01
			0.1841E+02	0.9600E-01
			0.2045E+02	0.1200E+00
			0.2045E+02	0.2400E+00
			0.2045E+02	0.3600E+00
			0.2045E+02	0.6000E+00
31	10	0.6344E+02	0.2045E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6136E+01	0.1920E-01
			0.1023E+02	0.3720E-01
			0.1534E+02	0.6840E-01

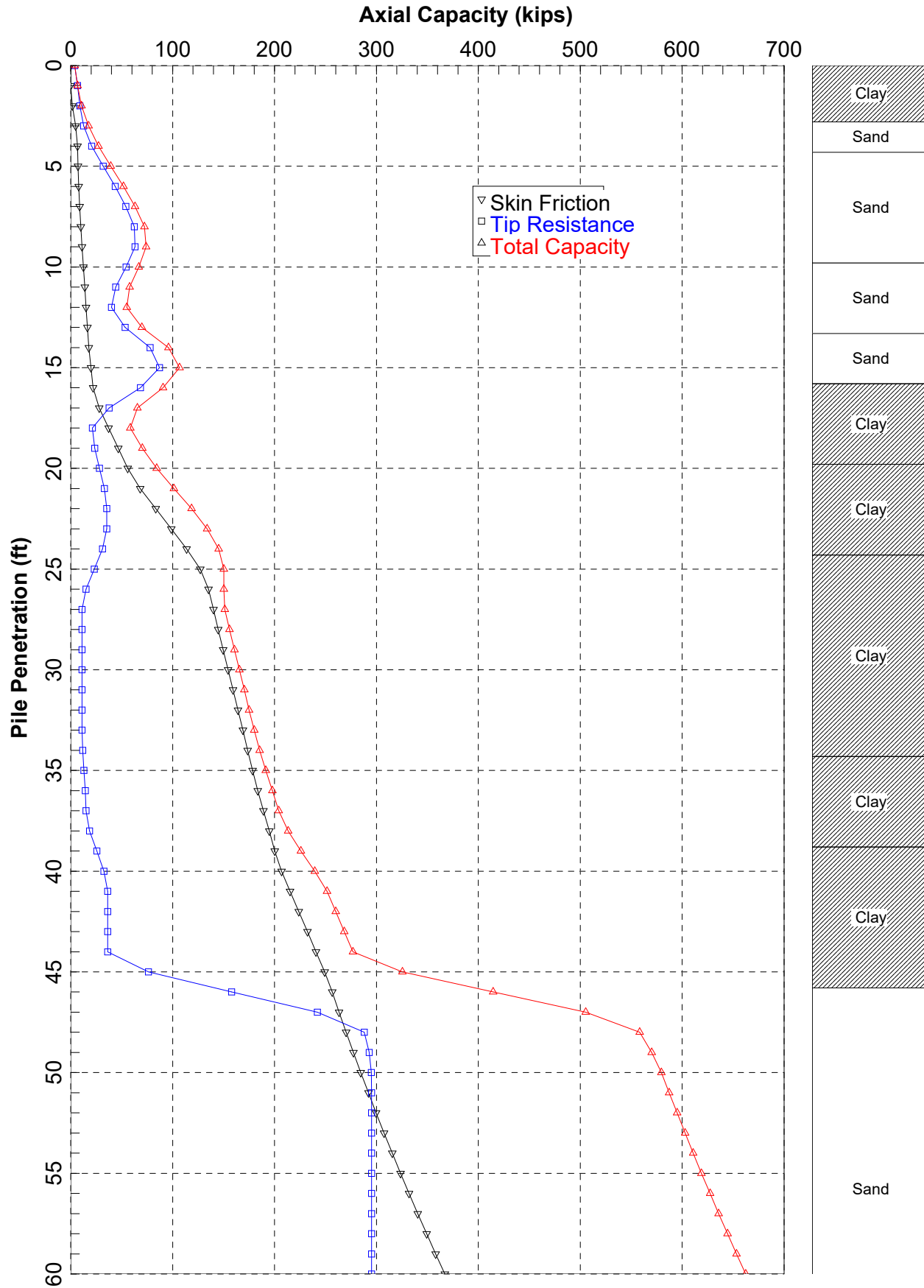
			0.1841E+02	0.9600E-01
			0.2045E+02	0.1200E+00
			0.2045E+02	0.2400E+00
			0.2045E+02	0.3600E+00
			0.2045E+02	0.6000E+00
			0.2045E+02	0.2400E+01
32	10	0.6665E+02	0.0000E+00	0.0000E+00
			0.6136E+01	0.1920E-01
			0.1023E+02	0.3720E-01
			0.1534E+02	0.6840E-01
			0.1841E+02	0.9600E-01
			0.2045E+02	0.1200E+00
			0.2045E+02	0.2400E+00
			0.2045E+02	0.3600E+00
			0.2045E+02	0.6000E+00
			0.2045E+02	0.2400E+01
33	10	0.6986E+02	0.0000E+00	0.0000E+00
			0.6136E+01	0.1920E-01
			0.1023E+02	0.3720E-01
			0.1534E+02	0.6840E-01
			0.1841E+02	0.9600E-01
			0.2045E+02	0.1200E+00
			0.2045E+02	0.2400E+00
			0.2045E+02	0.3600E+00
			0.2045E+02	0.6000E+00
			0.2045E+02	0.2400E+01

TIP LOAD KIP	TIP MOVEMENT IN.
0.0000E+00	0.0000E+00
0.1845E+02	0.6000E-02
0.3691E+02	0.1200E-01
0.7382E+02	0.2400E-01
0.1476E+03	0.1560E+00
0.2214E+03	0.5040E+00
0.2657E+03	0.8760E+00
0.2953E+03	0.1200E+01
0.2953E+03	0.1800E+01
0.2953E+03	0.2400E+01

LOAD VERSUS SETTLEMENT CURVE

TOP LOAD KIP	TOP MOVEMENT IN.	TIP LOAD KIP	TIP MOVEMENT IN.
0.7897E+01	0.8629E-02	0.3076E+00	0.1000E-03
0.7572E+02	0.8572E-01	0.3076E+01	0.1000E-02
0.2251E+03	0.3013E+00	0.1538E+02	0.5000E-02
0.2884E+03	0.4412E+00	0.3076E+02	0.1000E-01
0.3615E+03	0.6283E+00	0.6151E+02	0.2000E-01
0.4203E+03	0.8088E+00	0.8835E+02	0.5000E-01
0.4493E+03	0.9158E+00	0.1051E+03	0.8000E-01
0.4643E+03	0.9762E+00	0.1163E+03	0.1000E+00
0.5063E+03	0.1189E+01	0.1570E+03	0.2000E+00
0.5699E+03	0.1660E+01	0.2206E+03	0.5000E+00
0.6060E+03	0.2057E+01	0.2567E+03	0.8000E+00
0.6263E+03	0.2312E+01	0.2770E+03	0.1000E+01
0.6445E+03	0.3361E+01	0.2953E+03	0.2000E+01

RABT
12" Ult without Scour



RABT 12" Ult without Scour

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APILE for Windows, Version 2023.10.5

Serial Number : 546958499

A Program for Analyzing the Axial Capacity
and Short-term Settlement of Driven Piles
under Axial Loading.
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APILEO Sm Global, SmGlobal License

Path to file locations : C:\Users\yzimmerman\OneDrive - Gannett Fleming Inc\GF - 078318-Mink Street Bridge
Replacement\5_Working\05_Design_Support\Geotech\APILE\RABT\
Name of input data file : RABT_12ULT_NS.ap10d
Name of output file : RABT_12ULT_NS.ap10o
Name of plot output file : RABT_12ULT_NS.ap10p

Time and Date of Analysis

Date: June 23, 2025 Time: 14:49:59

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* INPUT INFORMATION *

PROJECT DESCRIPTION :
Mink Street BG RABT 12"Ult without Scour
DESIGNER : YLZ
JOB NUMBER : 78318

METHOD FOR UNIT LOAD TRANSFERS :
- FHWA (Federal Highway Administration)
Unfactored Unit Side Friction and Unit Side Resistance are used.

COMPUTATION METHOD(S) FOR PILE CAPACITY :
- FHWA (Federal Highway Administration)

TYPE OF LOADING :
- COMPRESSION

PILE TYPE :
Steel pipe pile or non-tapered portion of monotube pile
- Open-Ended Pile

AVERAGE DEPTH TO ESTIMATE TIP RESISTANCE:
- USE 1.5 DIAMETERS ABOVE AND BELOW TIP

DATA FOR AXIAL STIFFNESS :
- MODULUS OF ELASTICITY = 0.290E+08 PSI
- CROSS SECTION AREA = 9.23 IN2

CIRCULAR PILE PROPERTIES :
- OUTSIDE DIAMETER, OD = 12.00 IN.
- INTERNAL DIAMETER, ID = 11.50 IN.
- TOTAL PILE LENGTH, TL = 60.00 FT.

- BATTER ANGLE = 0.00 DEG
 - PILE STICKUP LENGTH, PSL = 0.00 FT.
 - ZERO FRICTION LENGTH, ZFL = 0.00 FT.
 - INCREMENT OF PILE LENGTH
 USED IN COMPUTATION = 1.00 FT.
 - PRINTING INCREMENT = 1
 - LENGTH OF ENHANCED
 END SECTION = 60.00 FT.
 - INTERNAL DIAMETER OF
 ENHANCED END SECTION = 11.50 IN.

PLUGGED/UNPLUGGED CONDITIONS :
 Plugged for open-ended pile

SOIL INFORMATIONS :

DEPTH FT.	SOIL TYPE	LATERAL EARTH PRESSURE	EFFECTIVE UNIT WEIGHT LB/FT^3	FRICTION ANGLE DEGREES	Nq FACTOR FHWA
0.00	CLAY	0.80*	55.60	0.00	4.80**
2.80	CLAY	0.80*	55.60	0.00	4.80**
2.80	SAND	0.80*	65.60	39.20	140.16**
4.30	SAND	0.80*	65.60	39.20	140.16**
4.30	SAND	0.80*	65.60	41.20	210.40**
9.80	SAND	0.80*	65.60	41.20	210.40**
9.80	SAND	0.80*	62.60	37.30	95.28**
13.30	SAND	0.80*	62.60	37.30	95.28**
13.30	SAND	0.80*	65.60	41.00	202.00**
15.80	SAND	0.80*	65.60	41.00	202.00**
15.80	CLAY	0.80*	62.60	0.00	4.80**
19.80	CLAY	0.80*	62.60	0.00	4.80**
19.80	CLAY	0.80*	69.60	0.00	4.80**
24.30	CLAY	0.80*	69.60	0.00	4.80**
24.30	CLAY	0.80*	57.60	0.00	4.80**
34.30	CLAY	0.80*	57.60	0.00	4.80**
34.30	CLAY	0.80*	59.60	0.00	4.80**
38.80	CLAY	0.80*	59.60	0.00	4.80**
38.80	CLAY	0.80*	69.60	0.00	4.80**
45.80	CLAY	0.80*	69.60	0.00	4.80**
45.80	SAND	7971.00	77.60	40.00	160.00**
65.80	SAND	7971.00	77.60	40.00	160.00**
65.80	SAND	0.80*	77.60	40.30	172.60**
72.30	SAND	0.80*	77.60	40.30	172.60**

* VALUE ASSUMED BY THE PROGRAM

** VALUE ESTIMATED BY THE PROGRAM BASED ON FRICTION ANGLE

MAXIMUM UNIT FRICTION KSF	MAXIMUM UNIT BEARING KSF	UNDISTURB SHEAR STRENGTH KSF	REMOLED SHEAR STRENGTH KSF	BLOW COUNT	UNIT SKIN FRICTION KSF	UNIT END BEARING KSF
0.10E+08*	0.10E+08*	1.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	1.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	1.56	0.00	0.00	0.00	0.00

0.10E+08*	0.10E+08*	1.56	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	2.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	2.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING
WERE SET TO LARGE VALUES INDICATING THAT APILE
USES THE LIMITS SPECIFIED BY EACH SELECTED
CRITERIA (IF ANY).

DEPTH FT.	LRFD FACTOR ON UNIT FRICTION	LRFD FACTOR ON UNIT BEARING
0.00	1.000	1.000
2.80	1.000	1.000
2.80	1.000	1.000
4.30	1.000	1.000
4.30	1.000	1.000
9.80	1.000	1.000
9.80	1.000	1.000
13.30	1.000	1.000
13.30	1.000	1.000
15.80	1.000	1.000
15.80	1.000	1.000
19.80	1.000	1.000
19.80	1.000	1.000
24.30	1.000	1.000
24.30	1.000	1.000
34.30	1.000	1.000
34.30	1.000	1.000
38.80	1.000	1.000
38.80	1.000	1.000
45.80	1.000	1.000
45.80	1.000	1.000
65.80	1.000	1.000
65.80	1.000	1.000
72.30	1.000	1.000

DEPTH FT.	Z PEAK IN.	T RESIDUAL
0.00	0.120 *	0.90 **
2.80	0.120 *	0.90 **
2.80	0.120 *	0.00
4.30	0.120 *	0.00
4.30	0.120 *	0.00
9.80	0.120 *	0.00
9.80	0.120 *	0.00
13.30	0.120 *	0.00
13.30	0.120 *	0.00
15.80	0.120 *	0.00
15.80	0.120 *	0.90 **
19.80	0.120 *	0.90 **
19.80	0.120 *	0.90 **
24.30	0.120 *	0.90 **
24.30	0.120 *	0.90 **
34.30	0.120 *	0.90 **
34.30	0.120 *	0.90 **
38.80	0.120 *	0.90 **
38.80	0.120 *	0.90 **

45.80	0.120 *	0.90 **
45.80	0.120 *	0.00
65.80	0.120 *	0.00
65.80	0.120 *	0.00
72.30	0.120 *	0.00

* DEFAULT VALUE = 0.01 D

** DEFAULT VALUE = 0.9

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 * COMPUTATION RESULT *

 * FED. HWY. METHOD *

PILE LENGTH BELOW GND. FT.	SKIN FRICTION KIP	END BEARING KIP	ULTIMATE CAPACITY KIP
0.00	0.0	4.0	4.0
1.00	0.0	6.6	6.6
2.00	1.6	9.1	10.7
3.00	4.8	12.8	17.5
4.00	6.6	20.5	27.2
5.00	7.2	32.0	39.2
6.00	7.9	43.8	51.7
7.00	8.8	54.2	63.0
8.00	9.9	62.5	72.4
9.00	11.1	63.0	74.0
10.00	12.4	54.4	66.8
11.00	13.8	44.1	57.9
12.00	15.0	40.0	55.1
13.00	16.4	53.4	69.9
14.00	17.9	78.0	96.0
15.00	19.8	87.1	106.9
16.00	22.0	68.5	90.6
17.00	27.9	37.6	65.5
18.00	37.3	21.2	58.5
19.00	46.7	23.6	70.3
20.00	56.0	28.3	84.3
21.00	68.2	33.0	101.2
22.00	83.4	35.3	118.7
23.00	98.6	35.3	133.9
24.00	113.8	31.3	145.1
25.00	127.1	23.2	150.3
26.00	135.2	15.1	150.3
27.00	140.0	11.0	151.1
28.00	144.8	11.0	155.9
29.00	149.6	11.0	160.7
30.00	154.5	11.0	165.5
31.00	159.3	11.0	170.3
32.00	164.1	11.0	175.1
33.00	168.9	11.0	180.0
34.00	173.7	11.7	185.4
35.00	178.4	13.0	191.5
36.00	183.6	14.4	197.9
37.00	189.2	15.0	204.2
38.00	194.8	18.6	213.4
39.00	200.1	25.6	225.8
40.00	206.9	32.7	239.5
41.00	215.3	36.2	251.6

42.00	223.8	36.2	260.0
43.00	232.3	36.2	268.5
44.00	240.7	36.2	277.0
45.00	249.2	76.2	325.4
46.00	256.7	157.9	414.5
47.00	263.3	242.0	505.3
48.00	270.2	288.1	558.3
49.00	277.3	292.8	570.1
50.00	284.6	295.0	579.6
51.00	292.1	295.3	587.3
52.00	299.7	295.3	595.0
53.00	307.5	295.3	602.8
54.00	315.5	295.3	610.8
55.00	323.7	295.3	618.9
56.00	332.0	295.3	627.3
57.00	340.5	295.3	635.8
58.00	349.2	295.3	644.5
59.00	358.1	295.3	653.4
60.00	367.2	295.3	662.4

NOTES:

- AN ASTERISK IS PLACED IN THE END-BEARING COLUMN IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.

 * COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
 * CURVES FOR AXIAL LOADING *

T-Z CURVE NO.	NO. OF POINTS	DEPTH TO CURVE FT.	LOAD TRANSFER PSI	PILE MOVEMENT IN.
1	10	0.4167E-01	0.0000E+00	0.0000E+00
			0.0000E+00	0.1920E-01
			0.0000E+00	0.3720E-01
			0.0000E+00	0.6840E-01
			0.0000E+00	0.9600E-01
			0.0000E+00	0.1200E+00
			0.0000E+00	0.2400E+00
			0.0000E+00	0.3600E+00
			0.0000E+00	0.6000E+00
			0.0000E+00	0.2400E+01
2	10	0.1400E+01	0.0000E+00	0.0000E+00
			0.8433E+00	0.1920E-01
			0.1405E+01	0.3720E-01
			0.2108E+01	0.6840E-01
			0.2530E+01	0.9600E-01
			0.2811E+01	0.1200E+00
			0.2530E+01	0.2400E+00
			0.2530E+01	0.3600E+00
			0.2530E+01	0.6000E+00
			0.2530E+01	0.2400E+01
3	10	0.2758E+01	0.0000E+00	0.0000E+00
			0.2108E+01	0.1920E-01
			0.3514E+01	0.3720E-01
			0.5271E+01	0.6840E-01
			0.6325E+01	0.9600E-01
			0.7027E+01	0.1200E+00
			0.6325E+01	0.2400E+00
			0.6325E+01	0.3600E+00
			0.6325E+01	0.6000E+00

4	10	0.2842E+01	0.6325E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.2108E+01	0.1920E-01
			0.3514E+01	0.3720E-01
			0.5271E+01	0.6840E-01
			0.6325E+01	0.9600E-01
			0.7027E+01	0.1200E+00
			0.7027E+01	0.2400E+00
			0.7027E+01	0.3600E+00
			0.7027E+01	0.6000E+00
5	10	0.3550E+01	0.7027E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1130E+01	0.1920E-01
			0.1883E+01	0.3720E-01
			0.2825E+01	0.6840E-01
			0.3390E+01	0.9600E-01
			0.3767E+01	0.1200E+00
			0.3767E+01	0.2400E+00
			0.3767E+01	0.3600E+00
			0.3767E+01	0.6000E+00
6	10	0.4258E+01	0.3767E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3537E+00	0.1920E-01
			0.5895E+00	0.3720E-01
			0.8843E+00	0.6840E-01
			0.1061E+01	0.9600E-01
			0.1179E+01	0.1200E+00
			0.1179E+01	0.2400E+00
			0.1179E+01	0.3600E+00
			0.1179E+01	0.6000E+00
7	10	0.4342E+01	0.1179E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3615E+00	0.1920E-01
			0.6024E+00	0.3720E-01
			0.9037E+00	0.6840E-01
			0.1084E+01	0.9600E-01
			0.1205E+01	0.1200E+00
			0.1205E+01	0.2400E+00
			0.1205E+01	0.3600E+00
			0.1205E+01	0.6000E+00
8	10	0.7050E+01	0.1205E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6571E+00	0.1920E-01
			0.1095E+01	0.3720E-01
			0.1643E+01	0.6840E-01
			0.1971E+01	0.9600E-01
			0.2190E+01	0.1200E+00
			0.2190E+01	0.2400E+00
			0.2190E+01	0.3600E+00
			0.2190E+01	0.6000E+00
9	10	0.9758E+01	0.2190E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.9271E+00	0.1920E-01
			0.1545E+01	0.3720E-01
			0.2318E+01	0.6840E-01
			0.2781E+01	0.9600E-01
			0.3090E+01	0.1200E+00
			0.3090E+01	0.2400E+00
			0.3090E+01	0.3600E+00
			0.3090E+01	0.6000E+00
10	10	0.9842E+01	0.3090E+01	0.2400E+01
			0.0000E+00	0.0000E+00

11	10	0.1155E+02	0.9354E+00	0.1920E-01
			0.1559E+01	0.3720E-01
			0.2338E+01	0.6840E-01
			0.2806E+01	0.9600E-01
			0.3118E+01	0.1200E+00
			0.3118E+01	0.2400E+00
			0.3118E+01	0.3600E+00
			0.3118E+01	0.6000E+00
			0.3118E+01	0.2400E+01
			0.0000E+00	0.0000E+00
12	10	0.1326E+02	0.8506E+00	0.1920E-01
			0.1418E+01	0.3720E-01
			0.2126E+01	0.6840E-01
			0.2552E+01	0.9600E-01
			0.2835E+01	0.1200E+00
			0.2835E+01	0.2400E+00
			0.2835E+01	0.3600E+00
			0.2835E+01	0.6000E+00
			0.2835E+01	0.2400E+01
			0.0000E+00	0.0000E+00
13	10	0.1334E+02	0.9764E+00	0.1920E-01
			0.1627E+01	0.3720E-01
			0.2441E+01	0.6840E-01
			0.2929E+01	0.9600E-01
			0.3255E+01	0.1200E+00
			0.3255E+01	0.2400E+00
			0.3255E+01	0.3600E+00
			0.3255E+01	0.6000E+00
			0.3255E+01	0.2400E+01
			0.0000E+00	0.0000E+00
14	10	0.1455E+02	0.9825E+00	0.1920E-01
			0.1638E+01	0.3720E-01
			0.2456E+01	0.6840E-01
			0.2948E+01	0.9600E-01
			0.3275E+01	0.1200E+00
			0.3275E+01	0.2400E+00
			0.3275E+01	0.3600E+00
			0.3275E+01	0.6000E+00
			0.3275E+01	0.2400E+01
			0.0000E+00	0.0000E+00
15	10	0.1576E+02	0.1251E+01	0.1920E-01
			0.2085E+01	0.3720E-01
			0.3128E+01	0.6840E-01
			0.3754E+01	0.9600E-01
			0.4171E+01	0.1200E+00
			0.4171E+01	0.2400E+00
			0.4171E+01	0.3600E+00
			0.4171E+01	0.6000E+00
			0.4171E+01	0.2400E+01
			0.0000E+00	0.0000E+00
16	10	0.1584E+02	0.1507E+01	0.1920E-01
			0.2511E+01	0.3720E-01
			0.3767E+01	0.6840E-01
			0.4521E+01	0.9600E-01
			0.5023E+01	0.1200E+00
			0.5023E+01	0.2400E+00
			0.5023E+01	0.3600E+00
			0.5023E+01	0.6000E+00
			0.5023E+01	0.2400E+01
			0.0000E+00	0.0000E+00
16	10	0.1584E+02	0.1515E+01	0.1920E-01
			0.2525E+01	0.3720E-01
			0.3788E+01	0.6840E-01

