Resource International, Inc.

Resource International, Inc.

GEA-087-03.18 BRIDGE REPLACEMENT
PID NO. 110999
GEAUGA COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT

Prepared For:
Ribway Engineering Group, Inc.
300 East Broad Street, Suite 500
Columbus, Ohio 43212

Prepared By:
Resource International, Inc.
9885 Rockside Road, Suite 145
Cleveland, Ohio 44125

Rii Project No. N-23-023

January 2024

Planning, Engineering, Construction Management, Technology
9885 Rockside Road, Suite 145, Cleveland Ohio 44125
P 216.573.0955

RESOURCE INTERNATIONAL, INC.
9885 Rockside Road, Suite 145
Cleveland, Ohio 44125
T: 216.573.0955

November 20, 2023 (Revised on January 23, 2024)

Mr. Andrew Eribo, P.E.
Principal
Ribway Engineering Group, Inc.
300 East Broad Street, Suite 500
Columbus, Ohio 43215

Re: Structure Foundation Exploration Report
GEA-087-03.18 Bridge Replacement
PID No. 110999
Geauga County, Ohio
Rii Project No. N-23-023 (Rev. 1)

Mr. Eribo:

Resource International, Inc. (Rii) is pleased to submit this structure foundation exploration report for the above referenced project. Engineering logs have been prepared and are attached to this report along with the results of laboratory testing. This report includes recommendations for the design and construction of the proposed replacement of the existing bridge (GEA-087-03.18) carrying State Route 87 over Silver Creek in Russell Township, Geauga County, Ohio. This revised report supersedes our previous submittal.

We sincerely appreciate the opportunity to be of service to you on this project. If you have any questions regarding the structure foundation exploration or this report, please contact us.

Sincerely,

RESOURCE INTERNATIONAL, INC.

Ashok Gaire, P.E. (MI)
Project Engineer

Jonathan P. Sterenberg, P.E.
Vice President – Geotechnical Services

Enclosure: Structure Foundation Exploration Report

TABLE OF CONTENTS

APPENDICES

EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed structure foundation exploration performed for the design and construction of the proposed replacement of the existing bridge (GEA-087-03.18) carrying State Route 87 over Silver Creek in Russell Township, Geauga County, Ohio.

Exploration and Findings

Between July 17 and 19, 2023, two (2) structure borings, designated as B-001-0-23 and B-002-0-23, were drilled in the vicinity of the proposed bridge replacement and were advanced to depths 101.0 and 95.5 feet below the existing grade, respectively. Prior to drilling the borings, pavement cores were obtained from each boring location. Additionally, four (4) cores, designated as X-001-0-23 through X-004-0-23, were obtained from the existing bridge deck.

Borings B-001-0-23 and B-002-0-23 were drilled through the pavement of SR 87 and encountered 10.0 and 18.5 inches of asphalt pavement. Four (4) cores were obtained from the existing bridge deck and encountered reinforced concrete ranging in thickness from 18.0 to 20.0 inches.

Below the pavement section, borings B-001-0-23 and B-002-0-23 encountered granular soils to a depth of 9.5 and 7.5 feet below the existing grade, respectively. Underlying the granular soils, the soil borings generally encountered cohesive soils extended to the top of bedrock. A layer of granular soils was encountered in both borings at a depth of 20.5 feet below existing grade. The encountered cohesive soils were described as clay, silt and clay, silty clay, sandy silt and silt (ODOT A-7-6, A-6a, A-6b, A-4a and A-4b) with varying amounts of sand and gravel. The encountered granular soils were described as gravel with sand, coarse and fine sand, gravel with sand and silt, and gravel with sand, silt and clay (ODOT A-1-b, A-3a, A-2-4 and A-2-6).

The top of bedrock was encountered in borings B-001-0-23 and B-002-0-23 at depths 89.0 and 88.5 feet below the existing grade. Bedrock coring was performed upon encountering auger refusal on bedrock at depths of 90.0 and 89.0 feet below existing grade in borings B-001-0-23 and B-002-0-23, respectively. The recovered bedrock samples were described as gray, very fine to fine grained, slightly weathered, strong sandstone and black, slightly weathered, slightly strong shale.

Groundwater was encountered initially during drilling in borings B-001-0-23 and B-002-0-23 at depths of 9.5 and 13.0 feet below the existing ground surface, respectively. Groundwater was not measured upon the completion of drilling due to the introduction of water as a circulating fluid during the rock coring process.

Analyses and Recommendations

Driven Pile Recommendations

Rii recommends that steel H-piles (ODOT Item 507.07) driven to refusal on bedrock be employed for the proposed foundation support. The geotechnical/structural resistance recommendations for HP 10x42 piles as provided in table below may be utilized for the proposed foundation design.

GEA– 087 – 3.18 Driven Pile Recommendations

Item	Substructure/ Boring Location	Boring Surface Elevation (feet msl)	Pile Type and Size [1]	Pile Elevation (feet msl)		Estimated Pile Length [4] (feet)	$P_{R\ max}$ [5] (kips/pile)	φ [6]
				Top [2]	Tip [3]			
Proposed single span bridge	Rear Abutment (B-001-0-23)	1043.7	HP 10x42	1033.00	954.70	80.0	310	N/A
	Forward Abutment (B-002-0-23)	1038.6	HP 10x42	1030.00	950.10	85.0	310	N/A

1. *H-piles should consist of Grade 50 steel with a yield strength of 50 ksi.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is the sum of proposed bottom of footing/pile cap elevation plus embedment depth of pile into footing.*
3. *The pile tip elevation is based on the top of bedrock elevation in the nearest boring per Section 305.3.5.2 of the 2020 ODOT BDM.*
4. *Per Section 305.3.5.2 of the 2020 ODOT BDM, the estimated pile length was determined as the pile cutoff elevation (top) minus the pile tip elevation, rounded up to the nearest 5.0 feet. Order (furnished) length for each pile should be calculated by adding 5 feet on estimated pile length.*
5. *The factored structural axial resistance for H-piles is based on the structural limit state of the steel H-pile section per Section 305.3.3 of the 2020 ODOT BDM. Factored axial load should be resisted by factored axial structural resistance.*
6. *For H-piles driven to refusal on bedrock, no geotechnical resistance factor should be applied to the factored structural axial resistance values. Factored structural axial resistance are calculated utilizing the structural resistance factor, $\varphi_c = 0.50$, for H-piles subject to damage due to severe driving conditions.*

Please note that this executive summary does not contain all the information presented in the report. The unabridged subsurface exploration report should be read in its entirety to obtain a more complete understanding of the information presented.

1.0 INTRODUCTION

This report is a presentation of the structure foundation exploration performed for the design and construction of the proposed replacement of the existing bridge (GEA-087-03.18) carrying State Route 87 over Silver Creek in Russell Township, Geauga County, Ohio.

Based on the available information, the existing structure is a three span (32 feet, 40 feet, 32 feet, center-to-center bearing) continuous slab bridge with abutments and piers supported on 12-inch diameter CIP concrete piles.

Based on the plans provided by Ribway on January 19, 2024, the proposed replacement consists of a single span bridge with composite prestressed I-beams on integral abutments and a span of 80 feet between the center to center of bearings. As per the available plans, up to approximately 6 feet of fill will be required to bring the site to the proposed grade. The new fill will be placed between the new abutments and the existing abutments.

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Site Geology

Physiographically the site lies within the Killbuck-Glaciated Pittsburgh Plateau region of the Glaciated Allegheny section. The Killbuck-Glaciated Pittsburgh Plateau region consists of ridges and flat uplands covered with thin drift and dissected by steep valleys. Valleys range between narrow rock-walled reaches and broad drift filled areas. Based on the ODNR mapping, the soils in the vicinity of this project site consists of clayey till deposited as flat to gently undulating ground moraine deposits. Ground moraines are deposited during the retreat of glacial ice, resulting in an undifferentiated mixture of clay, silt, sand and gravel.

Based on the Ohio Department of Natural Resources (ODNR) bedrock mapping, the overburden soils are underlain by the Cuyahoga bedrock formation. The Cuyahoga formation has a prominent member identified locally as the Black Hand Sandstone, which is prevalent within the smaller valleys. This formation consists of gray to brown shale interbedded with minor sandstone and siltstone grading into a massive sandstone, which is the Black Hand Member of the formation. This formation has planar to lenticular, thin to thick bedding and the undivided unit ranges from 250 to 1,050 feet thick. Based on the ODNR bedrock topography maps, the bedrock surface elevations in the vicinity of this project site is approximately 950 feet mean sea level (msl), which is approximately 90 to 95 feet below the existing ground surface.

2.2 Existing Conditions

The project site is located on SR 87 (Kinsman Road), approximately 0.46 miles east of SR 306 in Russell Township, Geauga County, Ohio. The existing bridge is a three-span structure with a total length of 105.5 feet and was originally built in 1950. The existing SR 87 road, in the vicinity of project site, is a bi-directional, asphalt surfaced roadway that is aligned east-west. Within the project limits, the topography of the existing roadway slopes downward from west to east with roadway surface elevations ranging approximately from 1,043 to 1,038 feet msl. Overhead electric and cable lines were observed at the northern portion of the site aligned east-west. The area immediately adjacent to the bridge along the creek appear vegetated with grass, shrubs, and trees.