17	10	0.1780E+02	0.4546E+01	0.9600E-01
			0.5051E+01	0.1200E+00
			0.4546E+01	0.2400E+00
			0.4546E+01	0.3600E+00
			0.4546E+01	0.6000E+00
			0.4546E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6250E+01	0.1920E-01
			0.1042E+02	0.3720E-01
			0.1562E+02	0.6840E-01
18	10	0.1976E+02	0.1875E+02	0.9600E-01
			0.2083E+02	0.1200E+00
			0.1875E+02	0.2400E+00
			0.1875E+02	0.3600E+00
			0.1875E+02	0.6000E+00
			0.1875E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6096E+01	0.1920E-01
			0.1016E+02	0.3720E-01
			0.1524E+02	0.6840E-01
19	10	0.1984E+02	0.1829E+02	0.9600E-01
			0.2032E+02	0.1200E+00
			0.1829E+02	0.2400E+00
			0.1829E+02	0.3600E+00
			0.1829E+02	0.6000E+00
			0.1829E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6079E+01	0.1920E-01
			0.1013E+02	0.3720E-01
			0.1520E+02	0.6840E-01
20	10	0.2205E+02	0.1824E+02	0.9600E-01
			0.2026E+02	0.1200E+00
			0.1824E+02	0.2400E+00
			0.1824E+02	0.3600E+00
			0.1824E+02	0.6000E+00
			0.1824E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1008E+02	0.1920E-01
			0.1680E+02	0.3720E-01
			0.2520E+02	0.6840E-01
21	10	0.2426E+02	0.3023E+02	0.9600E-01
			0.3359E+02	0.1200E+00
			0.3023E+02	0.2400E+00
			0.3023E+02	0.3600E+00
			0.3023E+02	0.6000E+00
			0.3023E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.9432E+01	0.1920E-01
			0.1572E+02	0.3720E-01
			0.2358E+02	0.6840E-01
22	10	0.2434E+02	0.2829E+02	0.9600E-01
			0.3144E+02	0.1200E+00
			0.2829E+02	0.2400E+00
			0.2829E+02	0.3600E+00
			0.2829E+02	0.6000E+00
			0.2829E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.9223E+01	0.1920E-01
			0.1537E+02	0.3720E-01
			0.2306E+02	0.6840E-01
			0.2767E+02	0.9600E-01
			0.3074E+02	0.1200E+00
			0.2767E+02	0.2400E+00

23	10	0.2930E+02	0.2767E+02	0.3600E+00
			0.2767E+02	0.6000E+00
			0.2767E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3194E+01	0.1920E-01
			0.5324E+01	0.3720E-01
			0.7986E+01	0.6840E-01
			0.9583E+01	0.9600E-01
			0.1065E+02	0.1200E+00
			0.9583E+01	0.2400E+00
24	10	0.3426E+02	0.9583E+01	0.3600E+00
			0.9583E+01	0.6000E+00
			0.9583E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3157E+01	0.1920E-01
			0.5262E+01	0.3720E-01
			0.7893E+01	0.6840E-01
			0.9472E+01	0.9600E-01
			0.1052E+02	0.1200E+00
			0.9472E+01	0.2400E+00
25	10	0.3434E+02	0.9472E+01	0.3600E+00
			0.9472E+01	0.6000E+00
			0.9472E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3145E+01	0.1920E-01
			0.5242E+01	0.3720E-01
			0.7863E+01	0.6840E-01
			0.9436E+01	0.9600E-01
			0.1048E+02	0.1200E+00
			0.9436E+01	0.2400E+00
26	10	0.3655E+02	0.9436E+01	0.3600E+00
			0.9436E+01	0.6000E+00
			0.9436E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3742E+01	0.1920E-01
			0.6237E+01	0.3720E-01
			0.9356E+01	0.6840E-01
			0.1123E+02	0.9600E-01
			0.1247E+02	0.1200E+00
			0.1123E+02	0.2400E+00
27	10	0.3876E+02	0.1123E+02	0.3600E+00
			0.1123E+02	0.6000E+00
			0.1123E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3394E+01	0.1920E-01
			0.5657E+01	0.3720E-01
			0.8486E+01	0.6840E-01
			0.1018E+02	0.9600E-01
			0.1131E+02	0.1200E+00
			0.1018E+02	0.2400E+00
28	10	0.3884E+02	0.1018E+02	0.3600E+00
			0.1018E+02	0.6000E+00
			0.1018E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3356E+01	0.1920E-01
			0.5593E+01	0.3720E-01
			0.8390E+01	0.6840E-01
			0.1007E+02	0.9600E-01
			0.1119E+02	0.1200E+00
			0.1007E+02	0.2400E+00
			0.1007E+02	0.3600E+00
			0.1007E+02	0.6000E+00
			0.1007E+02	0.2400E+01
			0.1007E+02	0.2400E+01

29	10	0.4230E+02	0.0000E+00	0.0000E+00
			0.5616E+01	0.1920E-01
			0.9360E+01	0.3720E-01
			0.1404E+02	0.6840E-01
			0.1685E+02	0.9600E-01
			0.1872E+02	0.1200E+00
			0.1685E+02	0.2400E+00
			0.1685E+02	0.3600E+00
			0.1685E+02	0.6000E+00
			0.1685E+02	0.2400E+01
30	10	0.4576E+02	0.0000E+00	0.0000E+00
			0.4596E+01	0.1920E-01
			0.7660E+01	0.3720E-01
			0.1149E+02	0.6840E-01
			0.1379E+02	0.9600E-01
			0.1532E+02	0.1200E+00
			0.1379E+02	0.2400E+00
			0.1379E+02	0.3600E+00
			0.1379E+02	0.6000E+00
			0.1379E+02	0.2400E+01
31	10	0.4584E+02	0.0000E+00	0.0000E+00
			0.4484E+01	0.1920E-01
			0.7473E+01	0.3720E-01
			0.1121E+02	0.6840E-01
			0.1345E+02	0.9600E-01
			0.1495E+02	0.1200E+00
			0.1495E+02	0.2400E+00
			0.1495E+02	0.3600E+00
			0.1495E+02	0.6000E+00
			0.1495E+02	0.2400E+01
32	10	0.5580E+02	0.0000E+00	0.0000E+00
			0.5569E+01	0.1920E-01
			0.9282E+01	0.3720E-01
			0.1392E+02	0.6840E-01
			0.1671E+02	0.9600E-01
			0.1856E+02	0.1200E+00
			0.1856E+02	0.2400E+00
			0.1856E+02	0.3600E+00
			0.1856E+02	0.6000E+00
			0.1856E+02	0.2400E+01
33	10	0.6576E+02	0.0000E+00	0.0000E+00
			0.6064E+01	0.1920E-01
			0.1011E+02	0.3720E-01
			0.1516E+02	0.6840E-01
			0.1819E+02	0.9600E-01
			0.2021E+02	0.1200E+00
			0.2021E+02	0.2400E+00
			0.2021E+02	0.3600E+00
			0.2021E+02	0.6000E+00
			0.2021E+02	0.2400E+01
34	10	0.6584E+02	0.0000E+00	0.0000E+00
			0.6064E+01	0.1920E-01
			0.1011E+02	0.3720E-01
			0.1516E+02	0.6840E-01
			0.1819E+02	0.9600E-01
			0.2021E+02	0.1200E+00
			0.2021E+02	0.2400E+00
			0.2021E+02	0.3600E+00
			0.2021E+02	0.6000E+00
			0.2021E+02	0.2400E+01
35	10	0.6905E+02	0.0000E+00	0.0000E+00
			0.6064E+01	0.1920E-01

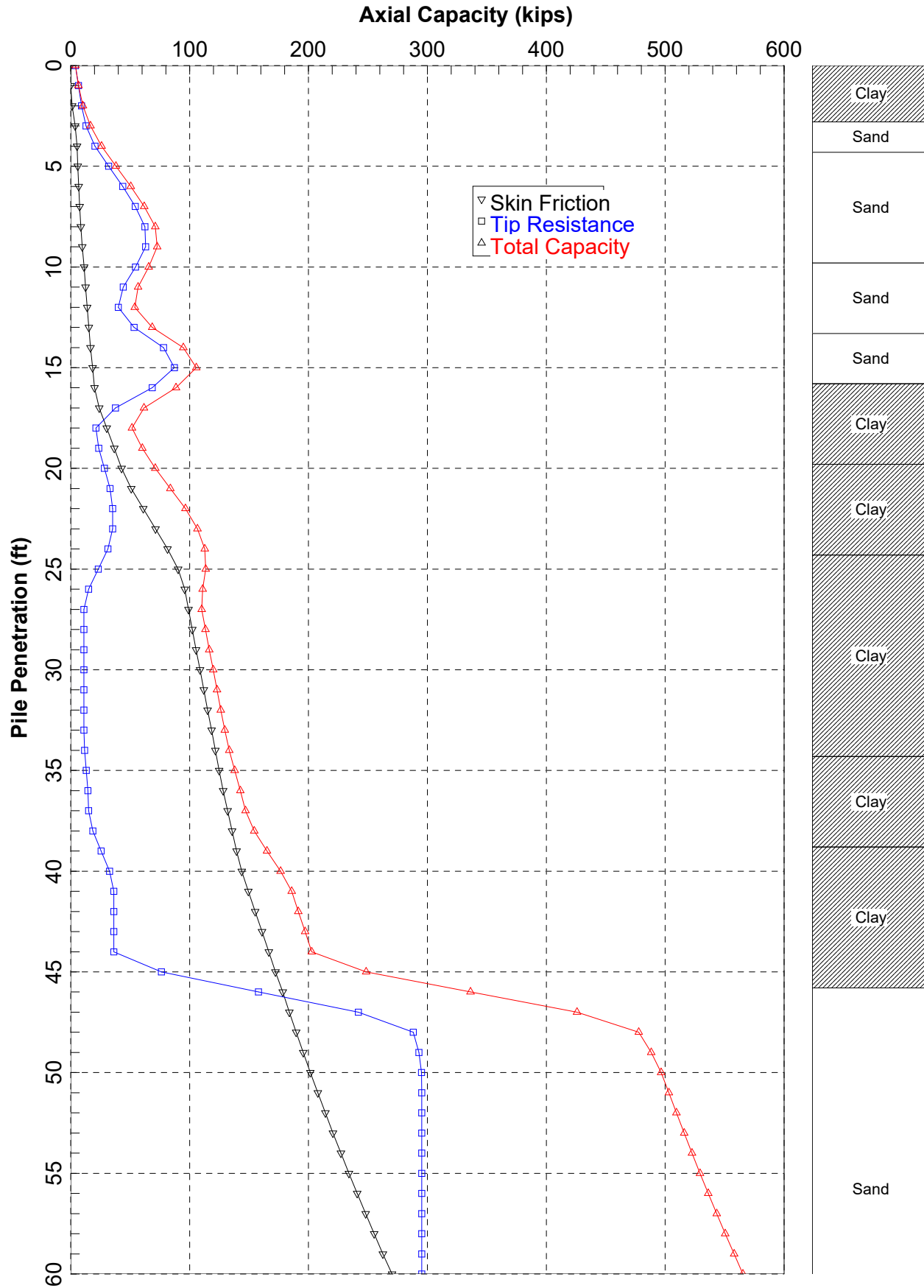
			0.1011E+02	0.3720E-01
			0.1516E+02	0.6840E-01
			0.1819E+02	0.9600E-01
			0.2021E+02	0.1200E+00
			0.2021E+02	0.2400E+00
			0.2021E+02	0.3600E+00
			0.2021E+02	0.6000E+00
			0.2021E+02	0.2400E+01
36	10	0.7226E+02		
			0.0000E+00	0.0000E+00
			0.6064E+01	0.1920E-01
			0.1011E+02	0.3720E-01
			0.1516E+02	0.6840E-01
			0.1819E+02	0.9600E-01
			0.2021E+02	0.1200E+00
			0.2021E+02	0.2400E+00
			0.2021E+02	0.3600E+00
			0.2021E+02	0.6000E+00
			0.2021E+02	0.2400E+01

TIP LOAD KIP	TIP MOVEMENT IN.
0.0000E+00	0.0000E+00
0.1845E+02	0.6000E-02
0.3691E+02	0.1200E-01
0.7382E+02	0.2400E-01
0.1476E+03	0.1560E+00
0.2214E+03	0.5040E+00
0.2657E+03	0.8760E+00
0.2953E+03	0.1200E+01
0.2953E+03	0.1800E+01
0.2953E+03	0.2400E+01

LOAD VERSUS SETTLEMENT CURVE

TOP LOAD KIP	TOP MOVEMENT IN.	TIP LOAD KIP	TIP MOVEMENT IN.
0.7863E+01	0.8251E-02	0.3076E+00	0.1000E-03
0.7462E+02	0.8276E-01	0.3076E+01	0.1000E-02
0.2208E+03	0.2954E+00	0.1538E+02	0.5000E-02
0.2873E+03	0.4360E+00	0.3076E+02	0.1000E-01
0.3565E+03	0.6174E+00	0.6151E+02	0.2000E-01
0.4156E+03	0.7982E+00	0.8835E+02	0.5000E-01
0.4441E+03	0.9042E+00	0.1051E+03	0.8000E-01
0.4587E+03	0.9637E+00	0.1163E+03	0.1000E+00
0.5004E+03	0.1176E+01	0.1570E+03	0.2000E+00
0.5641E+03	0.1647E+01	0.2206E+03	0.5000E+00
0.6002E+03	0.2044E+01	0.2567E+03	0.8000E+00
0.6205E+03	0.2299E+01	0.2770E+03	0.1000E+01
0.6387E+03	0.3348E+01	0.2953E+03	0.2000E+01

RABT 12" Driving without Scour



RABT

12" Driving without Scour

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APILE for Windows, Version 2023.10.5

Serial Number : 546958499

A Program for Analyzing the Axial Capacity
and Short-term Settlement of Driven Piles
under Axial Loading.
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Path to file locations : C:\Users\yzimmerman\OneDrive - Gannett Fleming Inc\GF - 078318-Mink Street Bridge
Replacement\5_Working\05_Design_Support\Geotech\APILE\RABT\
Name of input data file : RABT_12E0ID_NS.ap10d
Name of output file : RABT_12E0ID_NS.ap10o
Name of plot output file : RABT_12E0ID_NS.ap10p

Time and Date of Analysis

Date: June 23, 2025 Time: 15:04:16

1

* INPUT INFORMATION *

PROJECT DESCRIPTION :
Mink Street BG RABT 12"E0ID without Scour
DESIGNER : YLZ
JOB NUMBER : 78318

METHOD FOR UNIT LOAD TRANSFERS :
- FHWA (Federal Highway Administration)
Unfactored Unit Side Friction and Unit Side Resistance are used.

COMPUTATION METHOD(S) FOR PILE CAPACITY :
- FHWA (Federal Highway Administration)

TYPE OF LOADING :
- COMPRESSION

PILE TYPE :
Steel pipe pile or non-tapered portion of monotube pile
- Open-Ended Pile

AVERAGE DEPTH TO ESTIMATE TIP RESISTANCE:
- USE 1.5 DIAMETERS ABOVE AND BELOW TIP

DATA FOR AXIAL STIFFNESS :
- MODULUS OF ELASTICITY = 0.290E+08 PSI
- CROSS SECTION AREA = 9.23 IN²

CIRCULAR PILE PROPERTIES :
- OUTSIDE DIAMETER, OD = 12.00 IN.
- INTERNAL DIAMETER, ID = 11.50 IN.
- TOTAL PILE LENGTH, TL = 60.00 FT.

- BATTER ANGLE = 0.00 DEG
 - PILE STICKUP LENGTH, PSL = 0.00 FT.
 - ZERO FRICTION LENGTH, ZFL = 0.00 FT.
 - INCREMENT OF PILE LENGTH
 USED IN COMPUTATION = 1.00 FT.
 - PRINTING INCREMENT = 1
 - LENGTH OF ENHANCED
 END SECTION = 60.00 FT.
 - INTERNAL DIAMETER OF
 ENHANCED END SECTION = 11.50 IN.

PLUGGED/UNPLUGGED CONDITIONS :
 Plugged for open-ended pile

SOIL INFORMATIONS :

DEPTH FT.	SOIL TYPE	LATERAL EARTH PRESSURE	EFFECTIVE UNIT WEIGHT LB/FT^3	FRICTION ANGLE DEGREES	Nq FACTOR FHWA
0.00	CLAY	0.80*	55.60	0.00	4.80**
2.80	CLAY	0.80*	55.60	0.00	4.80**
2.80	SAND	0.80*	65.60	39.20	140.16**
4.30	SAND	0.80*	65.60	39.20	140.16**
4.30	SAND	0.80*	65.60	41.20	210.40**
9.80	SAND	0.80*	65.60	41.20	210.40**
9.80	SAND	0.80*	62.60	37.30	95.28**
13.30	SAND	0.80*	62.60	37.30	95.28**
13.30	SAND	0.80*	65.60	41.00	202.00**
15.80	SAND	0.80*	65.60	41.00	202.00**
15.80	CLAY	0.80*	62.60	0.00	4.80**
19.80	CLAY	0.80*	62.60	0.00	4.80**
19.80	CLAY	0.80*	69.60	0.00	4.80**
24.30	CLAY	0.80*	69.60	0.00	4.80**
24.30	CLAY	0.80*	57.60	0.00	4.80**
34.30	CLAY	0.80*	57.60	0.00	4.80**
34.30	CLAY	0.80*	59.60	0.00	4.80**
38.80	CLAY	0.80*	59.60	0.00	4.80**
38.80	CLAY	0.80*	69.60	0.00	4.80**
45.80	CLAY	0.80*	69.60	0.00	4.80**
45.80	SAND	7971.00	77.60	40.00	160.00**
65.80	SAND	7971.00	77.60	40.00	160.00**

* VALUE ASSUMED BY THE PROGRAM

** VALUE ESTIMATED BY THE PROGRAM BASED ON FRICTION ANGLE

MAXIMUM UNIT FRICTION KSF	MAXIMUM UNIT BEARING KSF	UNDISTURB SHEAR STRENGTH KSF	REMOLDED SHEAR STRENGTH KSF	BLOW COUNT	UNIT SKIN FRICTION KSF	UNIT END BEARING KSF
0.10E+08*	0.10E+08*	1.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	1.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	1.56	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	1.56	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	2.12	0.00	0.00	0.00	0.00

0.10E+08*	0.10E+08*	2.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	5.12	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING
WERE SET TO LARGE VALUES INDICATING THAT APILE
USES THE LIMITS SPECIFIED BY EACH SELECTED
CRITERIA (IF ANY).

DEPTH FT.	LRFD FACTOR ON UNIT FRICTION	LRFD FACTOR ON UNIT BEARING
0.00	0.750	1.000
2.80	0.750	1.000
2.80	0.830	1.000
4.30	0.830	1.000
4.30	1.000	1.000
9.80	1.000	1.000
9.80	1.000	1.000
13.30	1.000	1.000
13.30	1.000	1.000
15.80	1.000	1.000
15.80	0.670	1.000
19.80	0.670	1.000
19.80	0.670	1.000
24.30	0.670	1.000
24.30	0.670	1.000
34.30	0.670	1.000
34.30	0.670	1.000
38.80	0.670	1.000
38.80	0.670	1.000
45.80	0.670	1.000
45.80	0.830	1.000
65.80	0.830	1.000

DEPTH FT.	Z PEAK IN.	T RESIDUAL
0.00	0.120 *	0.90 **
2.80	0.120 *	0.90 **
2.80	0.120 *	0.00
4.30	0.120 *	0.00
4.30	0.120 *	0.00
9.80	0.120 *	0.00
9.80	0.120 *	0.00
13.30	0.120 *	0.00
13.30	0.120 *	0.00
15.80	0.120 *	0.00
15.80	0.120 *	0.90 **
19.80	0.120 *	0.90 **
19.80	0.120 *	0.90 **
24.30	0.120 *	0.90 **
24.30	0.120 *	0.90 **
34.30	0.120 *	0.90 **
34.30	0.120 *	0.90 **
38.80	0.120 *	0.90 **
38.80	0.120 *	0.90 **
45.80	0.120 *	0.90 **
45.80	0.120 *	0.00
65.80	0.120 *	0.00

* DEFAULT VALUE = 0.01 D
** DEFAULT VALUE = 0.9

 * COMPUTATION RESULT *

 * FED. HWY. METHOD *

PILE LENGTH BELOW GND. FT.	SKIN FRICTION KIP	END BEARING KIP	ULTIMATE CAPACITY KIP
0.00	0.0	4.0	4.0
1.00	0.0	6.6	6.6
2.00	1.2	9.1	10.3
3.00	3.8	12.8	16.6
4.00	5.4	20.5	25.9
5.00	5.9	32.0	38.0
6.00	6.7	43.8	50.5
7.00	7.6	54.2	61.8
8.00	8.6	62.5	71.1
9.00	9.8	63.0	72.8
10.00	11.2	54.4	65.6
11.00	12.5	44.1	56.6
12.00	13.8	40.0	53.8
13.00	15.2	53.4	68.6
14.00	16.7	78.0	94.7
15.00	18.5	87.1	105.6
16.00	20.0	68.5	88.6
17.00	24.0	37.6	61.6
18.00	30.3	21.2	51.5
19.00	36.6	23.6	60.2
20.00	42.8	28.3	71.1
21.00	51.0	33.0	83.9
22.00	61.1	35.3	96.5
23.00	71.3	35.3	106.7
24.00	81.5	31.3	112.8
25.00	90.4	23.2	113.6
26.00	95.9	15.1	111.0
27.00	99.1	11.0	110.1
28.00	102.3	11.0	113.4
29.00	105.5	11.0	116.6
30.00	108.8	11.0	119.8
31.00	112.0	11.0	123.0
32.00	115.2	11.0	126.3
33.00	118.5	11.0	129.5
34.00	121.7	11.7	133.4
35.00	124.8	13.0	137.9
36.00	128.3	14.4	142.6
37.00	132.0	15.0	147.1
38.00	135.8	18.6	154.4
39.00	139.4	25.6	165.0
40.00	143.9	32.7	176.6
41.00	149.5	36.2	185.8
42.00	155.2	36.2	191.4
43.00	160.9	36.2	197.1
44.00	166.6	36.2	202.8
45.00	172.2	76.2	248.4
46.00	178.4	157.9	336.3
47.00	183.9	242.0	425.9
48.00	189.7	288.1	477.8
49.00	195.6	292.8	488.3

50.00	201.6	295.0	496.6
51.00	207.8	295.3	503.1
52.00	214.2	295.3	509.4
53.00	220.6	295.3	515.9
54.00	227.3	295.3	522.5
55.00	234.0	295.3	529.3
56.00	241.0	295.3	536.2
57.00	248.0	295.3	543.3
58.00	255.3	295.3	550.5
59.00	262.6	295.3	557.9
60.00	270.2	295.3	565.4

NOTES:

- AN ASTERISK IS PLACED IN THE END-BEARING COLUMN IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.

 * COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
 * CURVES FOR AXIAL LOADING *

T-Z CURVE NO.	NO. OF POINTS	DEPTH TO CURVE FT.	LOAD TRANSFER PSI	PILE MOVEMENT IN.
1	10	0.4167E-01		
			0.0000E+00	0.0000E+00
			0.0000E+00	0.1920E-01
			0.0000E+00	0.3720E-01
			0.0000E+00	0.6840E-01
			0.0000E+00	0.9600E-01
			0.0000E+00	0.1200E+00
			0.0000E+00	0.2400E+00
			0.0000E+00	0.3600E+00
			0.0000E+00	0.6000E+00
2	10	0.1400E+01	0.0000E+00	0.2400E+01
			0.0000E+00	0.0000E+00
			0.8433E+00	0.1920E-01
			0.1405E+01	0.3720E-01
			0.2108E+01	0.6840E-01
			0.2530E+01	0.9600E-01
			0.2811E+01	0.1200E+00
			0.2530E+01	0.2400E+00
			0.2530E+01	0.3600E+00
			0.2530E+01	0.6000E+00
3	10	0.2758E+01	0.2530E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.2108E+01	0.1920E-01
			0.3514E+01	0.3720E-01
			0.5271E+01	0.6840E-01
			0.6325E+01	0.9600E-01
			0.7027E+01	0.1200E+00
			0.6325E+01	0.2400E+00
			0.6325E+01	0.3600E+00
			0.6325E+01	0.6000E+00
4	10	0.2842E+01	0.6325E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.2108E+01	0.1920E-01
			0.3514E+01	0.3720E-01
			0.5271E+01	0.6840E-01
			0.6325E+01	0.9600E-01
			0.7027E+01	0.1200E+00

			0.7027E+01	0.2400E+00
			0.7027E+01	0.3600E+00
			0.7027E+01	0.6000E+00
			0.7027E+01	0.2400E+01
5	10	0.3550E+01	0.0000E+00	0.0000E+00
			0.1130E+01	0.1920E-01
			0.1883E+01	0.3720E-01
			0.2825E+01	0.6840E-01
			0.3390E+01	0.9600E-01
			0.3767E+01	0.1200E+00
			0.3767E+01	0.2400E+00
			0.3767E+01	0.3600E+00
			0.3767E+01	0.6000E+00
			0.3767E+01	0.2400E+01
6	10	0.4258E+01	0.0000E+00	0.0000E+00
			0.3537E+00	0.1920E-01
			0.5895E+00	0.3720E-01
			0.8843E+00	0.6840E-01
			0.1061E+01	0.9600E-01
			0.1179E+01	0.1200E+00
			0.1179E+01	0.2400E+00
			0.1179E+01	0.3600E+00
			0.1179E+01	0.6000E+00
			0.1179E+01	0.2400E+01
7	10	0.4342E+01	0.0000E+00	0.0000E+00
			0.3615E+00	0.1920E-01
			0.6024E+00	0.3720E-01
			0.9037E+00	0.6840E-01
			0.1084E+01	0.9600E-01
			0.1205E+01	0.1200E+00
			0.1205E+01	0.2400E+00
			0.1205E+01	0.3600E+00
			0.1205E+01	0.6000E+00
			0.1205E+01	0.2400E+01
8	10	0.7050E+01	0.0000E+00	0.0000E+00
			0.6571E+00	0.1920E-01
			0.1095E+01	0.3720E-01
			0.1643E+01	0.6840E-01
			0.1971E+01	0.9600E-01
			0.2190E+01	0.1200E+00
			0.2190E+01	0.2400E+00
			0.2190E+01	0.3600E+00
			0.2190E+01	0.6000E+00
			0.2190E+01	0.2400E+01
9	10	0.9758E+01	0.0000E+00	0.0000E+00
			0.9271E+00	0.1920E-01
			0.1545E+01	0.3720E-01
			0.2318E+01	0.6840E-01
			0.2781E+01	0.9600E-01
			0.3090E+01	0.1200E+00
			0.3090E+01	0.2400E+00
			0.3090E+01	0.3600E+00
			0.3090E+01	0.6000E+00
			0.3090E+01	0.2400E+01
10	10	0.9842E+01	0.0000E+00	0.0000E+00
			0.9354E+00	0.1920E-01
			0.1559E+01	0.3720E-01
			0.2338E+01	0.6840E-01
			0.2806E+01	0.9600E-01
			0.3118E+01	0.1200E+00
			0.3118E+01	0.2400E+00
			0.3118E+01	0.3600E+00
			0.3118E+01	0.6000E+00

11	10	0.1155E+02	0.3118E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.8506E+00	0.1920E-01
			0.1418E+01	0.3720E-01
			0.2126E+01	0.6840E-01
			0.2552E+01	0.9600E-01
			0.2835E+01	0.1200E+00
			0.2835E+01	0.2400E+00
			0.2835E+01	0.3600E+00
			0.2835E+01	0.6000E+00
12	10	0.1326E+02	0.2835E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.9764E+00	0.1920E-01
			0.1627E+01	0.3720E-01
			0.2441E+01	0.6840E-01
			0.2929E+01	0.9600E-01
			0.3255E+01	0.1200E+00
			0.3255E+01	0.2400E+00
			0.3255E+01	0.3600E+00
			0.3255E+01	0.6000E+00
13	10	0.1334E+02	0.3255E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.9825E+00	0.1920E-01
			0.1638E+01	0.3720E-01
			0.2456E+01	0.6840E-01
			0.2948E+01	0.9600E-01
			0.3275E+01	0.1200E+00
			0.3275E+01	0.2400E+00
			0.3275E+01	0.3600E+00
			0.3275E+01	0.6000E+00
14	10	0.1455E+02	0.3275E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1251E+01	0.1920E-01
			0.2085E+01	0.3720E-01
			0.3128E+01	0.6840E-01
			0.3754E+01	0.9600E-01
			0.4171E+01	0.1200E+00
			0.4171E+01	0.2400E+00
			0.4171E+01	0.3600E+00
			0.4171E+01	0.6000E+00
15	10	0.1576E+02	0.4171E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1507E+01	0.1920E-01
			0.2511E+01	0.3720E-01
			0.3767E+01	0.6840E-01
			0.4521E+01	0.9600E-01
			0.5023E+01	0.1200E+00
			0.5023E+01	0.2400E+00
			0.5023E+01	0.3600E+00
			0.5023E+01	0.6000E+00
16	10	0.1584E+02	0.5023E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1515E+01	0.1920E-01
			0.2525E+01	0.3720E-01
			0.3788E+01	0.6840E-01
			0.4546E+01	0.9600E-01
			0.5051E+01	0.1200E+00
			0.4546E+01	0.2400E+00
			0.4546E+01	0.3600E+00
			0.4546E+01	0.6000E+00
17	10	0.1780E+02	0.4546E+01	0.2400E+01
			0.0000E+00	0.0000E+00

18	10	0.1976E+02	0.6250E+01	0.1920E-01
			0.1042E+02	0.3720E-01
			0.1562E+02	0.6840E-01
			0.1875E+02	0.9600E-01
			0.2083E+02	0.1200E+00
			0.1875E+02	0.2400E+00
			0.1875E+02	0.3600E+00
			0.1875E+02	0.6000E+00
			0.1875E+02	0.2400E+01
			0.0000E+00	0.0000E+00
19	10	0.1984E+02	0.6096E+01	0.1920E-01
			0.1016E+02	0.3720E-01
			0.1524E+02	0.6840E-01
			0.1829E+02	0.9600E-01
			0.2032E+02	0.1200E+00
			0.1829E+02	0.2400E+00
			0.1829E+02	0.3600E+00
			0.1829E+02	0.6000E+00
			0.1829E+02	0.2400E+01
			0.0000E+00	0.0000E+00
20	10	0.2205E+02	0.6079E+01	0.1920E-01
			0.1013E+02	0.3720E-01
			0.1520E+02	0.6840E-01
			0.1824E+02	0.9600E-01
			0.2026E+02	0.1200E+00
			0.1824E+02	0.2400E+00
			0.1824E+02	0.3600E+00
			0.1824E+02	0.6000E+00
			0.1824E+02	0.2400E+01
			0.0000E+00	0.0000E+00
21	10	0.2426E+02	0.1008E+02	0.1920E-01
			0.1680E+02	0.3720E-01
			0.2520E+02	0.6840E-01
			0.3023E+02	0.9600E-01
			0.3359E+02	0.1200E+00
			0.3023E+02	0.2400E+00
			0.3023E+02	0.3600E+00
			0.3023E+02	0.6000E+00
			0.3023E+02	0.2400E+01
			0.0000E+00	0.0000E+00
22	10	0.2434E+02	0.9432E+01	0.1920E-01
			0.1572E+02	0.3720E-01
			0.2358E+02	0.6840E-01
			0.2829E+02	0.9600E-01
			0.3144E+02	0.1200E+00
			0.2829E+02	0.2400E+00
			0.2829E+02	0.3600E+00
			0.2829E+02	0.6000E+00
			0.2829E+02	0.2400E+01
			0.0000E+00	0.0000E+00
23	10	0.2930E+02	0.9223E+01	0.1920E-01
			0.1537E+02	0.3720E-01
			0.2306E+02	0.6840E-01
			0.2767E+02	0.9600E-01
			0.3074E+02	0.1200E+00
			0.2767E+02	0.2400E+00
			0.2767E+02	0.3600E+00
			0.2767E+02	0.6000E+00
			0.2767E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3194E+01	0.1920E-01
			0.5324E+01	0.3720E-01
			0.7986E+01	0.6840E-01

24	10	0.3426E+02	0.9583E+01	0.9600E-01
			0.1065E+02	0.1200E+00
			0.9583E+01	0.2400E+00
			0.9583E+01	0.3600E+00
			0.9583E+01	0.6000E+00
			0.9583E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3157E+01	0.1920E-01
			0.5262E+01	0.3720E-01
			0.7893E+01	0.6840E-01
25	10	0.3434E+02	0.9472E+01	0.9600E-01
			0.1052E+02	0.1200E+00
			0.9472E+01	0.2400E+00
			0.9472E+01	0.3600E+00
			0.9472E+01	0.6000E+00
			0.9472E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3145E+01	0.1920E-01
			0.5242E+01	0.3720E-01
			0.7863E+01	0.6840E-01
26	10	0.3655E+02	0.9436E+01	0.9600E-01
			0.1048E+02	0.1200E+00
			0.9436E+01	0.2400E+00
			0.9436E+01	0.3600E+00
			0.9436E+01	0.6000E+00
			0.9436E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3742E+01	0.1920E-01
			0.6237E+01	0.3720E-01
			0.9356E+01	0.6840E-01
27	10	0.3876E+02	0.1123E+02	0.9600E-01
			0.1247E+02	0.1200E+00
			0.1123E+02	0.2400E+00
			0.1123E+02	0.3600E+00
			0.1123E+02	0.6000E+00
			0.1123E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3394E+01	0.1920E-01
			0.5657E+01	0.3720E-01
			0.8486E+01	0.6840E-01
28	10	0.3884E+02	0.1018E+02	0.9600E-01
			0.1131E+02	0.1200E+00
			0.1018E+02	0.2400E+00
			0.1018E+02	0.3600E+00
			0.1018E+02	0.6000E+00
			0.1018E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.3356E+01	0.1920E-01
			0.5593E+01	0.3720E-01
			0.8390E+01	0.6840E-01
29	10	0.4230E+02	0.1007E+02	0.9600E-01
			0.1119E+02	0.1200E+00
			0.1007E+02	0.2400E+00
			0.1007E+02	0.3600E+00
			0.1007E+02	0.6000E+00
			0.1007E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.5616E+01	0.1920E-01
			0.9360E+01	0.3720E-01
			0.1404E+02	0.6840E-01
			0.1685E+02	0.9600E-01
			0.1872E+02	0.1200E+00
			0.1685E+02	0.2400E+00

30	10	0.4576E+02	0.1685E+02	0.3600E+00
			0.1685E+02	0.6000E+00
			0.1685E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.4596E+01	0.1920E-01
			0.7660E+01	0.3720E-01
			0.1149E+02	0.6840E-01
			0.1379E+02	0.9600E-01
			0.1532E+02	0.1200E+00
			0.1379E+02	0.2400E+00
31	10	0.4584E+02	0.1379E+02	0.3600E+00
			0.1379E+02	0.6000E+00
			0.1379E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.4484E+01	0.1920E-01
			0.7473E+01	0.3720E-01
			0.1121E+02	0.6840E-01
			0.1345E+02	0.9600E-01
			0.1495E+02	0.1200E+00
			0.1495E+02	0.2400E+00
32	10	0.5580E+02	0.1495E+02	0.3600E+00
			0.1495E+02	0.6000E+00
			0.1495E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.5569E+01	0.1920E-01
			0.9282E+01	0.3720E-01
			0.1392E+02	0.6840E-01
			0.1671E+02	0.9600E-01
			0.1856E+02	0.1200E+00
			0.1856E+02	0.2400E+00
33	10	0.6576E+02	0.1856E+02	0.3600E+00
			0.1856E+02	0.6000E+00
			0.1856E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.6064E+01	0.1920E-01
			0.1011E+02	0.3720E-01
			0.1516E+02	0.6840E-01
			0.1819E+02	0.9600E-01
			0.2021E+02	0.1200E+00
			0.2021E+02	0.2400E+00
			0.2021E+02	0.3600E+00
			0.2021E+02	0.6000E+00
			0.2021E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.0000E+00	0.0000E+00

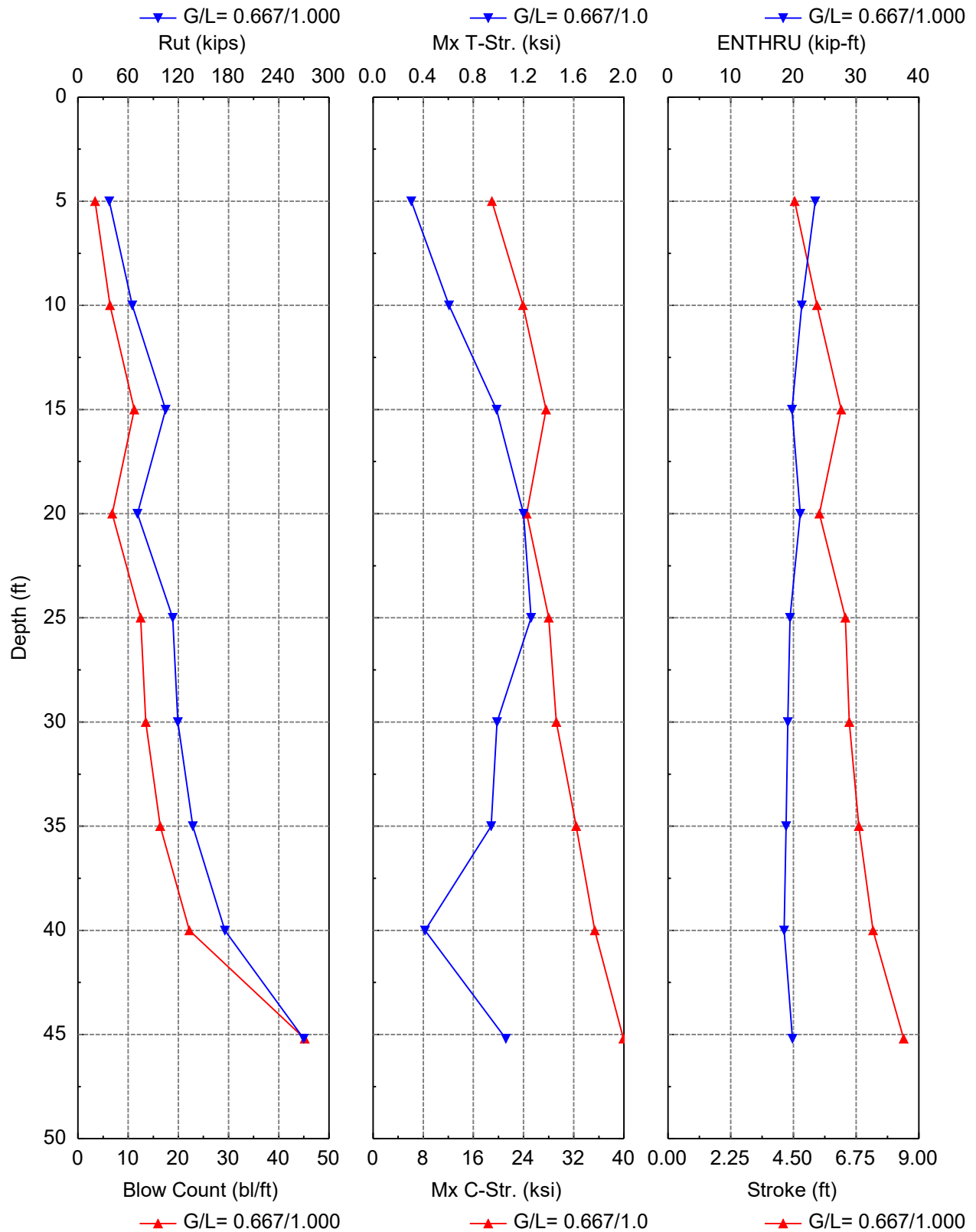
TIP LOAD KIP	TIP MOVEMENT IN.
0.0000E+00	0.0000E+00
0.1845E+02	0.6000E-02
0.3691E+02	0.1200E-01
0.7382E+02	0.2400E-01
0.1476E+03	0.1560E+00
0.2214E+03	0.5040E+00
0.2657E+03	0.8760E+00
0.2953E+03	0.1200E+01
0.2953E+03	0.1800E+01
0.2953E+03	0.2400E+01

LOAD VERSUS SETTLEMENT CURVE

TOP LOAD KIP	TOP MOVEMENT IN.	TIP LOAD KIP	TIP MOVEMENT IN.
0.7863E+01	0.8251E-02	0.3076E+00	0.1000E-03
0.7462E+02	0.8276E-01	0.3076E+01	0.1000E-02
0.2208E+03	0.2954E+00	0.1538E+02	0.5000E-02
0.2873E+03	0.4360E+00	0.3076E+02	0.1000E-01
0.3565E+03	0.6174E+00	0.6151E+02	0.2000E-01
0.4156E+03	0.7982E+00	0.8835E+02	0.5000E-01
0.4441E+03	0.9042E+00	0.1051E+03	0.8000E-01
0.4587E+03	0.9637E+00	0.1163E+03	0.1000E+00
0.5004E+03	0.1176E+01	0.1570E+03	0.2000E+00
0.5641E+03	0.1647E+01	0.2206E+03	0.5000E+00
0.6002E+03	0.2044E+01	0.2567E+03	0.8000E+00
0.6205E+03	0.2299E+01	0.2770E+03	0.1000E+01
0.6387E+03	0.3348E+01	0.2953E+03	0.2000E+01

**REAR ABUTMENT
GRLWEAP ANALYSIS**

Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.667/1.000

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow bl/ft	CtMx ksi	C-StrMx ksi	T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
5.0	37.4	5.3	32.1	3.4	18.956	0.306	4.54	23.5	D 19-42	
10.0	65.1	10.6	54.5	6.4	23.926	0.607	5.34	21.3	D 19-42	
15.0	104.9	17.9	87.0	11.2	27.581	0.986	6.21	19.8	D 19-42	
20.0	71.2	42.8	28.3	6.8	24.494	1.199	5.43	21.1	D 19-42	
25.0	113.4	90.3	23.1	12.5	28.030	1.260	6.36	19.4	D 19-42	
30.0	119.5	108.5	11.0	13.5	29.231	0.988	6.50	19.1	D 19-42	
35.0	137.4	124.5	12.9	16.4	32.379	0.941	6.84	18.8	D 19-42	
40.0	175.8	143.3	32.5	22.2	35.352	0.415	7.36	18.5	D 19-42	
45.2	269.9	172.7	97.2	45.2	39.932	1.059	8.45	19.8	D 19-42	

Total driving time: 13 minutes; Total Number of Blows: 572 (starting at penetration 5.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

Mink Street Bridge Replacement + MinkStr_RABT_12
GANNETT FLEMING, INC.

7/2/2026
GRLWEAP 14.1.20.1

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

The GRLWEAP program simulates the behavior of a preformed pile driven by either an impact hammer or a vibratory hammer. The program is based on mathematical models, which describe motion and forces of hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate, often complex, dynamic situations.

A wave equation analysis generally relies on input data, which represents normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. All of the input data selected by the user may be the best available information at the time when the analysis is performed. However, input data and therefore results may significantly differ from actual field conditions.

Therefore, the program authors recommend prudent use of the GRLWEAP results. Soil response and hammer performance should be verified by static and/or dynamic testing and measurements. Estimates of bending or other local stresses (e.g., helmet or clamp contact, uneven rock surfaces etc.), prestress effects and others must also be accounted for by the user.

The calculated capacity-blow count relationship, i.e. the bearing graph, should be used in conjunction with observed blow counts for the capacity assessment of a driven pile. Soil setup occurring after pile installation may produce bearing capacity values that differ substantially from those expected from a wave equation analysis due to soil setup or relaxation. This is particularly true for pile driven with vibratory hammers. The GRLWEAP user must estimate such effects and should also use proper care when applying blow counts from restrike because of the variability of hammer energy, soil resistance and blow count during early restriking.

Finally, the GRLWEAP capacities are ultimate values. They **MUST** be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of structure and other factors.