3.0 EXPLORATION

Between July 17 and 19, 2023, two (2) structure borings, designated as B-001-0-23 and B-002-0-23, were drilled in the vicinity of the proposed bridge replacement and were advanced to depths 101.0 and 95.5 feet below the existing grade, respectively. Prior to drilling the borings, pavement cores were obtained from each boring location. Additionally, four (4) cores, designated as X-001-0-23 through X-004-0-23, were obtained from the existing bridge deck.

The soil borings and pavement/bridge deck cores were performed at the locations shown on the boring plan provided in Appendix I of this report. A summary of soil borings and pavement/bridge deck core information is provided in Table 1.

Table 1. Test Boring Summary

Boring/Core Number	Station [1]	Offset [1]	Latitude	Longitude	Ground Elevation [1] (feet msl)	Boring Depth (feet)
B-001-023	167+43	7' RT	40.238705	-89.098415	1043.7	101.0
B-002-023	168+68	12' LT	40.238792	-89.097976	1038.6	95.5
X-001-0-23	167+78	8' RT	40.238712	-89.098291	1041.9	---
X-002-0-23	167+74	9' LT	40.238759	-89.098309	1042.1	---
X-003-0-23	168+33	8' RT	40.238728	-89.098095	1039.7	---
X-004-0-23	168+14	9' LT	40.238769	-89.098168	1040.5	---

1. *Station, offset and ground surface elevations were determined from basemapping provided by Ribway Engineering Group.*

The boring and pavement/bridge deck core locations were determined and located in the field by Rii personnel. Rii utilized a handheld GPS unit to obtain geographic latitude and longitude coordinates of the boring and pavement/bridge deck core locations. Ground surface elevations at the boring locations were interpolated from basemapping provided by Ribway Engineering Group.

The borings were drilled using a CME 55 truck mounted rotary drilling machine, utilizing 3.25-inch inside diameter hollow-stem augers to advance the holes. Standard penetration test (SPT) and split spoon sampling were performed at 2.5-foot intervals to a depth of 30.0 feet below the existing grade and at 5.0-foot intervals thereafter to the top of the bedrock. Additionally, continuous SPT sampling was performed for a 6-foot interval near the estimated face of the abutments to obtain soil samples for scour considerations.

The SPT, per the American Society for Testing and Materials (ASTM) designation D1586, is conducted using a 140-pound hammer falling 30.0 inches to drive a 2.0-inch outside diameter split spoon sampler 18.0 inches. Rii utilized a calibrated automatic drop hammer to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of blows per 6.0-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). Standard penetration blow counts aid in determining soil properties applicable in foundation design. Measured blow count (N) values are corrected to an equivalent (60%) energy ratio, N_{60}, by the following equation. Both values are represented on boring logs in Appendix III.

$$N_{60} = N^*(ER/60)$$

Where:
N = measured N value
ER = drill rod energy ratio, expressed as a percent, for the system used

The hammer for the CME 55 drill rig was calibrated on March 21, 2022 and has a drill rod energy ratio of 87.0 percent.

Hand penetrometer readings, which provide a rough estimate of the unconfined compressive strength of the soil, were reported on the boring logs in units of tons per square foot (tsf) and were utilized to classify the consistency of the cohesive soil in each layer. An indirect estimate of the unconfined compressive strength of the cohesive split spoon samples can also be made from a correlation with the blow counts (N_{60}). Please note that split spoon samples are considered to be disturbed and the laboratory determination of their shear strengths may vary from undisturbed conditions.

The depth to bedrock was determined by split spoon sampler refusal and/or auger refusal on bedrock, and increased resistance in the auger advancement. Both borings were extended into the bedrock using an NQ-2 double-tube diamond bit core barrel (utilizing wire line equipment). The rock cores obtained from the borings were logged in the field and visually classified in the laboratory. The retrieved cores were analyzed to identify the type of rock, color, mineral content, bedding planes and other geological and mechanical features of interest in this project. The Rock Quality Designation (RQD) for each rock core run was calculated according to the following equation:

$$RQD = \frac{\sum \text{segments equal to or longer than 4.0 inches}}{\text{core run length}} x\,100$$

Upon the completion of drilling, the boreholes were sealed with cement-bentonite grout in accordance with ODOT SGE standards. The pavement was patched with an equivalent thickness of cold patch asphalt. Upon the completion of coring, bridge deck was patched with quick set concrete.