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	50.000	Pile Penetration: (ft)	45.200
Pile Size: (ft)	1.00	Toe Area: (in ²)	113.10

Pile Profile

Lb Top ft	X-Area in ²	E-Modulus ksi	Spec. Wt lb/ft ³	Perim. ft	Crit. Index -
0.0	10.3	30,000.0	492.0	3.1	0
50.0	10.3	30,000.0	492.0	3.1	0

HAMMER INPUT

ID	41	Made By:	DELMAG
Model	D 19-42	Type:	OED

Hammer Data

ID	Ram Wt kips	Ram L. in	Ram Ar. in ²	Rtd. Stk ft	Effic. -	Rtd. Energy kip-ft
41	4.000	129.1	124.7	10.8	0.80	43.2

DRIVE SYSTEM FOR DELMAG D 19-42-OED

Type	X-Area in ²	E-Modulus ksi	Thickness in	COR	Round-out in	Stiffness kips/in
-				-		
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.555
Helmet Wt.	1.900	kips				

SOIL RESISTANCE DISTRIBUTION

Depth ft	Unit Rs ksf	Unit Rt ksf	Qs in	Qt in	Js s/ft	Jt s/ft	Set. F. -	Limit D. ft	Set. T. Hours	EB Area in ²
0.0	0.0	5.1	0.10	0.14	0.15	0.15	1.5	6.0	72.0	113.1
1.0	0.0	8.4	0.10	0.14	0.15	0.15	1.5	6.0	72.0	113.1
1.0	0.0	8.4	0.10	0.14	0.15	0.15	1.5	6.0	72.0	113.1
2.0	1.0	11.6	0.10	0.14	0.15	0.15	1.5	6.0	72.0	113.1
2.0	1.0	11.6	0.10	0.14	0.15	0.15	1.5	6.0	72.0	113.1
3.0	1.0	16.3	0.10	0.14	0.15	0.15	1.5	6.0	72.0	113.1
3.0	1.0	16.3	0.10	0.11	0.10	0.15	1.2	6.0	1.0	113.1
4.0	0.2	26.1	0.10	0.11	0.10	0.15	1.2	6.0	1.0	113.1
4.0	0.2	26.1	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
5.0	0.2	40.7	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
5.0	0.2	40.7	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
6.0	0.3	55.8	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1

6.0	0.3	55.8	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
7.0	0.3	68.9	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
7.0	0.3	68.9	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
8.0	0.4	79.6	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
8.0	0.4	79.6	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
9.0	0.4	80.2	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
9.0	0.4	80.2	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
10.0	0.5	69.3	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
10.0	0.5	69.3	0.10	0.13	0.05	0.15	1.0	6.0	1.0	113.1
11.0	0.4	56.2	0.10	0.13	0.05	0.15	1.0	6.0	1.0	113.1
11.0	0.4	56.2	0.10	0.13	0.05	0.15	1.0	6.0	1.0	113.1
12.0	0.4	51.0	0.10	0.13	0.05	0.15	1.0	6.0	1.0	113.1
12.0	0.4	51.0	0.10	0.13	0.05	0.15	1.0	6.0	1.0	113.1
13.0	0.5	68.1	0.10	0.13	0.05	0.15	1.0	6.0	1.0	113.1
13.0	0.5	68.1	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
14.0	0.5	99.4	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
14.0	0.5	99.4	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
15.0	0.7	110.9	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
15.0	0.7	110.9	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
16.0	0.7	87.3	0.10	0.11	0.05	0.15	1.0	6.0	1.0	113.1
16.0	0.7	87.3	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
17.0	3.0	47.8	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
17.0	3.0	47.8	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
18.0	3.0	26.9	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
18.0	3.0	26.9	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
19.0	3.0	30.1	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
19.0	3.0	30.1	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
20.0	2.9	36.1	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
20.0	2.9	36.1	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
21.0	4.8	42.0	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
21.0	4.8	42.0	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
22.0	4.8	44.9	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
22.0	4.8	44.9	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
23.0	4.8	44.9	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
23.0	4.8	44.9	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
24.0	4.8	39.9	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
24.0	4.8	39.9	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
25.0	3.6	29.4	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
25.0	3.6	29.4	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
26.0	1.5	19.2	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
26.0	1.5	19.2	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1

Mink Street Bridge Replacement + MinkStr_RABT_12							GANNETT FLEMING, INC.			
27.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
27.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
28.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
28.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
29.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
29.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
30.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
30.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
31.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
31.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
32.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
32.0	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
33.1	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
33.1	1.5	14.0	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
34.1	1.5	14.9	0.10	0.13	0.15	0.15	1.5	6.0	72.0	113.1
34.1	1.5	14.9	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
35.1	1.5	16.6	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
35.1	1.5	16.6	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
36.1	1.8	18.3	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
36.1	1.8	18.3	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
37.1	1.8	19.1	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
37.1	1.8	19.1	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
38.1	1.8	23.6	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
38.1	1.8	23.6	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
39.0	1.6	32.6	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
39.0	1.6	32.6	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
40.0	2.7	41.6	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
40.0	2.7	41.6	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
41.0	2.7	46.2	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
41.0	2.7	46.2	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
42.0	2.7	46.2	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
42.0	2.7	46.2	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
43.0	2.7	46.2	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
43.0	2.7	46.2	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
44.0	2.7	46.2	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
44.0	2.7	46.2	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
44.9	2.7	97.1	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
44.9	2.7	97.1	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
45.9	2.7	201.1	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1

FORWARD ABUTMENT

FABT
Without Scour

		0.00
Sand ϕ : [30.9, 30.9]		1.60
Clay c_u : [4000, 4000]		4.10
Sand ϕ : [41.5, 41.5]		11.10
Sand ϕ : [42.0, 42.0]		16.10
Clay c_u : [3375, 3375]		21.10
Clay c_u : [6163, 6163]		23.10
Clay c_u : [2000, 2000]	50.00 ft	36.10
Clay c_u : [6934, 6934]		46.10
Sand ϕ : [40.0, 40.0]	50.00	

**FORWARD ABUTMENT
12" PIPE PILE STATIC ANALYSIS**

FABT 12" Pipe Pile

FABT PILE Diam (in) **12**
Ult_No Scour

PILE LENGTH FT.	SKIN FRICTION KIP	END BEARING KIP	ULTIMATE CAPACITY KIP
0	0	0.3	0.3
1	0	5.3	5.3
2	0.1	14.7	14.8
3	6.4	23.8	30.3
4	19	30.8	49.8
5	31.6	38.1	69.7
6	38.3	48.4	86.7
7	39.2	59	98.2
8	40.3	67.9	108.2
9	41.5	76.7	118.2
10	42.9	85.5	128.4
11	44.4	96.2	140.6
12	46.1	109	155.1
13	48	122.4	170.3
14	49.9	134.4	184.3
15	52.1	144.7	196.8
16	54.4	131	185.4
17	56.9	90.7	147.6
18	63.5	47	110.5
19	74.1	23.9	97.9
20	84.7	23.9	108.5
21	95.3	27.1	122.4
22	105.9	33.7	139.6
23	120.9	35.4	156.2
24	137.4	28.9	166.2
25	147.1	19	166.1
26	152.9	14.1	167
27	158.6	14.1	172.7
28	164.4	14.1	178.5
29	170.1	14.1	184.3
30	175.9	14.1	190
31	181.6	14.1	195.8
32	187.4	14.1	201.5
33	193.2	14.1	207.3
34	198.9	14.1	213
35	204.7	14.1	218.8
36	210.4	19.9	230.4
37	215.8	31.6	247.3
38	224	43.2	267.2
39	235.6	49	284.6
40	247.1	49	296.2
41	258.7	49	307.7
42	270.3	49	319.3
43	281.9	49	330.9
44	293.4	49	342.4
45	305	49	354
46	316.6	90.1	406.6
47	327.4	172.1	499.5
48	336.1	254.2	590.3
49	343.6	295.3	638.8
50	351.2	295.3	646.5

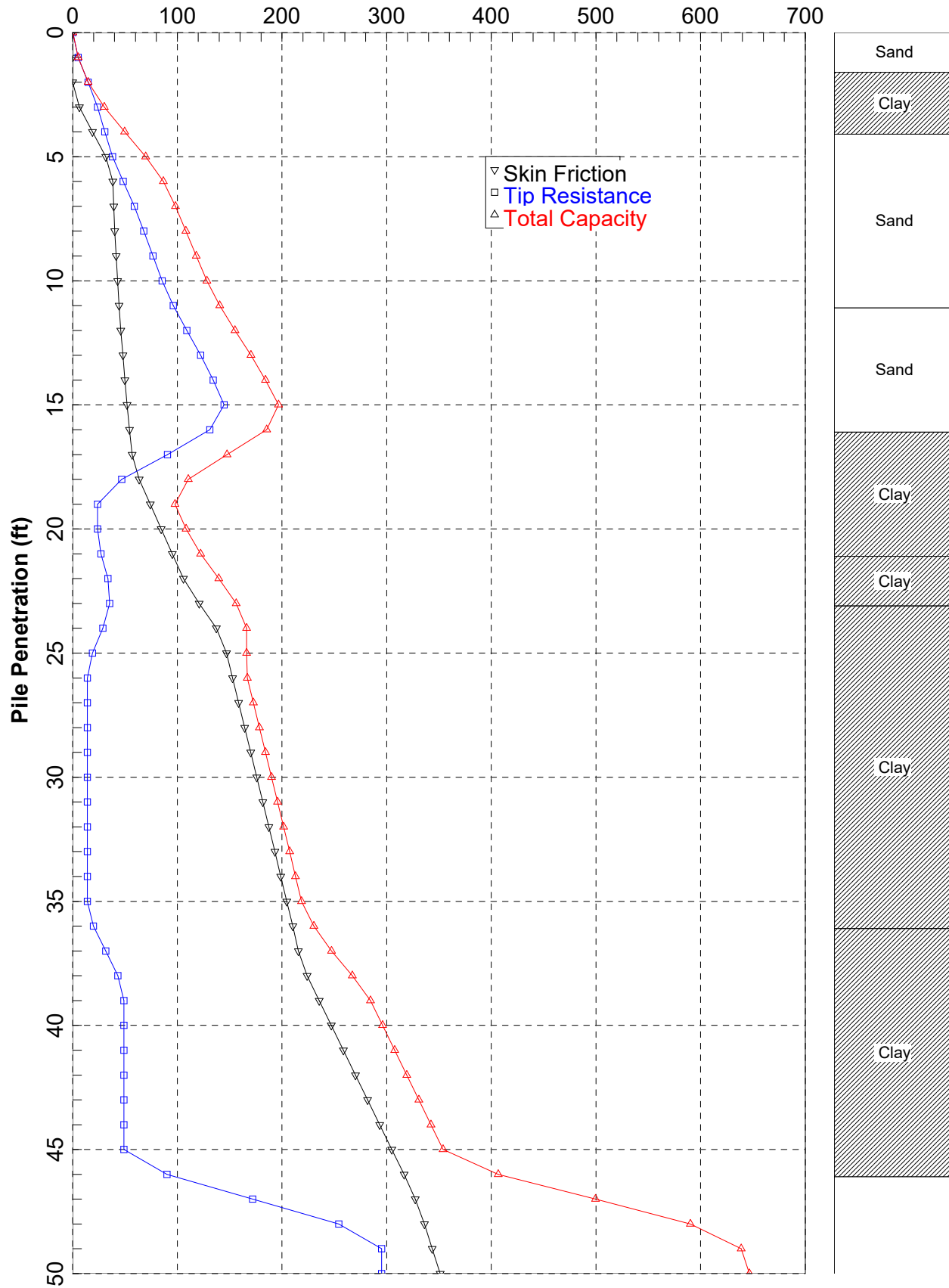
Rn (kip)	305	Length (ft.)	40.8
Rn1	296.2	Length 1	40
Rn2	307.7	Length 2	41
Rs (kip)	256.4	Length (ft.)	40.8
Rs1	247.1	Length 1	40
Rs2	258.7	Length 2	41
Rp (kip)	48.6		

EOID_No Scour

PILE LENGTH FT.	SKIN FRICTION KIP	END BEARING KIP	ULTIMATE CAPACITY KIP
0	0	0.3	0.3
1	0	5.3	5.3
2	0.1	14.7	14.8
3	3.7	23.8	27.5
4	10.8	30.8	41.7
5	23.4	38.1	61.5
6	30.1	48.4	78.5
7	31	59	90.1
8	32.1	67.9	100
9	33.4	76.7	110
10	34.7	85.5	120.2
11	36.3	96.2	132.4
12	38	109	147
13	39.8	122.4	162.2
14	41.8	134.4	176.2
15	43.9	144.7	188.7
16	46.3	131	177.3
17	47.9	90.7	138.7
18	52.3	47	99.3
19	59.4	23.9	83.3
20	66.5	23.9	90.4
21	73.6	27.1	100.8
22	80.7	33.7	114.4
23	90.8	35.4	126.1
24	101.8	28.9	130.7
25	108.3	19	127.4
26	112.2	14.1	126.3
27	116.1	14.1	130.2
28	119.9	14.1	134.1
29	123.8	14.1	137.9
30	127.6	14.1	141.8
31	131.5	14.1	145.6
32	135.3	14.1	149.5
33	139.2	14.1	153.3
34	143.1	14.1	157.2
35	146.9	14.1	161.1
36	150.8	19.9	170.7
37	154.3	31.6	185.9
38	159.9	43.2	203.1
39	167.6	49	216.6
40	175.4	49	224.4
41	183.1	49	232.1
42	190.9	49	239.9
43	198.6	49	247.7
44	206.4	49	255.4
45	214.1	49	263.2
46	221.9	90.1	312
47	228.7	172.1	400.8
48	234.1	254.2	488.3
49	239.1	295.3	534.3
50	244.2	295.3	539.4
51	249.4	295.3	544.7
52	254.7	295.3	550
53	260.2	295.3	555.5
54	265.8	295.3	561
55	271.5	295.3	566.7

UBV (kip)	305	Length (ft.)	46.7
UBV1	263.2	Length 1	45
UBV2	312	Length 2	47
Rssu (kip)	NA	EOID (kip)	NA
		EOID1	224.4
		EOID2	232.1

FABT
12" Ult without Scour
Axial Capacity (kips)



FABT

12" Ult without Scour

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APILE for Windows, Version 2023.10.5

Serial Number : 546958499

A Program for Analyzing the Axial Capacity
and Short-term Settlement of Driven Piles
under Axial Loading.
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Path to file locations : C:\Users\yzimmerman\OneDrive - Gannett Fleming Inc\GF - 078318-Mink Street Bridge
Replacement\5_Working\05_Design_Support\Geotech\APILE\FABT\
Name of input data file : FABT_12ULT_NS.ap10d
Name of output file : FABT_12ULT_NS.ap10o
Name of plot output file : FABT_12ULT_NS.ap10p

Time and Date of Analysis

Date: June 23, 2025 Time: 15:25:52

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* INPUT INFORMATION *

PROJECT DESCRIPTION :
Mink Street BG FABT 12"ULT No Scour
DESIGNER : YLZ
JOB NUMBER : 78318

METHOD FOR UNIT LOAD TRANSFERS :
- FHWA (Federal Highway Administration)
Unfactored Unit Side Friction and Unit Side Resistance are used.

COMPUTATION METHOD(S) FOR PILE CAPACITY :
- FHWA (Federal Highway Administration)

TYPE OF LOADING :
- COMPRESSION

PILE TYPE :
Steel pipe pile or non-tapered portion of monotube pile
- Open-Ended Pile

AVERAGE DEPTH TO ESTIMATE TIP RESISTANCE:
- USE 1.5 DIAMETERS ABOVE AND BELOW TIP

DATA FOR AXIAL STIFFNESS :
- MODULUS OF ELASTICITY = 0.290E+08 PSI
- CROSS SECTION AREA = 9.23 IN²

CIRCULAR PILE PROPERTIES :
- OUTSIDE DIAMETER, OD = 12.00 IN.
- INTERNAL DIAMETER, ID = 11.50 IN.
- TOTAL PILE LENGTH, TL = 50.00 FT.

- BATTER ANGLE = 0.00 DEG
 - PILE STICKUP LENGTH, PSL = 0.00 FT.
 - ZERO FRICTION LENGTH, ZFL = 0.00 FT.
 - INCREMENT OF PILE LENGTH
 USED IN COMPUTATION = 1.00 FT.
 - PRINTING INCREMENT = 1
 - LENGTH OF ENHANCED
 END SECTION = 50.00 FT.
 - INTERNAL DIAMETER OF
 ENHANCED END SECTION = 11.50 IN.

PLUGGED/UNPLUGGED CONDITIONS :
 Plugged for open-ended pile

SOIL INFORMATIONS :

DEPTH FT.	SOIL TYPE	LATERAL EARTH PRESSURE	EFFECTIVE UNIT WEIGHT LB/FT^3	FRICTION ANGLE DEGREES	Nq FACTOR FHWA
0.00	SAND	0.80*	55.60	30.90	34.68**
1.60	SAND	0.80*	55.60	30.90	34.68**
1.60	CLAY	0.80*	65.50	0.00	4.80**
4.10	CLAY	0.80*	65.50	0.00	4.80**
4.10	SAND	0.80*	65.60	41.50	223.00**
11.10	SAND	0.80*	65.60	41.50	223.00**
11.10	SAND	0.80*	69.60	42.00	244.00**
16.10	SAND	0.80*	69.60	42.00	244.00**
16.10	CLAY	0.80*	62.60	0.00	4.80**
21.10	CLAY	0.80*	62.60	0.00	4.80**
21.10	CLAY	0.80*	77.60	0.00	4.80**
23.10	CLAY	0.80*	77.60	0.00	4.80**
23.10	CLAY	0.80*	59.60	0.00	4.80**
36.10	CLAY	0.80*	59.60	0.00	4.80**
36.10	CLAY	0.80*	77.60	0.00	4.80**
46.10	CLAY	0.80*	77.60	0.00	4.80**
46.10	SAND	10000.00	77.60	40.00	160.00**
61.10	SAND	10000.00	77.60	40.00	160.00**

* VALUE ASSUMED BY THE PROGRAM

** VALUE ESTIMATED BY THE PROGRAM BASED ON FRICTION ANGLE

MAXIMUM UNIT FRICTION KSF	MAXIMUM UNIT BEARING KSF	UNDISTURB SHEAR STRENGTH KSF	REMOLDED SHEAR STRENGTH KSF	BLOW COUNT	UNIT SKIN FRICTION KSF	UNIT END BEARING KSF
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	4.00	0.00	-0.00	0.00	0.00
0.10E+08*	0.10E+08*	4.00	0.00	-0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.38	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.38	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	6.16	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	6.16	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	2.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	2.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	6.93	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	6.93	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING
 WERE SET TO LARGE VALUES INDICATING THAT APILE

USES THE LIMITS SPECIFIED BY EACH SELECTED
CRITERIA (IF ANY).

DEPTH FT.	LRFD FACTOR ON UNIT FRICTION	LRFD FACTOR ON UNIT BEARING
0.00	1.000	1.000
1.60	1.000	1.000
1.60	1.000	1.000
4.10	1.000	1.000
4.10	1.000	1.000
11.10	1.000	1.000
11.10	1.000	1.000
16.10	1.000	1.000
16.10	1.000	1.000
21.10	1.000	1.000
21.10	1.000	1.000
23.10	1.000	1.000
23.10	1.000	1.000
36.10	1.000	1.000
36.10	1.000	1.000
46.10	1.000	1.000
46.10	1.000	1.000
61.10	1.000	1.000

DEPTH FT.	Z PEAK IN.	T RESIDUAL
0.00	0.120 *	0.00
1.60	0.120 *	0.00
1.60	0.120 *	0.90 **
4.10	0.120 *	0.90 **
4.10	0.120 *	0.00
11.10	0.120 *	0.00
11.10	0.120 *	0.00
16.10	0.120 *	0.00
16.10	0.120 *	0.90 **
21.10	0.120 *	0.90 **
21.10	0.120 *	0.90 **
23.10	0.120 *	0.90 **
23.10	0.120 *	0.90 **
36.10	0.120 *	0.90 **
36.10	0.120 *	0.90 **
46.10	0.120 *	0.90 **
46.10	0.120 *	0.00
61.10	0.120 *	0.00

* DEFAULT VALUE = 0.01 D

** DEFAULT VALUE = 0.9

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* COMPUTATION RESULT *

* FED. HWY. METHOD *

PILE LENGTH BELOW GND.	SKIN FRICTION	END BEARING	ULTIMATE CAPACITY
FT.	KIP	KIP	KIP
0.00	0.0	0.3	0.3
1.00	0.0	5.3	5.3
2.00	0.1	14.7	14.8
3.00	6.4	23.8	30.3
4.00	19.0	30.8	49.8
5.00	31.6	38.1	69.7
6.00	38.3	48.4	86.7
7.00	39.2	59.0	98.2
8.00	40.3	67.9	108.2
9.00	41.5	76.7	118.2
10.00	42.9	85.5	128.4
11.00	44.4	96.2	140.6
12.00	46.1	109.0	155.1
13.00	48.0	122.4	170.3
14.00	49.9	134.4	184.3
15.00	52.1	144.7	196.8
16.00	54.4	131.0	185.4
17.00	56.9	90.7	147.6
18.00	63.5	47.0	110.5
19.00	74.1	23.9	97.9
20.00	84.7	23.9	108.5
21.00	95.3	27.1	122.4
22.00	105.9	33.7	139.6
23.00	120.9	35.4	156.2
24.00	137.4	28.9	166.2
25.00	147.1	19.0	166.1
26.00	152.9	14.1	167.0
27.00	158.6	14.1	172.7
28.00	164.4	14.1	178.5
29.00	170.1	14.1	184.3
30.00	175.9	14.1	190.0
31.00	181.6	14.1	195.8
32.00	187.4	14.1	201.5
33.00	193.2	14.1	207.3
34.00	198.9	14.1	213.0
35.00	204.7	14.1	218.8
36.00	210.4	19.9	230.4
37.00	215.8	31.6	247.3
38.00	224.0	43.2	267.2
39.00	235.6	49.0	284.6
40.00	247.1	49.0	296.2
41.00	258.7	49.0	307.7
42.00	270.3	49.0	319.3
43.00	281.9	49.0	330.9
44.00	293.4	49.0	342.4
45.00	305.0	49.0	354.0
46.00	316.6	90.1	406.6
47.00	327.4	172.1	499.5
48.00	336.1	254.2	590.3
49.00	343.6	295.3	638.8
50.00	351.2	295.3	646.5

NOTES:

- AN ASTERISK IS PLACED IN THE END-BEARING COLUMN IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.

 * COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
 * CURVES FOR AXIAL LOADING *

T-Z CURVE NO.	NO. OF POINTS	DEPTH TO CURVE FT.	LOAD TRANSFER PSI	PILE MOVEMENT IN.
1	10	0.4167E-01	0.0000E+00	0.0000E+00
			0.1412E-02	0.1920E-01
			0.2354E-02	0.3720E-01
			0.3531E-02	0.6840E-01
			0.4237E-02	0.9600E-01
			0.4708E-02	0.1200E+00
			0.4708E-02	0.2400E+00
			0.4708E-02	0.3600E+00
			0.4708E-02	0.6000E+00
			0.4708E-02	0.2400E+01
2	10	0.8000E+00	0.0000E+00	0.0000E+00
			0.2712E-01	0.1920E-01
			0.4519E-01	0.3720E-01
			0.6779E-01	0.6840E-01
			0.8135E-01	0.9600E-01
			0.9038E-01	0.1200E+00
			0.9038E-01	0.2400E+00
			0.9038E-01	0.3600E+00
			0.9038E-01	0.6000E+00
			0.9038E-01	0.2400E+01
3	10	0.1558E+01	0.0000E+00	0.0000E+00
			0.5282E-01	0.1920E-01
			0.8803E-01	0.3720E-01
			0.1320E+00	0.6840E-01
			0.1585E+00	0.9600E-01
			0.1761E+00	0.1200E+00
			0.1761E+00	0.2400E+00
			0.1761E+00	0.3600E+00
			0.1761E+00	0.6000E+00
			0.1761E+00	0.2400E+01
4	10	0.1642E+01	0.0000E+00	0.0000E+00
			0.5564E-01	0.1920E-01
			0.9274E-01	0.3720E-01
			0.1391E+00	0.6840E-01
			0.1669E+00	0.9600E-01
			0.1855E+00	0.1200E+00
			0.1669E+00	0.2400E+00
			0.1669E+00	0.3600E+00
			0.1669E+00	0.6000E+00
			0.1669E+00	0.2400E+01
5	10	0.2850E+01	0.0000E+00	0.0000E+00
			0.7094E+01	0.1920E-01
			0.1182E+02	0.3720E-01
			0.1773E+02	0.6840E-01
			0.2128E+02	0.9600E-01
			0.2365E+02	0.1200E+00
			0.2128E+02	0.2400E+00
			0.2128E+02	0.3600E+00
			0.2128E+02	0.6000E+00
			0.2128E+02	0.2400E+01
6	10	0.4058E+01	0.0000E+00	0.0000E+00
			0.8333E+01	0.1920E-01
			0.1389E+02	0.3720E-01
			0.2083E+02	0.6840E-01
			0.2500E+02	0.9600E-01
			0.2778E+02	0.1200E+00
			0.2500E+02	0.2400E+00
			0.2500E+02	0.3600E+00
			0.2500E+02	0.6000E+00
			0.2500E+02	0.2400E+01

7	10	0.4142E+01	0.0000E+00 0.8333E+01 0.1389E+02 0.2083E+02 0.2500E+02 0.2778E+02 0.2778E+02 0.2778E+02 0.2778E+02 0.2778E+02	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.2400E+01
8	10	0.7600E+01	0.0000E+00 0.7266E+00 0.1211E+01 0.1817E+01 0.2180E+01 0.2422E+01 0.2422E+01 0.2422E+01 0.2422E+01 0.2422E+01	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.2400E+01
9	10	0.1106E+02	0.0000E+00 0.1071E+01 0.1785E+01 0.2678E+01 0.3214E+01 0.3571E+01 0.3571E+01 0.3571E+01 0.3571E+01 0.3571E+01	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.2400E+01
10	10	0.1114E+02	0.0000E+00 0.1080E+01 0.1799E+01 0.2699E+01 0.3239E+01 0.3599E+01 0.3599E+01 0.3599E+01 0.3599E+01 0.3599E+01	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.2400E+01
11	10	0.1360E+02	0.0000E+00 0.1334E+01 0.2223E+01 0.3335E+01 0.4002E+01 0.4446E+01 0.4446E+01 0.4446E+01 0.4446E+01 0.4446E+01	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.2400E+01
12	10	0.1606E+02	0.0000E+00 0.1594E+01 0.2656E+01 0.3984E+01 0.4781E+01 0.5312E+01 0.5312E+01 0.5312E+01 0.5312E+01 0.5312E+01	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.2400E+01
13	10	0.1614E+02	0.0000E+00 0.1603E+01	0.0000E+00 0.1920E-01

14	10	0.1860E+02	0.2671E+01	0.3720E-01
			0.4006E+01	0.6840E-01
			0.4808E+01	0.9600E-01
			0.5342E+01	0.1200E+00
			0.4808E+01	0.2400E+00
			0.4808E+01	0.3600E+00
			0.4808E+01	0.6000E+00
			0.4808E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7031E+01	0.1920E-01
15	10	0.2106E+02	0.1172E+02	0.3720E-01
			0.1758E+02	0.6840E-01
			0.2109E+02	0.9600E-01
			0.2344E+02	0.1200E+00
			0.2109E+02	0.2400E+00
			0.2109E+02	0.3600E+00
			0.2109E+02	0.6000E+00
			0.2109E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7031E+01	0.1920E-01
16	10	0.2114E+02	0.1172E+02	0.3720E-01
			0.1758E+02	0.6840E-01
			0.2109E+02	0.9600E-01
			0.2344E+02	0.1200E+00
			0.2109E+02	0.2400E+00
			0.2109E+02	0.3600E+00
			0.2109E+02	0.6000E+00
			0.2109E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7031E+01	0.1920E-01
17	10	0.2210E+02	0.1172E+02	0.3720E-01
			0.1758E+02	0.6840E-01
			0.2109E+02	0.9600E-01
			0.2344E+02	0.1200E+00
			0.2109E+02	0.2400E+00
			0.2109E+02	0.3600E+00
			0.2109E+02	0.6000E+00
			0.2109E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7612E+01	0.1920E-01
18	10	0.2306E+02	0.1269E+02	0.3720E-01
			0.1903E+02	0.6840E-01
			0.2284E+02	0.9600E-01
			0.2537E+02	0.1200E+00
			0.2284E+02	0.2400E+00
			0.2284E+02	0.3600E+00
			0.2284E+02	0.6000E+00
			0.2284E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1262E+02	0.1920E-01
19	10	0.2314E+02	0.2103E+02	0.3720E-01
			0.3155E+02	0.6840E-01
			0.3786E+02	0.9600E-01
			0.4207E+02	0.1200E+00
			0.3786E+02	0.2400E+00
			0.3786E+02	0.3600E+00
			0.3786E+02	0.6000E+00
			0.3786E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1231E+02	0.1920E-01
			0.2051E+02	0.3720E-01
			0.3076E+02	0.6840E-01
			0.3692E+02	0.9600E-01

			0.4102E+02	0.1200E+00
			0.3692E+02	0.2400E+00
			0.3692E+02	0.3600E+00
			0.3692E+02	0.6000E+00
			0.3692E+02	0.2400E+01
20	10	0.2960E+02	0.0000E+00	0.0000E+00
			0.3818E+01	0.1920E-01
			0.6363E+01	0.3720E-01
			0.9544E+01	0.6840E-01
			0.1145E+02	0.9600E-01
			0.1273E+02	0.1200E+00
			0.1145E+02	0.2400E+00
			0.1145E+02	0.3600E+00
			0.1145E+02	0.6000E+00
			0.1145E+02	0.2400E+01
21	10	0.3606E+02	0.0000E+00	0.0000E+00
			0.3785E+01	0.1920E-01
			0.6308E+01	0.3720E-01
			0.9462E+01	0.6840E-01
			0.1135E+02	0.9600E-01
			0.1262E+02	0.1200E+00
			0.1135E+02	0.2400E+00
			0.1135E+02	0.3600E+00
			0.1135E+02	0.6000E+00
			0.1135E+02	0.2400E+01
22	10	0.3614E+02	0.0000E+00	0.0000E+00
			0.3738E+01	0.1920E-01
			0.6230E+01	0.3720E-01
			0.9345E+01	0.6840E-01
			0.1121E+02	0.9600E-01
			0.1246E+02	0.1200E+00
			0.1121E+02	0.2400E+00
			0.1121E+02	0.3600E+00
			0.1121E+02	0.6000E+00
			0.1121E+02	0.2400E+01
23	10	0.4110E+02	0.0000E+00	0.0000E+00
			0.7674E+01	0.1920E-01
			0.1279E+02	0.3720E-01
			0.1919E+02	0.6840E-01
			0.2302E+02	0.9600E-01
			0.2558E+02	0.1200E+00
			0.2302E+02	0.2400E+00
			0.2302E+02	0.3600E+00
			0.2302E+02	0.6000E+00
			0.2302E+02	0.2400E+01
24	10	0.4606E+02	0.0000E+00	0.0000E+00
			0.7617E+01	0.1920E-01
			0.1269E+02	0.3720E-01
			0.1904E+02	0.6840E-01
			0.2285E+02	0.9600E-01
			0.2539E+02	0.1200E+00
			0.2285E+02	0.2400E+00
			0.2285E+02	0.3600E+00
			0.2285E+02	0.6000E+00
			0.2285E+02	0.2400E+01
25	10	0.4614E+02	0.0000E+00	0.0000E+00
			0.7535E+01	0.1920E-01
			0.1256E+02	0.3720E-01
			0.1884E+02	0.6840E-01
			0.2260E+02	0.9600E-01
			0.2512E+02	0.1200E+00
			0.2512E+02	0.2400E+00
			0.2512E+02	0.3600E+00

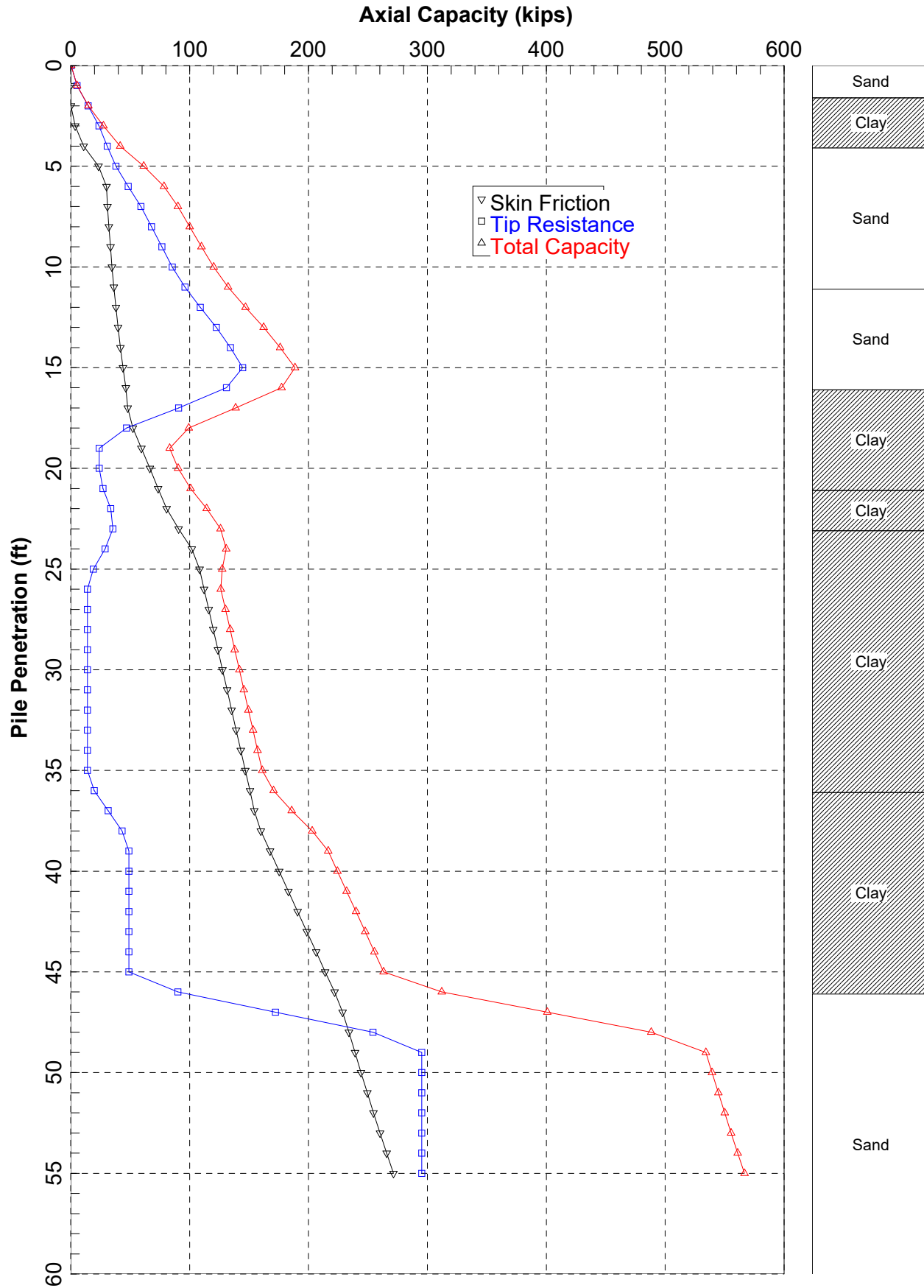
			0.2512E+02	0.6000E+00
			0.2512E+02	0.2400E+01
26	10	0.5360E+02		
			0.0000E+00	0.0000E+00
			0.5112E+01	0.1920E-01
			0.8520E+01	0.3720E-01
			0.1278E+02	0.6840E-01
			0.1534E+02	0.9600E-01
			0.1704E+02	0.1200E+00
			0.1704E+02	0.2400E+00
			0.1704E+02	0.3600E+00
			0.1704E+02	0.6000E+00
			0.1704E+02	0.2400E+01
27	10	0.6106E+02		
			0.0000E+00	0.0000E+00
			0.5112E+01	0.1920E-01
			0.8520E+01	0.3720E-01
			0.1278E+02	0.6840E-01
			0.1534E+02	0.9600E-01
			0.1704E+02	0.1200E+00
			0.1704E+02	0.2400E+00
			0.1704E+02	0.3600E+00
			0.1704E+02	0.6000E+00
			0.1704E+02	0.2400E+01

TIP LOAD KIP	TIP MOVEMENT IN.
0.0000E+00	0.0000E+00
0.1845E+02	0.6000E-02
0.3691E+02	0.1200E-01
0.7382E+02	0.2400E-01
0.1476E+03	0.1560E+00
0.2214E+03	0.5040E+00
0.2657E+03	0.8760E+00
0.2953E+03	0.1200E+01
0.2953E+03	0.1800E+01
0.2953E+03	0.2400E+01

LOAD VERSUS SETTLEMENT CURVE

TOP LOAD KIP	TOP MOVEMENT IN.	TIP LOAD KIP	TIP MOVEMENT IN.
0.6053E+01	0.4870E-02	0.3076E+00	0.1000E-03
0.5927E+02	0.4995E-01	0.3076E+01	0.1000E-02
0.1865E+03	0.2007E+00	0.1538E+02	0.5000E-02
0.2628E+03	0.3263E+00	0.3076E+02	0.1000E-01
0.3377E+03	0.4839E+00	0.6151E+02	0.2000E-01
0.4008E+03	0.6479E+00	0.8835E+02	0.5000E-01
0.4314E+03	0.7449E+00	0.1051E+03	0.8000E-01
0.4447E+03	0.7953E+00	0.1163E+03	0.1000E+00
0.4789E+03	0.9746E+00	0.1570E+03	0.2000E+00
0.5425E+03	0.1417E+01	0.2206E+03	0.5000E+00
0.5786E+03	0.1798E+01	0.2567E+03	0.8000E+00
0.5989E+03	0.2044E+01	0.2770E+03	0.1000E+01
0.6171E+03	0.3084E+01	0.2953E+03	0.2000E+01

FABT 12" Driving without Scour



FABT

12" Driving without Scour

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APILE for Windows, Version 2023.10.5

Serial Number : 546958499

A Program for Analyzing the Axial Capacity
and Short-term Settlement of Driven Piles
under Axial Loading.
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This program is licensed to :

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Path to file locations : C:\Users\yzimmerman\OneDrive - Gannett Fleming Inc\GF - 078318-Mink Street Bridge
Replacement\5_Working\05_Design_Support\Geotech\APILE\FABT\
Name of input data file : FABT_12E0ID_NS.ap10d
Name of output file : FABT_12E0ID_NS.ap10o
Name of plot output file : FABT_12E0ID_NS.ap10p

Time and Date of Analysis

Date: June 23, 2025 Time: 15:38:13

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* INPUT INFORMATION *

PROJECT DESCRIPTION :
Mink Street BG FABT 12"ULT
DESIGNER : YLZ
JOB NUMBER : 78318

METHOD FOR UNIT LOAD TRANSFERS :
- FHWA (Federal Highway Administration)
Unfactored Unit Side Friction and Unit Side Resistance are used.

COMPUTATION METHOD(S) FOR PILE CAPACITY :
- FHWA (Federal Highway Administration)

TYPE OF LOADING :
- COMPRESSION

PILE TYPE :
Steel pipe pile or non-tapered portion of monotube pile
- Open-Ended Pile

AVERAGE DEPTH TO ESTIMATE TIP RESISTANCE:
- USE 1.5 DIAMETERS ABOVE AND BELOW TIP

DATA FOR AXIAL STIFFNESS :
- MODULUS OF ELASTICITY = 0.290E+08 PSI
- CROSS SECTION AREA = 9.23 IN²

CIRCULAR PILE PROPERTIES :
- OUTSIDE DIAMETER, OD = 12.00 IN.
- INTERNAL DIAMETER, ID = 11.50 IN.
- TOTAL PILE LENGTH, TL = 55.00 FT.

- BATTER ANGLE = 0.00 DEG
 - PILE STICKUP LENGTH, PSL = 0.00 FT.
 - ZERO FRICTION LENGTH, ZFL = 0.00 FT.
 - INCREMENT OF PILE LENGTH
 USED IN COMPUTATION = 1.00 FT.
 - PRINTING INCREMENT = 1
 - LENGTH OF ENHANCED
 END SECTION = 55.00 FT.
 - INTERNAL DIAMETER OF
 ENHANCED END SECTION = 11.50 IN.

PLUGGED/UNPLUGGED CONDITIONS :
 Plugged for open-ended pile

SOIL INFORMATIONS :

DEPTH FT.	SOIL TYPE	LATERAL EARTH PRESSURE	EFFECTIVE UNIT WEIGHT LB/FT^3	FRICTION ANGLE DEGREES	Nq FACTOR FHWA
0.00	SAND	0.80*	55.60	30.90	34.68**
1.60	SAND	0.80*	55.60	30.90	34.68**
1.60	CLAY	0.80*	65.50	0.00	4.80**
4.10	CLAY	0.80*	65.50	0.00	4.80**
4.10	SAND	0.80*	65.60	41.50	223.00**
11.10	SAND	0.80*	65.60	41.50	223.00**
11.10	SAND	0.80*	69.60	42.00	244.00**
16.10	SAND	0.80*	69.60	42.00	244.00**
16.10	CLAY	0.80*	62.60	0.00	4.80**
21.10	CLAY	0.80*	62.60	0.00	4.80**
21.10	CLAY	0.80*	77.60	0.00	4.80**
23.10	CLAY	0.80*	77.60	0.00	4.80**
23.10	CLAY	0.80*	59.60	0.00	4.80**
36.10	CLAY	0.80*	59.60	0.00	4.80**
36.10	CLAY	0.80*	77.60	0.00	4.80**
46.10	CLAY	0.80*	77.60	0.00	4.80**
46.10	SAND	10000.00	77.60	40.00	160.00**
61.10	SAND	10000.00	77.60	40.00	160.00**

* VALUE ASSUMED BY THE PROGRAM

** VALUE ESTIMATED BY THE PROGRAM BASED ON FRICTION ANGLE

MAXIMUM UNIT FRICTION KSF	MAXIMUM UNIT BEARING KSF	UNDISTURB SHEAR STRENGTH KSF	REMOLDED SHEAR STRENGTH KSF	BLOW COUNT	UNIT SKIN FRICTION KSF	UNIT END BEARING KSF
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	4.00	0.00	-0.00	0.00	0.00
0.10E+08*	0.10E+08*	4.00	0.00	-0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.38	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	3.38	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	6.16	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	6.16	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	2.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	2.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	6.93	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	6.93	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00
0.10E+08*	0.10E+08*	0.00	0.00	0.00	0.00	0.00

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING
 WERE SET TO LARGE VALUES INDICATING THAT APILE

USES THE LIMITS SPECIFIED BY EACH SELECTED
CRITERIA (IF ANY).

DEPTH FT.	LRFD FACTOR ON UNIT FRICTION	LRFD FACTOR ON UNIT BEARING
0.00	0.830	1.000
1.60	0.830	1.000
1.60	0.570	1.000
4.10	0.570	1.000
4.10	1.000	1.000
11.10	1.000	1.000
11.10	1.000	1.000
16.10	1.000	1.000
16.10	0.670	1.000
21.10	0.670	1.000
21.10	0.670	1.000
23.10	0.670	1.000
23.10	0.670	1.000
36.10	0.670	1.000
36.10	0.670	1.000
46.10	0.670	1.000
46.10	0.670	1.000
61.10	0.670	1.000

DEPTH FT.	Z PEAK IN.	T RESIDUAL
0.00	0.120 *	0.00
1.60	0.120 *	0.00
1.60	0.120 *	0.90 **
4.10	0.120 *	0.90 **
4.10	0.120 *	0.00
11.10	0.120 *	0.00
11.10	0.120 *	0.00
16.10	0.120 *	0.00
16.10	0.120 *	0.90 **
21.10	0.120 *	0.90 **
21.10	0.120 *	0.90 **
23.10	0.120 *	0.90 **
23.10	0.120 *	0.90 **
36.10	0.120 *	0.90 **
36.10	0.120 *	0.90 **
46.10	0.120 *	0.90 **
46.10	0.120 *	0.00
61.10	0.120 *	0.00

* DEFAULT VALUE = 0.01 D

** DEFAULT VALUE = 0.9

1

* COMPUTATION RESULT *

* FED. HWY. METHOD *

PILE LENGTH BELOW GND.	SKIN FRICTION	END BEARING	ULTIMATE CAPACITY
FT.	KIP	KIP	KIP
0.00	0.0	0.3	0.3
1.00	0.0	5.3	5.3
2.00	0.1	14.7	14.8
3.00	3.7	23.8	27.5
4.00	10.8	30.8	41.7
5.00	23.4	38.1	61.5
6.00	30.1	48.4	78.5
7.00	31.0	59.0	90.1
8.00	32.1	67.9	100.0
9.00	33.4	76.7	110.0
10.00	34.7	85.5	120.2
11.00	36.3	96.2	132.4
12.00	38.0	109.0	147.0
13.00	39.8	122.4	162.2
14.00	41.8	134.4	176.2
15.00	43.9	144.7	188.7
16.00	46.3	131.0	177.3
17.00	47.9	90.7	138.7
18.00	52.3	47.0	99.3
19.00	59.4	23.9	83.3
20.00	66.5	23.9	90.4
21.00	73.6	27.1	100.8
22.00	80.7	33.7	114.4
23.00	90.8	35.4	126.1
24.00	101.8	28.9	130.7
25.00	108.3	19.0	127.4
26.00	112.2	14.1	126.3
27.00	116.1	14.1	130.2
28.00	119.9	14.1	134.1
29.00	123.8	14.1	137.9
30.00	127.6	14.1	141.8
31.00	131.5	14.1	145.6
32.00	135.3	14.1	149.5
33.00	139.2	14.1	153.3
34.00	143.1	14.1	157.2
35.00	146.9	14.1	161.1
36.00	150.8	19.9	170.7
37.00	154.3	31.6	185.9
38.00	159.9	43.2	203.1
39.00	167.6	49.0	216.6
40.00	175.4	49.0	224.4
41.00	183.1	49.0	232.1
42.00	190.9	49.0	239.9
43.00	198.6	49.0	247.7
44.00	206.4	49.0	255.4
45.00	214.1	49.0	263.2
46.00	221.9	90.1	312.0
47.00	228.7	172.1	400.8
48.00	234.1	254.2	488.3
49.00	239.1	295.3	534.3
50.00	244.2	295.3	539.4
51.00	249.4	295.3	544.7
52.00	254.7	295.3	550.0
53.00	260.2	295.3	555.5
54.00	265.8	295.3	561.0
55.00	271.5	295.3	566.7

NOTES:

- AN ASTERISK IS PLACED IN THE END-BEARING COLUMN IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.

* COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
 * CURVES FOR AXIAL LOADING *

T-Z CURVE NO.	NO. OF POINTS	DEPTH TO CURVE FT.	LOAD TRANSFER PSI	PILE MOVEMENT IN.
1	10	0.4167E-01	0.0000E+00 0.1412E-02 0.2354E-02 0.3531E-02 0.4237E-02 0.4708E-02 0.4708E-02 0.4708E-02 0.4708E-02 0.4708E-02 0.4708E-02	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.6000E+00 0.2400E+01
2	10	0.8000E+00	0.0000E+00 0.2712E-01 0.4519E-01 0.6779E-01 0.8135E-01 0.9038E-01 0.9038E-01 0.9038E-01 0.9038E-01 0.9038E-01 0.9038E-01	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.6000E+00 0.2400E+01
3	10	0.1558E+01	0.0000E+00 0.5282E-01 0.8803E-01 0.1320E+00 0.1585E+00 0.1761E+00 0.1761E+00 0.1761E+00 0.1761E+00 0.1761E+00 0.1761E+00	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.6000E+00 0.2400E+01
4	10	0.1642E+01	0.0000E+00 0.5564E-01 0.9274E-01 0.1391E+00 0.1669E+00 0.1855E+00 0.1669E+00 0.1669E+00 0.1669E+00 0.1669E+00 0.1669E+00	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.6000E+00 0.2400E+01
5	10	0.2850E+01	0.0000E+00 0.7094E+01 0.1182E+02 0.1773E+02 0.2128E+02 0.2365E+02 0.2128E+02 0.2128E+02 0.2128E+02 0.2128E+02 0.2128E+02	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01 0.1200E+00 0.2400E+00 0.3600E+00 0.6000E+00 0.6000E+00 0.2400E+01
6	10	0.4058E+01	0.0000E+00 0.8333E+01 0.1389E+02 0.2083E+02 0.2500E+02	0.0000E+00 0.1920E-01 0.3720E-01 0.6840E-01 0.9600E-01

7	10	0.4142E+01	0.2778E+02	0.1200E+00
			0.2500E+02	0.2400E+00
			0.2500E+02	0.3600E+00
			0.2500E+02	0.6000E+00
			0.2500E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.8333E+01	0.1920E-01
			0.1389E+02	0.3720E-01
			0.2083E+02	0.6840E-01
			0.2500E+02	0.9600E-01
8	10	0.7600E+01	0.2778E+02	0.1200E+00
			0.2778E+02	0.2400E+00
			0.2778E+02	0.3600E+00
			0.2778E+02	0.6000E+00
			0.2778E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7266E+00	0.1920E-01
			0.1211E+01	0.3720E-01
			0.1817E+01	0.6840E-01
			0.2180E+01	0.9600E-01
9	10	0.1106E+02	0.2422E+01	0.1200E+00
			0.2422E+01	0.2400E+00
			0.2422E+01	0.3600E+00
			0.2422E+01	0.6000E+00
			0.2422E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1071E+01	0.1920E-01
			0.1785E+01	0.3720E-01
			0.2678E+01	0.6840E-01
			0.3214E+01	0.9600E-01
10	10	0.1114E+02	0.3571E+01	0.1200E+00
			0.3571E+01	0.2400E+00
			0.3571E+01	0.3600E+00
			0.3571E+01	0.6000E+00
			0.3571E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1080E+01	0.1920E-01
			0.1799E+01	0.3720E-01
			0.2699E+01	0.6840E-01
			0.3239E+01	0.9600E-01
11	10	0.1360E+02	0.3599E+01	0.1200E+00
			0.3599E+01	0.2400E+00
			0.3599E+01	0.3600E+00
			0.3599E+01	0.6000E+00
			0.3599E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1334E+01	0.1920E-01
			0.2223E+01	0.3720E-01
			0.3335E+01	0.6840E-01
			0.4002E+01	0.9600E-01
12	10	0.1606E+02	0.4446E+01	0.1200E+00
			0.4446E+01	0.2400E+00
			0.4446E+01	0.3600E+00
			0.4446E+01	0.6000E+00
			0.4446E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1594E+01	0.1920E-01
			0.2656E+01	0.3720E-01
			0.3984E+01	0.6840E-01
			0.4781E+01	0.9600E-01
			0.5312E+01	0.1200E+00
			0.5312E+01	0.2400E+00
			0.5312E+01	0.3600E+00
			0.5312E+01	0.3600E+00

13	10	0.1614E+02	0.5312E+01	0.6000E+00
			0.5312E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1603E+01	0.1920E-01
			0.2671E+01	0.3720E-01
			0.4006E+01	0.6840E-01
			0.4808E+01	0.9600E-01
			0.5342E+01	0.1200E+00
			0.4808E+01	0.2400E+00
			0.4808E+01	0.3600E+00
14	10	0.1860E+02	0.4808E+01	0.6000E+00
			0.4808E+01	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7031E+01	0.1920E-01
			0.1172E+02	0.3720E-01
			0.1758E+02	0.6840E-01
			0.2109E+02	0.9600E-01
			0.2344E+02	0.1200E+00
			0.2109E+02	0.2400E+00
			0.2109E+02	0.3600E+00
15	10	0.2106E+02	0.2109E+02	0.6000E+00
			0.2109E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7031E+01	0.1920E-01
			0.1172E+02	0.3720E-01
			0.1758E+02	0.6840E-01
			0.2109E+02	0.9600E-01
			0.2344E+02	0.1200E+00
			0.2109E+02	0.2400E+00
			0.2109E+02	0.3600E+00
16	10	0.2114E+02	0.2109E+02	0.6000E+00
			0.2109E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7031E+01	0.1920E-01
			0.1172E+02	0.3720E-01
			0.1758E+02	0.6840E-01
			0.2109E+02	0.9600E-01
			0.2344E+02	0.1200E+00
			0.2109E+02	0.2400E+00
			0.2109E+02	0.3600E+00
17	10	0.2210E+02	0.2109E+02	0.6000E+00
			0.2109E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7612E+01	0.1920E-01
			0.1269E+02	0.3720E-01
			0.1903E+02	0.6840E-01
			0.2284E+02	0.9600E-01
			0.2537E+02	0.1200E+00
			0.2284E+02	0.2400E+00
			0.2284E+02	0.3600E+00
18	10	0.2306E+02	0.2284E+02	0.6000E+00
			0.2284E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.1262E+02	0.1920E-01
			0.2103E+02	0.3720E-01
			0.3155E+02	0.6840E-01
			0.3786E+02	0.9600E-01
			0.4207E+02	0.1200E+00
			0.3786E+02	0.2400E+00
			0.3786E+02	0.3600E+00
19	10	0.2314E+02	0.3786E+02	0.6000E+00
			0.3786E+02	0.2400E+01
			0.3786E+02	0.3600E+00

20	10	0.2960E+02	0.0000E+00	0.0000E+00
			0.1231E+02	0.1920E-01
			0.2051E+02	0.3720E-01
			0.3076E+02	0.6840E-01
			0.3692E+02	0.9600E-01
			0.4102E+02	0.1200E+00
			0.3692E+02	0.2400E+00
			0.3692E+02	0.3600E+00
			0.3692E+02	0.6000E+00
			0.3692E+02	0.2400E+01
21	10	0.3606E+02	0.0000E+00	0.0000E+00
			0.3818E+01	0.1920E-01
			0.6363E+01	0.3720E-01
			0.9544E+01	0.6840E-01
			0.1145E+02	0.9600E-01
			0.1273E+02	0.1200E+00
			0.1145E+02	0.2400E+00
			0.1145E+02	0.3600E+00
			0.1145E+02	0.6000E+00
			0.1145E+02	0.2400E+01
22	10	0.3614E+02	0.0000E+00	0.0000E+00
			0.3785E+01	0.1920E-01
			0.6308E+01	0.3720E-01
			0.9462E+01	0.6840E-01
			0.1135E+02	0.9600E-01
			0.1262E+02	0.1200E+00
			0.1135E+02	0.2400E+00
			0.1135E+02	0.3600E+00
			0.1135E+02	0.6000E+00
			0.1135E+02	0.2400E+01
23	10	0.4110E+02	0.0000E+00	0.0000E+00
			0.3738E+01	0.1920E-01
			0.6230E+01	0.3720E-01
			0.9345E+01	0.6840E-01
			0.1121E+02	0.9600E-01
			0.1246E+02	0.1200E+00
			0.1121E+02	0.2400E+00
			0.1121E+02	0.3600E+00
			0.1121E+02	0.6000E+00
			0.1121E+02	0.2400E+01
24	10	0.4606E+02	0.0000E+00	0.0000E+00
			0.7674E+01	0.1920E-01
			0.1279E+02	0.3720E-01
			0.1919E+02	0.6840E-01
			0.2302E+02	0.9600E-01
			0.2558E+02	0.1200E+00
			0.2302E+02	0.2400E+00
			0.2302E+02	0.3600E+00
			0.2302E+02	0.6000E+00
			0.2302E+02	0.2400E+01
25	10	0.4614E+02	0.0000E+00	0.0000E+00
			0.7564E+01	0.1920E-01
			0.1261E+02	0.3720E-01
			0.1891E+02	0.6840E-01
			0.2269E+02	0.9600E-01
			0.2521E+02	0.1200E+00
			0.2269E+02	0.2400E+00
			0.2269E+02	0.3600E+00
			0.2269E+02	0.6000E+00
			0.2269E+02	0.2400E+01
			0.0000E+00	0.0000E+00
			0.7406E+01	0.1920E-01
			0.1234E+02	0.3720E-01

			0.1851E+02	0.6840E-01
			0.2222E+02	0.9600E-01
			0.2469E+02	0.1200E+00
			0.2469E+02	0.2400E+00
			0.2469E+02	0.3600E+00
			0.2469E+02	0.6000E+00
			0.2469E+02	0.2400E+01
26	10	0.5360E+02		
			0.0000E+00	0.0000E+00
			0.5536E+01	0.1920E-01
			0.9227E+01	0.3720E-01
			0.1384E+02	0.6840E-01
			0.1661E+02	0.9600E-01
			0.1845E+02	0.1200E+00
			0.1845E+02	0.2400E+00
			0.1845E+02	0.3600E+00
			0.1845E+02	0.6000E+00
			0.1845E+02	0.2400E+01
27	10	0.6106E+02		
			0.0000E+00	0.0000E+00
			0.5701E+01	0.1920E-01
			0.9502E+01	0.3720E-01
			0.1425E+02	0.6840E-01
			0.1710E+02	0.9600E-01
			0.1900E+02	0.1200E+00
			0.1900E+02	0.2400E+00
			0.1900E+02	0.3600E+00
			0.1900E+02	0.6000E+00
			0.1900E+02	0.2400E+01

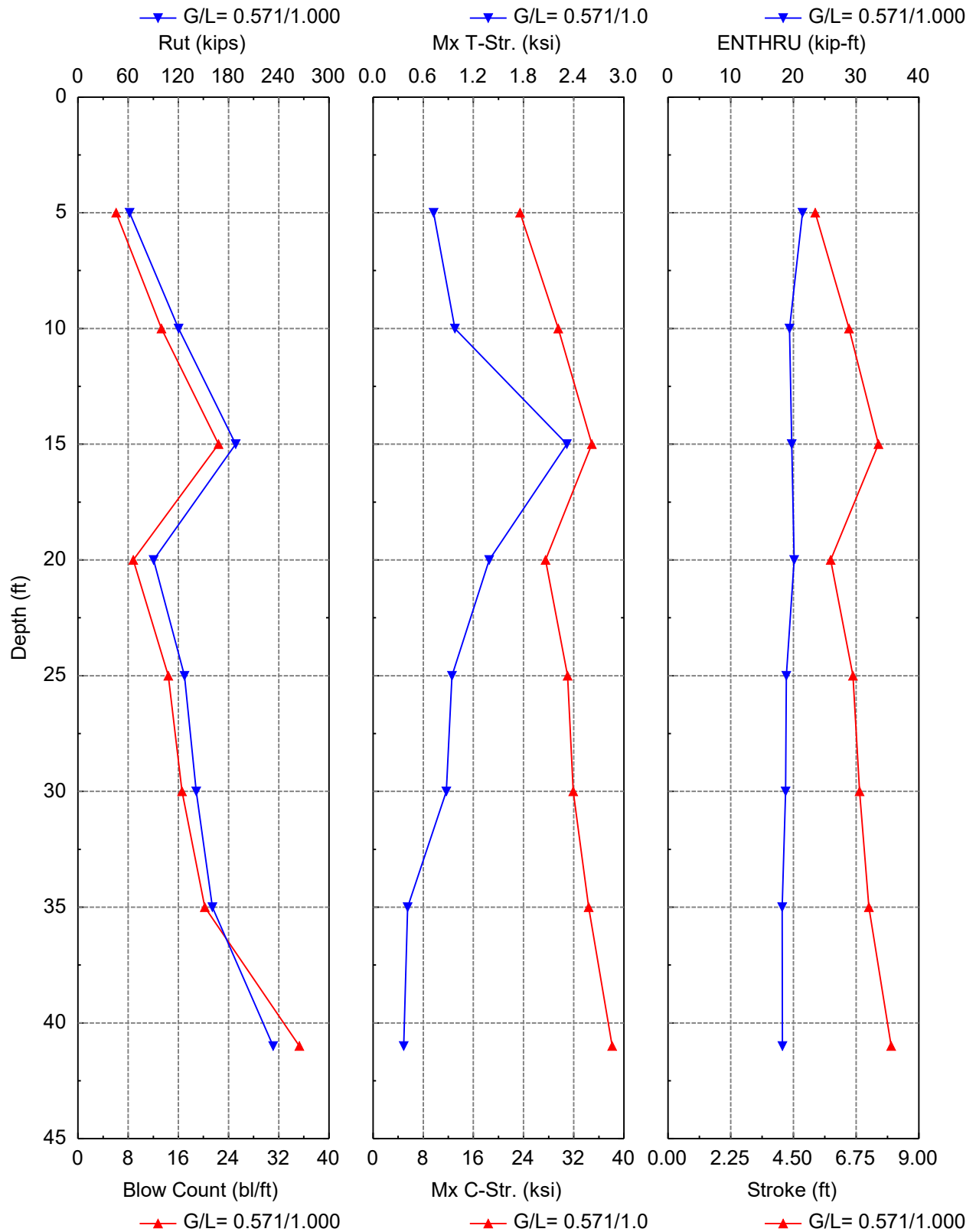
TIP LOAD KIP	TIP MOVEMENT IN.
0.0000E+00	0.0000E+00
0.1845E+02	0.6000E-02
0.3691E+02	0.1200E-01
0.7382E+02	0.2400E-01
0.1476E+03	0.1560E+00
0.2214E+03	0.5040E+00
0.2657E+03	0.8760E+00
0.2953E+03	0.1200E+01
0.2953E+03	0.1800E+01
0.2953E+03	0.2400E+01

LOAD VERSUS SETTLEMENT CURVE

TOP LOAD KIP	TOP MOVEMENT IN.	TIP LOAD KIP	TIP MOVEMENT IN.
0.8851E+01	0.7085E-02	0.3076E+00	0.1000E-03
0.8130E+02	0.7135E-01	0.3076E+01	0.1000E-02
0.2257E+03	0.2634E+00	0.1538E+02	0.5000E-02
0.3007E+03	0.4032E+00	0.3076E+02	0.1000E-01
0.3751E+03	0.5788E+00	0.6151E+02	0.2000E-01
0.4399E+03	0.7572E+00	0.8835E+02	0.5000E-01
0.4671E+03	0.8539E+00	0.1051E+03	0.8000E-01
0.4798E+03	0.9063E+00	0.1163E+03	0.1000E+00
0.5182E+03	0.1103E+01	0.1570E+03	0.2000E+00
0.5819E+03	0.1560E+01	0.2206E+03	0.5000E+00
0.6180E+03	0.1949E+01	0.2567E+03	0.8000E+00
0.6383E+03	0.2199E+01	0.2770E+03	0.1000E+01
0.6565E+03	0.3244E+01	0.2953E+03	0.2000E+01

**FORWARD ABUTMENT
GRLWEAP ANALYSIS**

Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.571/1.000

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Blow CtMx bl/ft	C-StrMx ksi	T-Str. ksi	Stroke ft	ENTHRU kip-ft	Hammer -
5.0	61.7	23.5	38.2	6.1	23.452	0.724	5.28	21.4	D 19-42
10.0	120.2	34.8	85.4	13.3	29.538	0.978	6.49	19.4	D 19-42
15.0	188.6	44.0	144.6	22.4	34.896	2.317	7.54	19.7	D 19-42
20.0	90.5	66.5	23.9	8.8	27.506	1.389	5.83	20.1	D 19-42
25.0	127.2	108.2	19.0	14.4	31.032	0.945	6.63	18.9	D 19-42
30.0	141.5	127.4	14.1	16.6	31.909	0.877	6.87	18.8	D 19-42
35.0	160.6	146.5	14.1	20.2	34.366	0.413	7.21	18.2	D 19-42
41.0	233.4	184.3	49.0	35.3	38.123	0.366	8.00	18.2	D 19-42

Total driving time: 14 minutes; Total Number of Blows: 609 (starting at penetration 5.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

Mink Street Bridge Replacement + MinkStr_FABT_12
GANNETT FLEMING, INC.

7/2/2026
GRLWEAP 14.1.20.1

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

The GRLWEAP program simulates the behavior of a preformed pile driven by either an impact hammer or a vibratory hammer. The program is based on mathematical models, which describe motion and forces of hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate, often complex, dynamic situations.

A wave equation analysis generally relies on input data, which represents normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. All of the input data selected by the user may be the best available information at the time when the analysis is performed. However, input data and therefore results may significantly differ from actual field conditions.

Therefore, the program authors recommend prudent use of the GRLWEAP results. Soil response and hammer performance should be verified by static and/or dynamic testing and measurements. Estimates of bending or other local stresses (e.g., helmet or clamp contact, uneven rock surfaces etc.), prestress effects and others must also be accounted for by the user.

The calculated capacity-blow count relationship, i.e. the bearing graph, should be used in conjunction with observed blow counts for the capacity assessment of a driven pile. Soil setup occurring after pile installation may produce bearing capacity values that differ substantially from those expected from a wave equation analysis due to soil setup or relaxation. This is particularly true for pile driven with vibratory hammers. The GRLWEAP user must estimate such effects and should also use proper care when applying blow counts from restrike because of the variability of hammer energy, soil resistance and blow count during early restriking.

Finally, the GRLWEAP capacities are ultimate values. They **MUST** be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of structure and other factors.

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	45.000	Pile Penetration: (ft)	41.000
Pile Size: (ft)	1.00	Toe Area: (in ²)	113.10

Pile Profile

Lb Top ft	X-Area in ²	E-Modulus ksi	Spec. Wt lb/ft ³	Perim. ft	Crit. Index -
0.0	10.3	30,000.0	492.0	3.1	0
45.0	10.3	30,000.0	492.0	3.1	0

HAMMER INPUT

ID	41	Made By:	DELMAG
Model	D 19-42	Type:	OED

Hammer Data

ID	Ram Wt kips	Ram L. in	Ram Ar. in ²	Rtd. Stk ft	Effic. -	Rtd. Energy kip-ft
41	4.000	129.1	124.7	10.8	0.80	43.2

DRIVE SYSTEM FOR DELMAG D 19-42-OED

Type	X-Area in ²	E-Modulus ksi	Thickness in	COR	Round-out in	Stiffness kips/in
-				-		
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.555
Helmet Wt.	1.900	kips				

SOIL RESISTANCE DISTRIBUTION

Depth ft	Unit Rs ksf	Unit Rt ksf	Qs in	Qt in	Js s/ft	Jt s/ft	Set. F. -	Limit D. ft	Set. T. Hours	EB Area in ²
0.0	0.0	0.4	0.10	0.20	0.10	0.15	1.2	6.0	1.0	113.1
1.0	0.0	6.7	0.10	0.20	0.10	0.15	1.2	6.0	1.0	113.1
1.0	0.0	6.7	0.10	0.20	0.10	0.15	1.2	6.0	1.0	113.1
2.0	0.0	18.7	0.10	0.20	0.10	0.15	1.2	6.0	1.0	113.1
2.0	0.0	18.7	0.10	0.10	0.20	0.15	1.8	6.0	168.0	113.1
3.0	4.0	30.3	0.10	0.10	0.20	0.15	1.8	6.0	168.0	113.1
3.0	4.0	30.3	0.10	0.10	0.20	0.15	1.8	6.0	168.0	113.1
4.0	4.0	39.3	0.10	0.10	0.20	0.15	1.8	6.0	168.0	113.1
4.0	4.0	39.3	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
5.0	4.0	48.5	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
5.0	4.0	48.5	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
6.0	0.3	61.6	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1

6.0	0.3	61.6	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
7.0	0.3	75.2	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
7.0	0.3	75.2	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
8.0	0.4	86.5	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
8.0	0.4	86.5	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
9.0	0.4	97.7	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
9.0	0.4	97.7	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
10.0	0.5	108.8	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
10.0	0.5	108.8	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
11.0	0.5	122.4	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
11.0	0.5	122.4	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
12.0	0.6	138.7	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
12.0	0.6	138.7	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
13.0	0.6	155.8	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
13.0	0.6	155.8	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
14.0	0.7	171.1	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
14.0	0.7	171.1	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
15.0	0.7	184.2	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
15.0	0.7	184.2	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
16.0	0.8	166.9	0.10	0.10	0.05	0.15	1.0	6.0	1.0	113.1
16.0	0.8	166.9	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
17.0	0.8	115.5	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
17.0	0.8	115.5	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
18.0	3.4	59.9	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
18.0	3.4	59.9	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
19.0	3.4	30.5	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
19.0	3.4	30.5	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
20.0	3.4	30.5	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
20.0	3.4	30.5	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
21.0	3.4	34.5	0.10	0.11	0.15	0.15	1.5	6.0	72.0	113.1
21.0	3.4	34.5	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
22.0	3.4	42.8	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
22.0	3.4	42.8	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
23.0	6.2	45.1	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
23.0	6.2	45.1	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
24.0	4.3	36.8	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
24.0	4.3	36.8	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
25.0	1.8	24.2	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
25.0	1.8	24.2	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
26.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
26.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1

27.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
27.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
28.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
28.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
29.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
29.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
30.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
30.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
31.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
31.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
32.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
32.0	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
33.1	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
33.1	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
34.1	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
34.1	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
35.1	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
35.1	1.8	18.0	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
36.1	1.8	25.3	0.10	0.12	0.15	0.15	1.5	6.0	72.0	113.1
36.1	1.8	25.3	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
37.1	1.6	40.3	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
37.1	1.6	40.3	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
38.1	3.9	54.9	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
38.1	3.9	54.9	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
39.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
39.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
40.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
40.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
41.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
41.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
42.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
42.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
43.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
43.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1
44.0	3.9	62.4	0.10	0.10	0.15	0.15	1.5	6.0	72.0	113.1

SOIL PARAMETER CALCULATION

Objective:

The purpose of these calculations is to determine the subsurface soil strata based on project boring logs to provide geotechnical design parameters to develop subsurface profile for Mink Street Bridge Replacement

Source of Data:

2024 Project Boring Logs

Assumptions:

1. The subsurface profiles were developed for bridge subsurface profile;
2. The moisture unit weight of each soil stratum is developed according to the density of soil (N60 value) per Table 400-4 of ODOT Geotechnical Design Manual;
3. The saturated unit weight of soil is assumed to be the moist unit weight of soil plus 10 pcf; the unit weight of water is assumed to be 62.4 pcf;
4. When refusal encountered, an approximate N60 number has been assumed for calculation purpose;
5. All the data highlighted in yellow is possible outlier and neglected from calculation.