In general, for instances of no recovery from standard split spoon sampling, a 2.5-inch outside diameter split spoon sampler was driven the full length of the standard split spoon interval plus an additional 6.0 inches to obtain a representative sample. These samples are designated with a "2S" preceding the sample number on the boring logs. Only the final 6.0 inches of sample were retained for classification.

During drilling, Rii personnel prepared field logs showing the encountered subsurface conditions. Soil samples obtained from the drilling operation were preserved and sealed in glass jars, rock core samples were preserved in core boxes, and the soil and rock samples were delivered to the laboratory. In the laboratory, the soil and rock samples were visually classified and select samples were tested, as noted in Table 2.

Table 2. Laboratory Test Schedule

Laboratory Test	Test Designation	Number of Tests Performed
Natural Moisture Content	ASTM D 2216	50
Plastic and Liquid Limits	AASHTO T89, T90	12
Gradation – Sieve/Hydrometer	AASHTO T88	15
Unconfined Compressive Strength Testing (Soil)	ASTM D2166	3
Unconfined Compressive Strength Testing (Rock)	ASTM D 7012	2

The tests performed are necessary to classify the existing soil and rock according to the Ohio Department of Transportation (ODOT) classification system and to estimate engineering properties of importance for foundation design and construction recommendations. Results of the laboratory testing are presented on the boring logs in Appendix III and also in Appendix IV.

4.0 FINDINGS

Interpreted engineering logs have been prepared based on the field logs, visual examination of samples and laboratory test results. Classification follows the version of the ODOT Specifications for Geotechnical Explorations (SGE) at the time the exploration borings were performed. The following is a summary of what was found in the test borings and what is represented on the boring logs. A description of the soil and rock terms used throughout this report is presented in Appendix II.

4.1 Surface Materials

Borings B-001-0-23 and B-002-0-23 were drilled through the pavement of SR 87 and encountered 10.0 and 18.5 inches of asphalt pavement. Four (4) cores were obtained from the existing bridge deck and encountered reinforced concrete ranging in thickness from 18.0 to 20.0 inches. A summary of pavement/bridge deck cores information is provided in Table 3, and a detailed description of pavement cores including core photographs are provided in Appendix V of this report.

Table 3. Summary of Pavement/Bridge Deck Cores

Pavement/Bridge Deck Core Number	Core Location	Core Type	Asphalt Thickness (Inches)	Concrete Thickness (Inches)	Aggregate Base Thickness (Inches)
B-001-0-23	Eastbound Driving Lane	Full Depth Asphalt	10.0	---	---[1]
B-002-0-23	Westbound Shoulder	Full Depth Asphalt	18.5	---	---[1]
X-001-0-23	Eastbound Bridge Deck	Reinforced Concrete	---	18.5	NA
X-002-0-23	Westbound Bridge Deck	Reinforced Concrete	---	20.0	NA
X-003-0-23	Eastbound Bridge Deck	Reinforced Concrete	---	18.0	NA
X-004-0-23	Westbound Bridge Deck	Reinforced Concrete	---	20.0	NA

1. Sand and gravel layer encountered below the pavement.

4.2 Subsurface Soils

Below the pavement section, borings B-001-0-23 and B-002-0-23 encountered granular soils to a depth of 9.5 and 7.5 feet below the existing grade, respectively. Underlying the granular soils, the soil borings generally encountered cohesive soils extended to the top of bedrock. A layer of granular soils was encountered in both borings at a depth of 20.5 feet below existing grade.

The encountered cohesive soils were described as clay, silt and clay, silty clay, sandy silt and silt (ODOT A-7-6, A-6a, A-6b, A-4a and A-4b) with varying amounts of sand and gravel. The consistency of the cohesive soils is primarily derived from the hand penetrometer values (HP). The consistency of the cohesive soils encountered ranged from soft ($0.25 \leq$ HP ≤ 0.5 tsf) to hard (HP > 4.0 tsf) with the majority of the cohesive soils exhibiting consistency ranging from soft to medium stiff. The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 0.5 to 4.0 tsf.

The encountered granular soils were described as gravel with sand, coarse and fine sand, gravel with sand and silt, and gravel with sand, silt and clay (ODOT A-1-b, A-3a, A-2-4 and A-2-6). The relative density of granular soils is primarily derived from SPT blow counts (N_{60}) values. Based on the SPT blow counts obtained, the relative density of the granular soils ranged from loose ($5 \leq N_{60} \leq 10$ blows per foot [bpf]) to dense ($30 < N_{60} \leq 50$ bpf). The blow counts of the granular soils ranged from 7 to 38 bpf.

Natural moisture contents of the cohesive soil samples tested ranged from 14 to 28 percent and the natural moisture contents of the granular soil samples tested ranged from 6 to 19 percent. The natural moisture content of the cohesive soil samples tested for plasticity index ranged from 0 to 12 percent above to their corresponding plastic limits indicating natural moisture contents to be moderately to significantly above their estimated optimum moisture levels.

4.3 Bedrock

Bedrock was encountered at depths as shown in Table 4.

Table 4. Top of Bedrock Elevations

Boring Number	Ground Surface Elevation (feet msl)	Top of Bedrock	
		Depth (feet)	Elevation (feet msl)
B-001-0-23	1043.7	89.0	954.7
B-002-0-23	1038.6	88.5	950.1

The top of bedrock was encountered in borings B-001-0-23 and B-002-0-23 at depths 89.0 and 88.5 feet below the existing grade corresponding to elevations 954.7 and 950.1 feet msl, respectively. Bedrock coring was performed upon encountering auger refusal on bedrock at depths of 90.0 and 89.0 feet below existing grade in borings B-001-0-23 and B-002-0-23, respectively. The recovered bedrock samples were described as gray, very fine to fine grained, slightly weathered, strong sandstone and black, slightly weathered, slightly strong shale.

The recovered bedrock core samples exhibited recovery values ranging from 56 to 100 percent and Rock Quality Designation (RQD) values ranging from 25 to 68 percent. Uniaxial compressive strength testing performed on selected rock core samples exhibited unconfined compressive strength (Qu) values of 7,820 psi and 9,782 psi. Detailed information of the rock cores along with rock cores photographs are provided in Appendix III, and a summary of rock core information is provided below in Table 5.

Table 5. Rock Core Summary

Boring	Core No.	Depth (feet)	Recovery (%)	RQD (%)	Remarks
B-001-0-23	RC-1	90.0-91.0	58	50	Qu @ 90.5' = 7,828 psi
	RC-2	91.0-96.0	100	68	---
	RC-3	96.0-101.0	95	43	---
B-002-0-23	RC-1	89.0-90.5	56	33	Qu @ 90.0' =9,782 psi
	RC-2	90.5-93.5	83	25	---

4.4 Groundwater

Groundwater was encountered at depths as shown below in Table 6.

Table 6. Groundwater Levels

Boring Number	Boring Depth (feet)	Ground Elevation (feet msl)	Initial Groundwater		Upon Completion [1]	
			Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-001-0-23	101.0	1043.7	9.5	1034.2	---[1]	---[1]
B-002-0-23	95.5	1038.6	13.0	1025.6	---[1]	---[1]

1. *Groundwater at completion was not measured due to the introduction of water as a circulating fluid during the rock coring process.*

Groundwater was encountered initially during drilling in borings B-001-0-23 and B-002-0-23 at depths of 9.5 and 13.0 feet below the existing ground surface, respectively. Groundwater was not measured upon the completion of drilling due to the introduction of water as a circulating fluid during the rock coring process.

Please note that short-term water level readings, especially in cohesive soils, are not necessarily an accurate indication of the actual groundwater level. In addition, groundwater levels or the presence of groundwater are considered to be dependent on seasonal fluctuations in precipitation.

A more comprehensive description of what was encountered during the drilling process may be found on the boring logs in Appendix III.

5.0 ANALYSES AND RECOMMENDATIONS

Data obtained from the subsurface exploration has been used to determine the foundation support capabilities and the settlement potential for the soils encountered at the site. These parameters have been used to provide guidelines for the design of foundation systems for the proposed bridge, as well as the construction specifications related to the placement of foundation systems and general earthwork recommendations, which are discussed in the following paragraphs.

Design details of the proposed structure were provided by Ribway via email on January 19, 2024. A summary of proposed bridge alternatives including footing elevations and loads as provided by Ribway is summarized below in Table 7.

Table 7. Summary of Bridge Design Information

Item	Substructure Unit	Bottom of Footing Elevation (feet msl)	Unfactored Load (kips)
Proposed single span bridge	Rear Abutment (B-001-0-23)	1,031.00	1067 kips per Abutment
	Forward Abutment (B-002-0-23)	1,028.00	

5.1 Driven Pile Recommendations

The soil borings drilled for the proposed bridge replacement generally encountered soft to medium stiff cohesive soils extended to the top of the bedrock. *Pile capacity analyses performed for friction piles indicated that adequate pile capacities cannot be achieved utilizing the friction piles driven within the overburden soils. For reference, utilizing a 12-inch diameter CIP pipe pile driven 72 feet below the estimated bottom of pile cap, a nominal axial geotechnical axial capacity (UBV) of 166 kips (including set up), and a nominal axial resistance at the end of the initial drive (R_{ndr}) of 122 kips were calculated.*

Rii recommends that steel H-piles (ODOT Item 507.07) driven to refusal on bedrock be employed for the proposed foundation support. The geotechnical/structural resistance recommendations for HP 10x42 piles as provided in Table 8 may be utilized for the proposed foundation design. However, if higher load per pile is anticipated for the proposed foundation then Rii should be provided the information for our analyses and recommendations revised.