References:

1. GEOTECH CIRCULAR No. 5 Evaluation of Soil & Rock Properties: FHWA-IF-02-034, Ohio Department of Transportation, GeoSyntec Consultants, April 2002.
2. AASHTO LRFD bridge design manual 9th edition, 2020
3. Ohio Department of Transportation Geotechnical Design Manual

**Definition of parameters:****Soil Page** :**Depth** Depth of top of the Spoon**Sample Interval** Length between the bottoms of last spoon and this spoon **γ** Moist weight of soil sample
obtained based on blow count N_{60} according to Table 1 ref. 1 **γ'** Effective unit weight of soil sample
obtained based on γ and water table and strata depths **N_{60}** N_{60} is the SPT N-value corrected for field procedures and apparatus
 $N_{60} = \text{blow counts} \times \text{energy ratio} / 60\% = (ER/60\%)N$ **σ'_v** Vertical effective stress at the location of the SPT N-value (KSF) **C_N** $C_N = [0.77 \log_{10} (40/\sigma'_v)]$, $C_N < 2.0$ **$N1_{60}$** $N1_{60} = C_N \times (N_{60})$ **CLASF.** AASHTO Soil Classification (ODOT)**HP** Hand penetrometer readings **ϕ'** Drained friction angle developed based on AASHTO LRFD Table 10.4.6.2.4-1 with
adjustment according to GDM Table 400-3; **S_u** Undrained shear strength from GDM 404.1 **C'** Drained cohesion for overall stability tests based on GDM 404.1**PI** Plastic Index **W_a** Moisture content **ϕ'_{PI}** Drained friction angle based on PI (Terzaghi, Peck, and Mesri, 1996, See Fig. 74 Ref. 2)

Boring ID: B-001-0-24
Ground Elevation 1041
Ground Water Depth (ft.)= 8

Hammer Energy Ratio = 0.768
BTF elv= 1031.8
Ground Water Elevation: = 1033

Depth (Top of Spoon)	Elevation (Top of Spoon)	Smpl. Depth	Depth (Bottom of Spoon)	effect. Unit Wght. γ'	N_2	N_3	N_{60}	Middle-spoon σ'_v	C_N	N_{160}	CLAS.	Cohesive or Granular	H.P.	PI	f_1	S_u	AASHTO ϕ'	AREMA ϕ'	APILE reduction factor
(ft.)	(ft.)	(ft.)	(ft.)	(ksf.)	(dim.)	(dim.)	(dim.)	(ksf.)	(ksf.)	(dim.)		(psf.)	(tsf.)	(%)		(psf.)	(deg.)	(deg.)	
2.5	1038.5	1.5	4.0	0.109	4	4	10	0.354	1.58062	16	A-7-5	C	0.75	155.0	3.60	1250			0.57
5	1036.0	1.5	6.5	0.108	4	3	9	0.621	1.39291	13	A-7-5	C	1		5.30	1125			0.57
7.5	1033.5	1.5	9.0	0.056	3	2	6	0.464	1.49022	9	A-2-4	G			5.70		32.5	28.7	0.83
10	1031.0	1.5	11.5	0.056	2	5	9	0.598	1.40569	13	A-4a	C	1.75	9.0	5.59	1125			0.67
12	1029.0	1.5	13.5	0.064	10	13	29	0.817	1.30106	38	A-2-4	G		7.0	5.61		39.2	20.5	0.83
13.5	1027.5	1.5	15.0	0.066	13	14	35	0.938	1.25511	44	A-1-b	G			5.70		41.1	35.0	1
15	1026.0	1.5	16.5	0.066	15	15	38	1.046	1.21861	46	A-1-b	G			5.70		41.4	35.6	1
17.5	1023.5	1.5	19.0	0.066	16	14	38	1.212	1.16934	44	A-1-b	G			5.70		41.1	35.6	1
20	1021.0	1.5	21.5	0.061	10	6	20	1.274	1.15259	23	A-1-b	G			5.70		37.3	32.0	1
22.5	1018.5	1.5	24.0	0.067	14	17	40	1.553	1.08636	43	A-1-b	G			5.70		41.0	36.0	1
25	1016.0	1.5	26.5	0.061	9	10	24	1.583	1.07999	26	A-4a	C	4	10.0	5.57	3000			0.67
30	1011.0	1.5	31.5	0.068	16	15	40	2.094	0.98642	39	A-4a	C			5.60	5000			0.67
35	1006.0	1.5	36.5	0.057	4	5	12	2.047	0.99402	12	A-4a	C			5.60	1500			0.67
40	1001.0	1.5	41.5	0.058	5	5	13	2.347	0.94826	12	A-4a	C			5.60	1625			0.67
45	996.0	1.5	46.5	0.059	6	7	17	2.696	0.90191	15	A-4a	C			5.60	2125			0.67
50	991.0	1.5	51.5	0.069	16	16	41	3.481	0.81643	33	A-4a	C			5.60	5125			0.67
55	986.0	1.5	56.5	0.078	30	30	77	4.326	0.74378	57	A-4a	C			5.60	9126			0.67
60	981.0	1.5	61.5	0.078	50		64	4.714	0.71506	46	A-4a	C			5.60	7586			0.67
65	976.0	1.5	66.5	0.078	50		64	5.102	0.68861	44	A-4a	C			5.60	7586			0.67
70	971.0	1.5	71.5	0.078	50		64	5.490	0.6641	43	A-4a	C			5.60	7586			0.67
75	966.0	1.5	76.5	0.078	29	31	77	5.878	0.64127	49	A-2-4	G			5.70		40.9	40.0	0.83
80	961.0	1.5	81.5	0.073	21	30	65	5.903	0.63987	42	A-2-4	G			5.70		39.8	40.0	0.83

Strata No.	Cohesive or Granular	Top Depth	Bottom Depth	Bottom Elevation	Depth BLF	Under Water	Strata Depth	Avg. N_{60}	Avg N_{160}	γ_{moist}	γ'	$C=HP/2$	$C=S_u$	C'	Avg PI.	ϕ'_{PI}	AASHTO ϕ'	AREMA ϕ'	APILE reduction factor
		(ft.)	(ft.)	(ft.)	(ft.)	(Y/N)	(ft.)	(dim.)	(dim.)	(pcf.)	(pcf.)	(psf.)	(psf.)		(%)	(deg.)	(deg.)	(deg.)	
Soil 1	C	9.2	12.0	1029.0	2.8	Y	2.8	8	11	118	55.6	200	1125	20	9	32.5			0.75
Soil 2	G	12.0	13.5	1027.5	4.3	Y	1.5	29	38	128	65.6				7	33.0	39.2	20.5	0.83
Soil 3	G	13.5	19.0	1022.0	9.8	Y	5.5	37	45	128	65.6						41.2	35.4	1.00
Soil 4	G	19.0	22.5	1018.5	13.3	Y	3.5	20	23	125	62.6						37.3	32.0	1.00
Soil 5	G	22.5	25.0	1016.0	15.8	Y	2.5	40	43	128	65.6						41.0	36.0	1.00
Soil 6	C	25.0	29.0	1012.0	19.8	Y	4.0	24	26	125	62.6	400	3000	40	10	32.5			0.67
Soil 7	C	29.0	33.5	1007.5	24.3	Y	4.5	40	39	132	69.6		5000	359					0.67
Soil 8	C	33.5	43.5	997.5	34.3	Y	10.0	13	12	120	57.6		1563	156					0.67
Soil 9	C	43.5	48.0	993.0	38.8	Y	4.5	17	15	122	59.6		2125	207					0.67
Soil 10	C	48.0	55.0	986.0	45.8	Y	7.0	41	33	132	69.6		5125	365					0.67
Soil 11	C	55.0	75.0	966.0	65.8	Y	20.0	67	48	140	77.6		7971	494					0.67
Soil 12	SL	75.0	81.5	959.5	72.3	Y	6.5	71	46	140	77.6						40.3	40.0	0.83

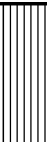
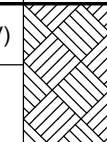
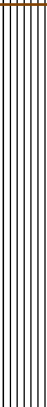
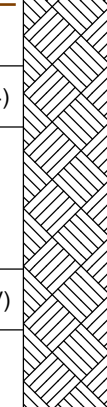
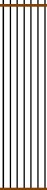
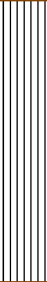
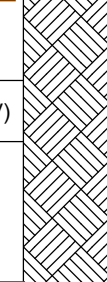
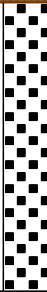
Boring ID: B-002-0-24
Ground Elevation 1041
Ground Water Depth (ft.)= 8

Hammer Energy Ratio = 0.768
BTF elv= 1032.2
Ground Water Elevation: = 1033

Depth (Top of Spoon)	Elevation (Top of Spoon)	Smpl. Depth	Depth (Bottom of Spoon)	effect. Unit Wght. γ'	N_2	N_3	N_{60}	Middle-spoon σ'_v	C_N	$N1_{60}$	CLASF.	Cohesive or Granular	H.P.	PI	f1	S_u	AASHTO ϕ'	APILE reduction factor
(ft.)	(ft.)	(ft.)	(ft.)	(ksf.)	(dim.)	(dim.)	(dim.)	(ksf.)	(ksf.)	(dim.)		(psf.)	(tsf.)	(%)		(psf.)	(deg.)	
2.5	1038.5	1.5	4.0	0.111	5	4	12	0.362	1.57353	19	A-2-4	G			5.70		35.3	0.83
5	1036.0	1.5	6.5	0.111	4	4	10	0.636	1.38475	14	A-2-4	G			5.70		34.0	0.83
7.5	1033.5	1.5	9.0	0.054	1	1	3	0.442	1.50646	5	A-2-4	G			5.70		30.5	0.83
9	1032.0	1.5	10.5	0.056	1	3	5	0.542	1.43835	7	A-2-4	G	2		5.70		31.5	0.83
10.5	1030.5	1.5	12.0	0.061	10	8	23	0.687	1.35895	31	A-6b	C	2		5.40	2875		0.57
12	1029.0	1.5	13.5	0.069	15	17	41	0.875	1.27837	52	A-6b	C	2	18.0	5.45	5125		0.57
13.5	1027.5	1.5	15.0	0.066	13	15	36	0.941	1.2541	45	A-1-b	G			5.70		41.3	1
15	1026.0	1.5	16.5	0.068	18	18	46	1.071	1.21065	56	A-1-b	G			5.70		42.0	1
16.5	1024.5	1.5	18.0	0.066	14	16	38	1.145	1.18819	45	A-1-b	G			5.70		41.3	1
20	1021.0	1.5	21.5	0.068	20	16	46	1.411	1.11845	51	A-1-b	G			5.70		42.0	1
22.5	1018.5	1.5	24.0	0.068	16	20	46	1.581	1.08041	50	A-1-b	G			5.70		42.0	1
25	1016.0	1.5	26.5	0.063	11	10	27	1.612	1.07393	29	A-4a	C	3.5	9.0	5.59	3375		0.67
30	1011.0	1.5	31.5	0.073	30	11	52	2.248	0.96273	50	A-4a	C			5.60	6163		0.67
35	1006.0	1.5	36.5	0.059	6	7	17	2.107	0.98439	17	A-4a	C	3		5.60	2125		0.67
40	1001.0	1.5	41.5	0.058	6	6	15	2.374	0.94441	14	A-4a	C	2.75		5.60	1875		0.67
45	996.0	1.5	46.5	0.078	18	24	54	3.550	0.80989	44	A-4a	C	3		5.60	6400		0.67
50	991.0	1.5	51.5	0.078	24	25	63	3.938	0.77521	49	A-4a	C			5.60	7467		0.67
55	986.0	1.5	56.5	0.078	24	42	84	4.326	0.74378	62	A-4a	C			5.60	9956		0.67
60	981.0	1.5	61.5	0.078	50	50	128	4.714	0.71506	92	A-4a	C			5.60	15171		0.67
65	976.0	1.5	66.5	0.078	24	27	65	5.102	0.68861	45	A-4a	C			5.60	7704		0.67
70	971.0	1.5	71.5	0.078	30	39	88	5.490	0.6641	58	A-4a	C	3.25	9.0	5.59	10404		0.67
75	966.0	1.5	76.5	0.078	50	50	128	5.878	0.64127	82	A-4a	C			5.60	15171		0.67
80	961.0	1.5	81.5	0.078	34	50	108	6.266	0.61989	67	A-4a	C			5.60	12801		0.67
85	956.0	1.5	86.5	0.072	18	21	50	6.193	0.62381	31	A-4a	C	4.5	9.0	5.59	6250		0.67

Strata No.	Cohesive or Granular	Top Depth	Bottom Depth	Bottom Elevation	Depth BLF	Under Water	Strata Depth	Avg. N_{60}	Avg $N1_{60}$	γ_{moist}	γ'	$C=HP/2$	$C=S_u$	C'	Avg PI.	ϕ'_{PI}	AASHTO ϕ'	APILE reduction factor
		(ft.)	(ft.)	(ft.)	(ft.)	(Y/N)	(ft.)	(dim.)	(dim.)	(pcf.)	(pcf.)	(psf.)	(psf.)		(%)	(deg.)	(deg.)	
Soil 1	G	8.8	10.5	1030.5	1.7	Y	1.7	4	6	118	55.6	0					30.9	0.83
Soil 2	C	10.5	13.0	1028.0	4.2	Y	2.5	32	42	128	65.6	200	4000	20	18	30.5		0.57
Soil 3	G	13.0	20.0	1021.0	11.2	Y	7.0	40	49	128	65.6						41.5	1.00
Soil 4	G	20.0	25.0	1016.0	16.2	Y	5.0	46	51	132	69.6						42.0	1.00
Soil 5	C	25.0	30.0	1011.0	21.2	Y	5.0	27	29	125	62.6	400	3375	40	9	32.5		0.67
Soil 6	C	30.0	32.0	1009.0	23.2	Y	2.0	52	50	140	77.6		6163	414				0.67
Soil 7	C	32.0	45.0	996.0	36.2	Y	13.0	16	16	122	59.6	300	2000	30				0.67
Soil 8	C	45.0	55.0	986.0	46.2	Y	10.0	59	47	140	77.6	300	6934	30				0.67
Soil 9	C	55.0	70.0	971.0	61.2	Y	15.0	92	66	140	77.6		10944	617				0.67

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT GDT - 6/24/24 05:05 - C:\USERS\JYEAKLEY\ONE DRIVE - GANNETT FLEMING INC\GF - 078318-MINK STREET BRIDGE REPLACEMENT

PID: 19707	SFN: 4563743	PROJECT: LIC-41-05.60	STATION / OFFSET: RT.				START: 5/21/24	END: 5/21/24	PG 2 OF 3		B-001-0-24										
MATERIAL DESCRIPTION AND NOTES			ELEV. 1011.0	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				
VERY STIFF, DARK GRAY, SANDY SILT , LITTLE GRAVEL, SOME CLAY, DAMP <i>(continued)</i>				Stratum 7	31	10 16 15	40	33	SS-12	-	-	-	-	-	-	-	-	16	A-4a (V)		
					32																
					33																
					34																
Stratum 8				Stratum 8	35	9 4 5	12	56	SS-13	-	18	12	16	33	21	23	14	9	14	A-4a (4)	
					36																
					37																
					38																
					39																
					40	3 5 5	13	33	SS-14	-	-	-	-	-	-	-	-	-	17	A-4a (V)	
					41																
					42																
					43																
					Stratum 9				Stratum 9	44											
45	6 6 7	17	22	SS-15						-	-	-	-	-	-	-	-	16	A-4a (V)		
46																					
47																					
Stratum 10				Stratum 10	48																
					49																
					50	20 16 16	41	100	SS-16	-	-	-	-	-	-	-	-	10	A-4a (V)		
					51																
					52																
					53																
					54																
					55																
					56																
					VERY DENSE, DARK GRAY, SANDY SILT , LITTLE GRAVEL, SOME CLAY, [BOULDER ZONE], DAMP				Stratum 11	57											
58																					
59																					
60	60/3"	-	100	SS-18						-	-	-	-	-	-	-	-	10	A-4a (V)		
61																					
62																					
63																					

APPENDIX E

Geotechnical Checklist



Ohio Department of Transportation Geotechnical Engineering Design Checklists



Version 6.0
January 20, 2023

Preface

Geotechnical design features that arise in the development of roadway projects vary both in type and complexity. Cuts, embankments, wetlands, mine issues, and rock slopes are just some geotechnical issues encountered on transportation projects. Consistent and comprehensive reconnaissance, analysis, and plan preparation are necessary to ensure that all possible geotechnical issues that may occur on a project will be adequately identified and accounted for on the final plans.

A set of topical review checklists, a reference list, and a technical publications list have been developed to aid the project development personnel in their production of geotechnically sound project plans. All projects that contain geotechnical related issues will benefit from the use of this document. Although it is expected that the District Geotechnical Engineer will be one of the main users of these checklists, any personnel responsible for a geotechnical aspect of the project plan development will use this document. Possible users of this checklist include, but are not limited to, design and geotechnical Consultants and District and Central Office reviewers and project engineers.

The design checklists are provided to assist the project development personnel in:

- Developing a comprehensive geotechnical scope of services
- Developing and reviewing geotechnical reports and assimilating information
- Analyzing, designing, and reviewing geotechnical related aspects of a transportation project, including needs assessment, plans, and specifications
- Recognizing cost-saving opportunities
- Identifying deficiencies due to inadequate geotechnical exploration, analysis, or design
- Recognizing when to request additional technical assistance from a geotechnical specialist
- Defining areas of needed training

At first glance, the design checklist will seem to be inordinately lengthy. One, however, should not avoid using the checklist because of this. Only on major and complex projects will it be necessary to complete most of the checklist. Just those checklists that pertain to a specific geotechnical feature encountered on the project should be completed. Therefore, for most projects, only a small portion of the checklist will need to be completed.

Since several entities may be involved in the geotechnical development of a transportation project, it is possible that there may be more than one set of checklists completed for a specific project, or different entities may fill out different sections of the checklist. It is anticipated that all completed checklists will be included with the project file in District or Central Office.

To utilize the checklists,

- First fill out the project information on the Checklist Cover tab. The project information in the headings of the rest of the checklists will autopopulate. Also indicate which checklists will be utilized.
- Complete only the checklists that apply to the project by using the dropdown boxes.
- Submit the checklist cover along with all completed checklists with the report and plan submission

Additional topics and questions may be added as the development of these checklists continues and input is received from the users. All additional updates and design guidance will be issued from the Office of Geotechnical Engineering (OGE) and available on the internet at the Design Reference Resource Center and the OGE website. The OGE Administrator will be the point of contact regarding the checklist, and any questions, recommendations, and training requests should be directed to the Office Administrator.