Per Section 305.3.1.2 of the 2020 ODOT Bridge Design Manual (BDM), refusal is met during driving when the pile penetration is an inch or less after receiving at least 20 blows from the pile hammer. As per ODOT Geotechnical Design manual (GDM) Section 1304.1, the bearing resistance of the point bearing piles on bedrock is not limited by geotechnical resistance but by the structural resistance of the pile. Table 8 shows the recommended pile lengths and the corresponding factored structural axial resistance ($P_{R\ max}$) of the steel H-piles.

Table 8. GEA– 087 – 3.18 Driven Pile Recommendations

Item	Substructure/ Boring Location	Boring Surface Elevation (feet msl)	Pile Type and Size [1]	Pile Elevation (feet msl)		Estimated Pile Length [4] (feet)	$P_{R\ max}$ [5] (kips/pile)	φ [6]
				Top [2]	Tip [3]			
Proposed single span bridge	Rear Abutment (B-001-0-23)	1043.7	HP 10x42	1033.00	954.70	80.0	310	N/A
	Forward Abutment (B-002-0-23)	1038.6	HP 10x42	1030.00	950.10	85.0	310	N/A

1. *H-piles should consist of Grade 50 steel with a yield strength of 50 ksi.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is the sum of proposed bottom of footing/pile cap elevation plus embedment depth of pile into footing.*
3. *The pile tip elevation is based on the top of bedrock elevation in the nearest boring per Section 305.3.5.2 of the 2020 ODOT BDM.*
4. *Per Section 305.3.5.2 of the 2020 ODOT BDM, the estimated pile length was determined as the pile cutoff elevation (top) minus the pile tip elevation, rounded up to the nearest 5.0 feet. Order (furnished) length for each pile should be calculated by adding 5 feet on estimated pile length.*
5. *The factored structural axial resistance for H-piles is based on the structural limit state of the steel H-pile section per Section 305.3.3 of the 2020 ODOT BDM. Factored axial load should be resisted by factored axial structural resistance.*
6. *For H-piles driven to refusal on bedrock, no geotechnical resistance factor should be applied to the factored structural axial resistance values. Factored structural axial resistance are calculated utilizing the structural resistance factor, $\varphi_c = 0.50$, for H-piles subject to damage due to severe driving conditions.*

As stated, the factored resistance of H-piles driven to refusal on bedrock is typically governed by the structural resistance of the pile element. **The factored structural axial resistances listed in Table 8 consider an axially loaded pile with negligible moment, no appreciable loss of section due to deterioration throughout the life of the structure**, a steel yield strength of 50 ksi, a structural resistance factor for H-piles (φ_c = 0.50 per Section 6.5.4.2 of the 2020 AASHTO LRFD BDS) **and piles fully braced along the length.** Static or dynamic load testing is not required for H-piles driven to refusal on bedrock. It is anticipated that the piles will be able to be driven a few inches into the surficial bedrock before satisfying the driving conditions that meet the refusal criterion. Settlement is estimated to be less than 1.0 inch for H-piles driven to refusal on bedrock.

5.1.1 Driveability

A drivability analysis was performed in accordance with Section 10.7.8 of the 2020 AASHTO LRFD BDS using the GRLWEAP software program, and the results are provided in Appendix VI. In the driveability analysis, a Delmag 19-42 hammer with a rated energy of approximately 43,000 ft-lbs was used in conjunction with the H-pile sections. Based on the results of this analysis, driving stresses induced on the H-piles **would not exceed** 90 percent of the yield stress of the steel (f_y = 50 ksi, 0.9f_y = 45 ksi) if driven through the overburden soils to the bedrock elevations provided in Table 8. Care should be taken during pile driving operations when approaching the bedrock, and when extending the piles into the surficial bedrock material, to ensure that the driving stresses induced on the pile elements do not exceed the maximum allowable value of 90 percent of the yield stress of the steel, subsequently damaging the pile elements. Pile driving should be terminated upon achieving the required 20 blows (on bedrock) from the pile hammer with an inch or less of penetration to reduce the possibility of damaging the pile element.

5.1.2 Lateral Design

If lateral loads or moments are expected to be applied on the foundation elements, they should be analyzed to verify the pile has enough lateral and bending resistance against these loads. A boring-by-boring tabulation of parameters for lateral loading design provided in Appendix VII should be used in lateral pile analyses. In order to evaluate the lateral capacity, it is recommended that a derivation of COM624, such as LPILE, be utilized to determine the proper embedment depth required to resist the lateral load for a given end condition and deflection. Table 9 lists the eleven (11) different soil types internal to the LPILE program. These strata were utilized to define the soil strata in the soil profile for each boring provided in Appendix VII.

Table 9. Subsurface Strata Description

Strata	Description
1	Soft Clay
2	Stiff Clay with Water
3	Stiff Clay without Free Water
4	Sand (Reese)
5	User Defined
6	Vuggy Limestone (Strong Rock)
7	Silt (with cohesion and internal friction angle)
8	API Sand
9	Weak Rock
10	Liquefiable Sand (Rollins)
11	Stiff Clay without free water with a specified initial K (Brown)

5.2 Settlement Analysis

As stated, for Alternatives 1 and 2 up to approximately 6 feet of fill will be required to bring the site to the proposed grade. The new fill will be placed between the new abutments and the existing abutments.

Rii performed settlement analysis utilizing the estimated surcharge load from the proposed fill, general soil profile obtained from the field exploration, and soil parameters based on results of the soil laboratory tests. Total settlement due to the fill placement will vary across the site based on the underlying soil conditions and the height of the fill placement. It is estimated that the maximum total settlement due to the placement of the proposed embankment fill will be approximately 0.4 inches.

5.3 Scour Data

Soil borings performed for the proposed bridge replacement encountered granular soils consisting of coarse and fine sand, gravel with sand and silt (ODOT A-3a, A-1-b) and cohesive soils consisting of sandy silt, silt and clay, silty clay (ODOT A-4a, A-6a, A-6b) at or near the estimated face of the abutment elevation. Grain size analysis were performed on the soil samples recovered from near the estimated face of the abutment elevation to perform scour analysis. D_{50} value of these soil samples ranged from 0.019 mm to 0.90 mm. Additional soil parameters required for scour analysis are tabulated in Table 10.

Table 10. Parameters for Scour Analysis

Boring Number	Sample	Elevation (feet msl)	Soil Type	D_{50}, mm	τ_C (psf)	$D_{50, equiv.}$ (mm)	Erosion Category (EC)
B-001-0-23	SS-3	1037.7-1036.2	A-3a	0.339	0.0071	---	1.636
	SS-4	1036.2-1034.2	A-1-b	0.727	0.0152	---	2.034
	SS-5	1034.2-1032.7	A-4a	0.157	0.0288	1.3778	2.361
	SS-6	1032.7-1031.2	A-4a	0.135	0.0293	1.4044	2.361
B-002-0-23	SS-3	1032.6-1031.1	A-1-b	0.900	0.0188	---	2.145
	SS-4	1031.1-1029.6	A-6a	0.034	0.1724	8.257	3.075
	SS-5	1029.6-1028.1	A-6b	0.019	0.1643	7.865	3.484
	SS-6	1028.1-1026.6	A-4a	0.043	0.1546	7.404	3.168

5.4 Lateral Earth Pressure

For the soil types encountered in the borings, the "in-situ" unit weight (γ), cohesion (c), effective angle of friction (φ'), and lateral earth pressure coefficients for at-rest conditions (k_o), active conditions (k_a), and passive conditions (k_p) have been estimated and are provided in Table 11 and Table 12.

Table 11. Estimated Undrained (Short-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	c (psf)	φ	k_a	k_o	k_p
Soft to Medium Stiff Cohesive Soil	120	500	0°	N/A	N/A	N/A
Stiff Cohesive Soil	125	1,500	0°	N/A	N/A	N/A
Very Stiff to Hard Cohesive Soil	125	2,500	0°	N/A	N/A	N/A
Very Loose to Loose Granular Soil	120	0	28°	0.36	0.53	2.77
Medium Dense to Dense Granular Soil	125	0	32°	0.31	0.47	3.25
Compacted Cohesive Engineered Fill	120	2,000	0°	N/A	N/A	N/A
Compacted Granular Engineered Fill	125	0	32°	0.31	0.47	3.25

1. *When below groundwater table, use effective unit weight, $\gamma' = \gamma - 62.4$ pcf and add hydrostatic water pressure.*