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	B. Geotechnical Reports (General Presentation)
VII.	References

Symbols and Abbreviations

Y	Yes
N	No
X	Not Applicable (Reason should be explained in the "Notes" area of the checklist)
✓	Selected item utilized
AASHTO	American Association of State Highway and Transportation Officials
AML	Abandoned Mine Land Reclamation Program, DMRM, ODNR
AUMIRA	Manual for Abandoned Underground Mine Inventory and Risk Assessment, ODOT
BDM	Bridge Design Manual, ODOT
CBR	California Bearing Ratio
C&MS	Construction and Material Specifications, ODOT
DGE	District Geotechnical Engineer, ODOT District
DGS	Division of Geological Survey, ODNR
DMRM	Division of Mineral Resources Management, ODNR
DSWC	Division of Soil and Water Conservation, ODA
EPA	Ohio Environmental Protection Agency
FHWA	Federal Highway Administration
F.S.	Factor of Safety
GDM	Geotechnical Design Manual, ODOT
L&D1	Location & Design Manual, Volume 1, ODOT
L&D3	Location & Design Manual, Volume 3, ODOT
LRFD	Load and Resistance Factor Design
N ₆₀	Standard Penetration Value, normalized to 60 percent of drill rod energy ratio
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OGE	Office of Geotechnical Engineering, ODOT
OSMRE	Office of Surface Mining Reclamation and Enforcement, U.S. Dept. of the Interior
ROW	Right of Way
RQD	Rock Quality Designation
SDI	Slake Durability Index
SGE	Specifications for Geotechnical Explorations, ODOT
SPT	Standard Penetration Test
TIMS	Transportation Information Mapping System
UBV	Ultimate Bearing Value
USGS	U.S. Geological Survey
WEAP	Wave Equation Analysis of Pile Driving (Software)

I. Geotechnical Design Checklists	
Project: LIC-CR41-5.6	PDP Path:
PID: NA	Review Stage:

Checklist	Included in This Submission
II. Reconnaissance and Planning	✓
III. A. Centerline Cuts III. B. Embankments III. C. Subgrade	
IV. A. Foundations of Structures IV. B. Retaining Wall	✓
V. A. Landslide Remediation V. B. Rockfall Remediation V. C. Wetland or Peat Remediation V. D. Underground Mine Remediation V. E. Surface Mine Remediation V. F. Karst Remediation	
VI. A. Geotechnical Profile	✓
VI. D. Geotechnical Reports	✓

II. Reconnaissance and Planning Checklist

C-R-S:	LIC-CR41-5.6	PID:	NA	Reviewer:	YLZ	Date:	11/22/2024
Reconnaissance				(Y/N/X)	Notes:		
1	Based on Section 302.1 in the SGE, have the necessary plans been developed in the following areas prior to the commencement of the subsurface exploration reconnaissance:						
	Roadway plans						
	Structures plans			✓			
	Geohazards plans						
2	Have the resources listed in Section 302.2.1 of the SGE been reviewed as part of the office reconnaissance?			Y			
3	Have all the features listed in Section 302.3 of the SGE been observed and evaluated during the field reconnaissance?			Y			
4	If notable features were discovered in the field reconnaissance, were the GPS coordinates of these features recorded?			N			
Planning - General				(Y/N/X)	Notes:		
5	In planning the geotechnical exploration program for the project, have the specific geologic conditions, the proposed work, and historic subsurface exploration work been considered?			Y			
6	Has the ODOT Transportation Information Mapping System (TIMS) been accessed to find all available historic boring information and inventoried geohazards?			Y			
7	Have the borings been located to develop the maximum subsurface information while using a minimum number of borings, utilizing historic geotechnical explorations to the fullest extent possible?			Y			
8	Have the topography, geologic origin of materials, surface manifestation of soil conditions, and any other special design considerations been utilized in determining the spacing and depth of borings?			Y			
9	Have the borings been located so as to provide adequate overhead clearance for the equipment, clearance of underground utilities, minimize damage to private property, and minimize disruption of traffic, without compromising the quality of the exploration?			Y			

II. Reconnaissance and Planning Checklist

Planning - General		(Y/N/X)	Notes:
10	Have the scaled boring plans, showing all project and historic borings, and a schedule of borings in tabular format, been submitted to the District Geotechnical Engineer?	Y	
The schedule of borings should present the following information for each boring:			
a.	exploration identification number	Y	
b.	location by station and offset	Y	
c.	estimated amount of rock and soil, including the total for each for the entire program.	Y	
Planning – Exploration Number		(Y/N/X)	Notes:
11	Have the coordinates, stations and offsets of all explorations (borings, soundings, test pits, etc.) been identified?	Y	
12	Has each exploration been assigned a unique identification number, in the following format X-ZZZ-W-YY, as per Section 303.2 of the SGE?	Y	
13	When referring to historic explorations that did not use the identification scheme in 12 above, have the historic explorations been assigned identification numbers according to Section 303.2 of the SGE?	X	

II. Reconnaissance and Planning Checklist

Planning – Boring Types		(Y/N/X)	Notes:
14	Based on Sections 303.3 to 303.7.6 of the SGE, have the location, depth, and sampling requirements for the following boring types been determined for the project?		
	Check all boring types utilized for this project:		
	Existing Subgrades (Type A)		
	Roadway Borings (Type B)		
	Embankment Foundations (Type B1)		
	Cut Sections (Type B2)		
	Sidehill Cut Sections (Type B3)		
	Sidehill Cut-Fill Sections (Type B4)		
	Sidehill Fill Sections on Unstable Slopes (Type B5)		
	Geohazard Borings (Type C)		
	Lakes, Ponds, and Low-Lying Areas (Type C1)		
	Peat Deposits, Compressible Soils, and Low Strength Soils (Type C2)		
	Uncontrolled Fills, Waste Pits, and Reclaimed Surface Mines (Type C3)		
	Underground Mines (C4)		
	Landslides (Type C5)		
	Rock Slope (Type C6)		
	Karst (Type C7)		
	Proposed Underground Utilities (Type D)		
	Structure Borings (Type E)		
	Bridges (Type E1)	✓	
	Culverts (Type E2 a,b,c)		
	Retaining Walls (Type E3 a and b)		
	Noise Barrier (Type E4)		
	CCTV & High Mast Lighting Towers (Type E5)		
	Buildings and Salt Domes (Type E6)		

IV.A Foundations of Structures Checklist

C-R-S:	LIC-CR41-5.6	PID:	NA	Reviewer:	YLZ	Date:	11/22/2024
<p>Use this Checklist in conjunction with the bridge foundation design guidance in GDM Section 1300 If you do not have such a foundation or structure on the project, you do not have to fill out this checklist.</p>							
Soil and Bedrock Strength Data				(Y/N/X)	Notes:		
1	Has the shear strength of the foundation soils been determined?						
	Check method used:						
	laboratory shear tests						
	estimation from SPT or field tests			✓			
2	Have sufficient soil shear strength, consolidation, and other parameters been determined so that the required allowable loads for the foundation/structure can be designed?			Y			
3	Has the shear strength of the foundation bedrock been determined?						
	Check method used:						
	laboratory shear tests						
	other (describe other methods)						
Spread Footings				(Y/N/X)	Notes:		
4	Are there spread footings on the project? If no, go to Question 11						
5	Have the recommended bottom of footing elevation and reason for this recommendation been provided?						
a.	Has the recommended bottom of footing elevation taken scour from streams or other water flow into account?						
6	Were representative sections analyzed for the entire length of the structure for the following:						
a.	factored bearing resistance?						
b.	factored sliding resistance?						
c.	eccentric load limitations (overturning)?						
d.	predicted settlement?						
e.	overall (global) stability?						
7	Has the need for a shear key been evaluated?						
a.	If needed, have the details been included in the plans?						
8	If special conditions exist (e.g. geometry, sloping rock, varying soil conditions), was the bottom of footing "stepped" to accommodate them?						
9	Have the Service I and Maximum Strength Limit States for bearing pressure on soil or rock been provided?						

IV.A Foundations of Structures Checklist

Spread Footings		(Y/N/X)	Notes:
10	If weak soil is present at the proposed foundation level, has the removal / treatment of this soil been developed and included in the plans?		
a.	Have the procedure and quantities related to this removal / treatment been included in the plans?		
Pile Structures		(Y/N/X)	Notes:
11	Are there piles on the project? If no, go to Question 17		
12	Has an appropriate pile type been selected?		
	Check the type selected:		
	H-pile (driven)		
	H-pile (prebored)		
	Cast In-place Reinforced Concrete Pipe	✓	
	Micropile		
	Continuous Flight Auger (CFA)		
	other (describe other types)		
13	Have the estimated pile length or tip elevation and section (diameter) based on either the Ultimate Bearing Value (UBV) or the depth to top of bedrock been specified? Indicate method used.	Y	
14	If scour is predicted, has pile resistance in the scour zone been neglected?	✓	
15	Has a wave equation drivability analysis been performed as per BDM 305.3.1.2 to determine whether the pile can be driven to either the UBV, the pile tip elevation, or refusal on bedrock without overstressing the pile?	Y	
16	If required for design, have sufficient soil parameters been provided and calculations performed to evaluate the:		
a.	Nominal unit tip resistance and maximum settlement of the piles?		
b.	Nominal unit side resistance for each contributing soil layer and maximum deflection of the piles?	X	As per BDM Section 305.1.2, no p-y analysis is necessary for integral abutments in the in-service condition.
c.	Downdrag load on piles driven through new embankment or compressible soil layers, as per BDM 305.3.2.2?		
d.	Potential for and impact of lateral squeeze from soft foundation soils?		

IV.A Foundations of Structures Checklist

Pile Structures	(Y/N/X)	Notes:
17 If piles are to be driven to strong bedrock ($Q_u > 7.5$ ksi) or through very dense granular soils or overburden containing boulders, have “pile points” been recommended in order to protect the tips of the steel piling, as per BDM 305.3.5.6?		
18 If subsurface obstacles exist, has preboring been recommended to avoid these obstructions?		
19 If piles will be driven through 15 feet or more of new embankment, has preboring been specified as per BDM 305.3.5.7?		

IV.A Foundations of Structures Checklist

Drilled Shafts		(Y/N/X)	Notes:
20	Are there drilled shafts on the project? If no, go to the next checklist.		
21	Have the drilled shaft diameter and embedment length been specified?		
22	Have the recommended drilled shaft diameter and embedment been developed based on the nominal unit side resistance and nominal unit tip resistance for vertical loading situations?		
23	For shafts undergoing lateral loading, have the following been determined:		
	a. total factored lateral shear?		
	b. total factored bending moment?		
	c. maximum deflection?		
	d. reinforcement design?		
24	If a bedrock socket is required, has a minimum rock socket length equal to 1.5 times the rock socket diameter been used, as per BDM 305.4.2?		
25	Generally, bedrock sockets are 6" smaller in diameter than the soil embedment section of the drilled shaft. Has this factor been accounted for in the drilled shaft design?		
26	If scour is predicted, has shaft resistance in the scour zone been neglected?		
27	Has the site been assessed for groundwater influence?		
	a. If yes, and if artesian flow is a potential concern, does the design address control of groundwater flow during construction?		
28	Have all the proper items been included in the plans for integrity testing?		
29	If special construction features (e.g., slurry, casing, load tests) are required, have all the proper items been included in the plans?		
30	If necessary, have wet construction methods been specified?		
General		(Y/N/X)	Notes:
31	Has the need for load testing of the foundations been evaluated?		
	a. If needed, have details and plan notes for load testing been included in the plans?	Y	

VI.A. Geotechnical Profile Checklist

C-R-S:	LIC-CR41-5.6	PID:	NA	Reviewer:	YLZ	Date:	Nov/22/2024
General Presentation				(Y/N/X)	Notes:		
1	Has an electronic copy of all geotechnical submissions been provided to the District Geotechnical Engineer (DGE)?			Y			
2	Have the cadd files been prepared using the appropriate version of the ODOT CADD standards?			Y			
3	Has the geotechnical specification (title and date) under which the work was performed been clearly identified on every submission (reports, plans, etc.)?			Y			
4	Has the first complete version of all documents being submitted been labeled as 'Draft'?			Y			
5	Subsequent to ODOT's review and approval, has the complete version of the revised documents being submitted been labeled as 'Final'?			N	Not applicable		
a.	Have the C-R-S, PID number, and product title been included in the folder name?			N	Not applicable		
6	If the project includes structures, have all structure explorations been presented together under the same cover sheet? (Do not create separate Geotechnical Profile - Bridge Sheets)			Y			
7	Has a scale of 1"=1' been used for cover sheets, laboratory test data sheets, and boring log sheets, if applicable?			Y			
8	Based on the project length, has the correct horizontal scale been used to plot the project data?			Y			
Check scale used:							
1" = 5', 10', 20', 25', 40', or 50' for projects 1500' or less (use largest scale appropriate to present entire plan on one sheet)			✓				
1" = 50' projects greater than 1500'							
9	Has a scale of 1" = 10' been utilized for the vertical scale of the project data?			Y			
10	If the project includes structures, has the plan and profile view been shown at the same scale as the Site Plan for the proposed structure(s), when possible?			Y			

VI.A. Geotechnical Profile Checklist

General Presentation		(Y/N/X)	Notes:
11	If the project includes culverts, have the plan and profile been presented along the flowline of the culvert?	N	Not applicable
12	Have the cross-sections been plotted at a scale of 1" = 10' (preferred) or 1" = 20' (for higher or wider slopes)?	N	Not applicable
Cover Sheet		(Y/N/X)	Notes:
13	Has the following general information been provided on the cover sheet:		
a.	Brief description of the project, including the bridge number of each bridge involved in the plan set, if any?	Y	
b.	Brief description of historic geotechnical explorations referenced in this exploration? State if no historic records are available.	Y	
c.	Generalized information about the geology of the project area, including terrain, soil origin, bedrock types, and age?	Y	
d.	Brief presentation of geological and topographical information derived from the field reconnaissance? Include comments on structure and pavement conditions.	Y	
e.	Brief presentation of test boring and sampling methods? Include date of last calibration and drill rod energy ratio as a percent for the hammer systems used.	Y	
f.	Summary of general soil, bedrock, and groundwater conditions, including a generalized interpretation of findings?	Y	
g.	A statement of which version (date) of the SGE specification the exploration was performed in accordance with?	Y	
h.	Statement of where geotechnical reports are available for review?	Y	
i.	Initials of personnel and dates they performed field reconnaissance, subsurface exploration and preparation of the geotechnical profile?	Y	

VI.A. Geotechnical Profile Checklist

Cover Sheet		(Y/N/X)	Notes:
14	Has a Legend been provided?	Y	
15	Have the following items been included in the Legend:		
a.	Symbols and usual descriptions for only the soil and bedrock types presented in the Geotechnical Profile, as per the Soil and Rock Symbolology Chart in Appendix D of the SGE?	Y	
b.	All miscellaneous symbols and acronyms, used on any of the sheets, defined?	Y	
c.	The number of soil samples for each classification that were mechanically classified and visually described in the current exploration?	Y	
16	Has a Location Map, showing the beginning and end stations for the project, been shown on the cover sheet, sized per the L&D3 Manual?	Y	
17	Have the station limits for each plan and profile sheet for projects with multiple alignments, or greater than 1500', been identified in a table?	Y	
18	Have the station limits for any cross section sheets been identified in the same table?	Y	
19	Has a list of any structures for which structure foundation explorations been performed been identified in the same table?	Y	
20	If sampling and testing for a scour analysis was performed, has this data been shown in tabular form?	Y	
21	Has a summary table of test data for all roadway and subgrade boring samples been shown?	Y	
22	If borings from previous subsurface explorations are being used, has that data been shown in a separate table?	Y	
23	In the summary table, has the data been displayed by roadway and subgrade boring in ascending stationing order for each roadway?	Y	
24	Have the centerline or baseline station, offset, and exploration identification number been provided for each boring presented in the table?	Y	

VI.A. Geotechnical Profile Checklist

Cover Sheet		(Y/N/X)	Notes:
25	For each sample, has the following information been provided in the summary table:		
a.	Sample depth interval?	N	Not applicable
b.	Sample number and type?	N	Not applicable
c.	N ₆₀ ?	N	Not applicable
d.	Percent recovery?	N	Not applicable
e.	Hand Penetrometer?	N	Not applicable
f.	Percentage of aggregate, coarse sand, fine sand, silt, and clay size particles?	N	Not applicable
g.	Liquid limit, plastic limit, plasticity index, and water content, all rounded to the nearest percent or whole number?	N	Not applicable
h.	ODOT classification and Group Index?	N	Not applicable
i.	Visual description of samples not mechanically classified, including water content, and estimated ODOT classification with 'Visual' in parentheses?	N	Not applicable
j.	Sulfate Content test results?	N	Not applicable
26	Have all undisturbed test results been displayed in graphical format on the sheet prior to the plan and profile sheets?	N	Not applicable
Surface Data		(Y/N/X)	Notes:
27	Has the following information been shown on each roadway plan drawing:		
a.	Existing surface features described in Section 702.5.1?	Y	
b.	Proposed construction items, as described in Section 702.5.2?	Y	
c.	Project and historic boring locations, with appropriate exploration targets and exploration identification numbers?	Y	
d.	Notes regarding observations not readily shown by drawings?	N	Not applicable
28	Have the existing ground surface contours been presented?	Y	
29	If cross sections are to be developed for stationing covered on a plan sheet, has an index for the appropriate cross section sheets been included on the plan sheet?	N	Not applicable

VI.A. Geotechnical Profile Checklist

Subsurface Data		(Y/N/X)	Notes:
30	Has all the subsurface data been presented in the form of a profile along the centerline or baseline, and on cross sections where applicable?	Y	
31	Have the graphical boring logs been correctly shown, as follows:		
a.	Location and depth of boring indicated by a heavy dashed vertical line?	Y	
b.	Exploration identification number above the boring?	Y	
c.	Logs indicate soil and bedrock layers with symbols 0.4" wide and centered on the heavy dashed vertical line where possible?	Y	
d.	Bedrock exposures with 0.4" wide symbols, but without a heavy dashed vertical line?	Y	
e.	Soil and bedrock symbols as per ODOT Soil and Rock Symbolology chart (SGE - Appendix D)?	Y	
f.	Historical borings shown in same manner with the exploration identification number above the boring?	N	
32	Have the proposed groundline and existing groundline been shown on the profile view, according to ODOT CADD standards?	Y	
33	Have the locations of the proposed structure foundation elements been shown on the profile view?	Y	
34	Have the offsets from centerline or baseline been indicated above the borings in the profile view?	Y	
35	Have borings located immediately adjacent to the centerline or baseline and considered representative of centerline or baseline subsurface conditions been referenced directly to the centerline or baseline?	Y	
36	Have offset borings in or near the same elevation interval of a centerline or baseline boring been plotted either on a cross section or immediately above or below the centerline boring in a box containing an elevation scale?	Y	
37	Have cross-sections been developed to show subsurface conditions disclosed by a series of borings drilled transverse to centerline or baseline?	N	Not applicable

VI.A. Geotechnical Profile Checklist

Subsurface Data	(Y/N/X)	Notes:
38 Have the existing and proposed groundlines been displayed on cross section sheets according to ODOT CADD standards?	N	Not applicable
39 Have bedrock exposures shown on the cross sections been plotted along the contour of the cross section?	N	
40 Has the following information been provided adjacent to the graphical logs or bedrock exposure:		
a. Thickness, to the nearest inch, of sod/topsoil or other shallow surface material written above the boring (with corresponding symbology at top of log)?	Y	
b. Moisture content, to nearest whole percent, with the bottom of the text aligned with the bottom of the sample? Label this column as 'WC' at bottom of the boring.	Y	
c. N_{60} , aligned with the bottom of sample? Label column as ' N_{60} ' at bottom of boring.	Y	
d. Free water indicated by a horizontal line with a 'w' attached, and water level at the end of drilling indicated by an open equilateral triangle, point down?	Y	
e. Complete geologic description of each bedrock unit, including unit core loss, unit RQD, SDI, and compressive strength test results? (Do not present geologic descriptions for structure borings for which this information is presented on the boring logs as described in 703.3)	N	Not applicable
f. Visual description of any uncontrolled fill or interval not adequately defined by a graphical symbol?	N	Not applicable
g. Organic content with modifiers, per 603.5?	N	Not applicable
h. Designate a plastic soil with moisture content equal to or greater than the liquid limit minus three with a 1/8" solid black circle adjacent to the moisture content?	Y	
i. Designate a non-plastic soil with moisture content exceeding 25% or exceeding 19% but appearing wet initially, with a 1/8" open circle with a horizontal line through it adjacent to the moisture content?	Y	
j. The reason for discontinuing a boring prior to reaching the planned depth indicated immediately below the boring?	N	Not applicable

VI.A. Geotechnical Profile Checklist

Boring Logs	(Y/N/X)	Notes:
41 Have the boring logs of all structure borings, all geohazard borings, and any roadway borings drilled in the vicinity of the structures or geohazard been shown on the boring log sheets following the plan and profile sheets? (Create the logs in accordance with 703.3)	Y	
42 Have the boring logs been developed by integrating the driller's field logs, laboratory test data, and visual descriptions?	Y	
43 Has the following boring information been included in the heading of each boring log:		
a. Exploration identification number?	Y	
b. Project designation (C-R-S) and PID?	N	Not applicable
c. Structure File Number (if applicable) and project type?	N	Not applicable
d. Centerline or baseline name, station, offset, and surface elevation?	Y	
e. Coordinates?	Y	
f. Method of drilling?	Y	
g. Date started and date completed?	Y	
h. Method and material (including quantity) used for backfilling or sealing, including type of instrumentation, if any (reported in the footer)?	Y	
i. Date of last calibration and drill rod energy ratio (ER) in percent for the hammer system(s) used, not to exceed 90%?	Y	
44 Has the following boring information been included in each boring log:		
a. A depth and elevation scale?	Y	
b. Indication of stratum change?	Y	
c. Description of material in each stratum?	Y	
d. Depth of bottom of boring?	Y	
e. Depth of boulders or cobbles, if encountered?	Y	
f. Caving depth?	N	Not applicable
g. Water level observations?	Y	
h. Artesian water level and height of rise?	N	Not applicable
i. Heaving sand?	N	Not applicable
j. Cavities or other unusual conditions?	N	Not applicable
k. Depth interval represented by sample?	Y	
l. Sample number and type?	Y	
m. Percent recovery for each sample?	Y	
n. Measured blow counts for each 6 inches of drive for split spoon samples, not to exceed 18 inches total?	Y	
o. N_{60} to the nearest whole number?	Y	

VI.A. Geotechnical Profile Checklist

p. Hand penetrometer?	Y	
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VI.A. Geotechnical Profile Checklist

Boring Logs	(Y/N/X)	Notes:
q. Particle-size analysis?	Y	
r. Liquid limit, plastic limit, plasticity index?	Y	
s. Water content?	Y	
t. ODOT soil classifications, with "V" in parentheses for those samples that are not mechanically classified?	Y	
u. Top of bedrock and bedrock descriptions?	N	Not applicable
v. Rock core run percent recovery?	N	Not applicable
w. Run RQD?	N	Not applicable
x. Unit rock core percent recovery?	N	Not applicable
y. Unit RQD?	N	Not applicable
z. SDI, if applicable?	N	Not applicable
aa. Rock compressive strength test results, if applicable?	N	Not applicable

VI.B. Geotechnical Reports

C-R-S:	LIC-CR41-5.6	PID:	NA	Reviewer:	YLZ	Date:	Nov/22/2024
General				(Y/N/X)	Notes:		
1	Has an electronic copy of all geotechnical submissions been provided to the District Geotechnical Engineer (DGE)?			N	Not applicable		
2	Has the first complete version of a geotechnical report being submitted been labeled as 'Draft'?			Y			
3	Subsequent to ODOT's review and approval, has the complete version of the revised geotechnical report being submitted been labeled 'Final'?			N	Not applicable		
4	Has the boring data been submitted in a native format that is DIGGS (Data Interchange for Geotechnical and Geoenvironmental) compatible? gINT files meet this demand?			Y			
5	Does the report cover format follow ODOT's Brand and Identity Guidelines Report Standards found at http://www.dot.state.oh.us/brand/Pages/default.aspx ?			Y			
6	Have all geotechnical reports being submitted been titled correctly as prescribed in Section 706.1 of the SGE?			Y			
Report Body				(Y/N/X)	Notes:		
7	Do all geotechnical reports being submitted contain the following:						
a.	an Executive Summary as described in Section 706.2 of the SGE?			Y			
b.	an Introduction as described in Section 706.3 of the SGE?			Y			
c.	a section titled "Geology and Observations of the Project," as described in Section 706.4 of the SGE?			Y			
d.	a section titled "Exploration," as described in Section 706.5 of the SGE?			Y			
e.	a section titled "Findings," as described in Section 706.6 of the SGE?			Y			
f.	a section titled "Analyses and Recommendations," as described in Section 706.7 of the SGE?			Y			
Appendices				(Y/N/X)	Notes:		
8	Do all geotechnical reports being submitted contain all applicable Appendices as described in Section 706.8 of the SGE?						
9	Do the Appendices present a site Boring Plan showing all boring locations as described in Section 706.8.1 of the SGE?						

VI.B. Geotechnical Reports

Appendices	(Y/N/X)	Notes:
10 Do the Appendices include boring logs and color pictures of rock, if applicable, as described in Section 706.8.2 of the SGE?	Y	
11 Do the Appendices include reports of undisturbed test data as described in Section 706.8.3 of the SGE?	Y	
12 Do the Appendices include calculations in a logical format to support recommendations as described in Section 706.8.4 of the SGE?	Y	