Table 12. Estimated Drained (Long-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	c (psf)	φ'	k_a	k_o	k_p
Soft to Medium Stiff Cohesive Soil	120	0	22°	0.45	0.63	2.20
Stiff Cohesive Soil	125	0	26°	0.39	0.56	2.56
Very Stiff to Hard Cohesive Soil	125	0	28°	0.36	0.53	2.77
Very Loose to Loose Granular Soil	120	0	28°	0.36	0.53	2.77
Medium Dense to Dense Granular Soil	125	0	32°	0.31	0.47	3.25
Compacted Cohesive Engineered Fill	120	0	28°	0.36	0.53	2.77
Compacted Granular Engineered Fill	125	0	32°	0.31	0.47	3.25

1. *When below groundwater table, use effective unit weight, $\gamma' = \gamma - 62.4$ pcf and add hydrostatic water pressure.*

These parameters are considered appropriate for the design of all subsurface structures and any excavation support systems. Subsurface structures (where the top of the structure is restrained from movement) should be designed based on at-rest conditions (k_o). For proposed temporary retaining structures (where the top of the structure is allowed to move), earth pressure distributions should be based on active (k_a) and passive (k_p) conditions.

These recommendations do not take into consideration the effect of any surcharge loading or a sloped ground surface (a flat surface is assumed). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage. Surcharge loads, such as that imposed by traffic loading, will create additional lateral loading on the subsurface structures and excavation support systems. The resulting lateral earth pressure should be evaluated based on active (k_a) and at-rest (k_o) conditions and the anticipated magnitude of the loading.

Where necessary, temporary retaining structures, such as sheet pile system, should be designed using the undrained soil parameters provided in Table 11, and the design should follow all applicable guidelines for the type of retaining structure utilized. Permanent retaining and subsurface structures should be designed using the drained soil parameters provided in Table 12. Regardless of whether the retaining structure is temporary or permanent, the effective unit weight ($\gamma' = \gamma - 62.4$ pcf) plus the hydrostatic water pressure ($\gamma_w * h_w$, where h_w is the height of water behind the wall above the base of the wall) should be utilized below the design groundwater level. The lateral earth pressure coefficients should only be applied to the horizontal pressure resulting from the effective overburden pressure, and should not be applied to the hydrostatic water pressure.

5.5 Construction Considerations

All site work shall conform to local codes and to the latest ODOT Construction and Materials Specifications (CMS), including that all excavation and embankment preparation and construction should follow ODOT Item 200 (Earthwork).

5.5.1 Excavation Considerations

All excavations should be shored / braced or laid back at a safe angle in accordance with Occupational Safety and Health Administration (OSHA) guidelines. During excavation, if slopes cannot be laid back to OSHA Standards due to adjacent structures or other obstructions, temporary shoring may be required. The following table should be utilized as a general guide for implementing OSHA guidelines when estimating excavation back slopes at the various boring locations. Actual excavation back slopes must be field verified by qualified personnel at the time of excavation in strict accordance with OSHA guidelines.

Table 13. Excavation Back Slopes

Soil	Maximum Back Slope	Notes
Soft to Medium Stiff Cohesive	1.5 : 1.0	Above Ground Water Table and No Seepage
Stiff Cohesive	1.0 : 1.0	Above Ground Water Table and No Seepage
Very Stiff to Hard Cohesive	0.75 : 1.0	Above Ground Water Table and No Seepage
All Granular & Cohesive Soil Below Ground Water Table or with Seepage	1.5 : 1.0	None

5.5.2 Groundwater Considerations

Groundwater should be anticipated at or near the elevation as indicated in Table 6. Additionally, groundwater conditions affecting construction may be encountered within the trapped/perched zones. These trapped/perched zones are generally the layer(s) of granular soils that are isolated within the fine-grained soil layers and may not be identified in boring logs.

Groundwater, wherever encountered, proper groundwater control measures should be implemented to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or “boiling” condition if soft/loose silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36.0 inches below the deepest excavation. Note that determining and maintaining actual groundwater levels during construction is the responsibility of the contractor.

6.0 LIMITATIONS OF STUDY

The above recommendations are predicated upon construction inspection by a qualified soil technician under the direct supervision of a professional geotechnical engineer. Adequate testing and inspection during construction are considered necessary to assure an adequate foundation system and are part of these recommendations.

The recommendations for this project were developed utilizing soil and bedrock information obtained from the test borings that were made at the proposed site for the current investigation. Resource International is not responsible for the data, conclusions, opinions or recommendations made by others during previous investigations at this site. At this time we would like to point out that soil borings only depict the soil and bedrock conditions at the specific locations and time at which they were made. The conditions at other locations on the site may differ from those occurring at the boring locations.

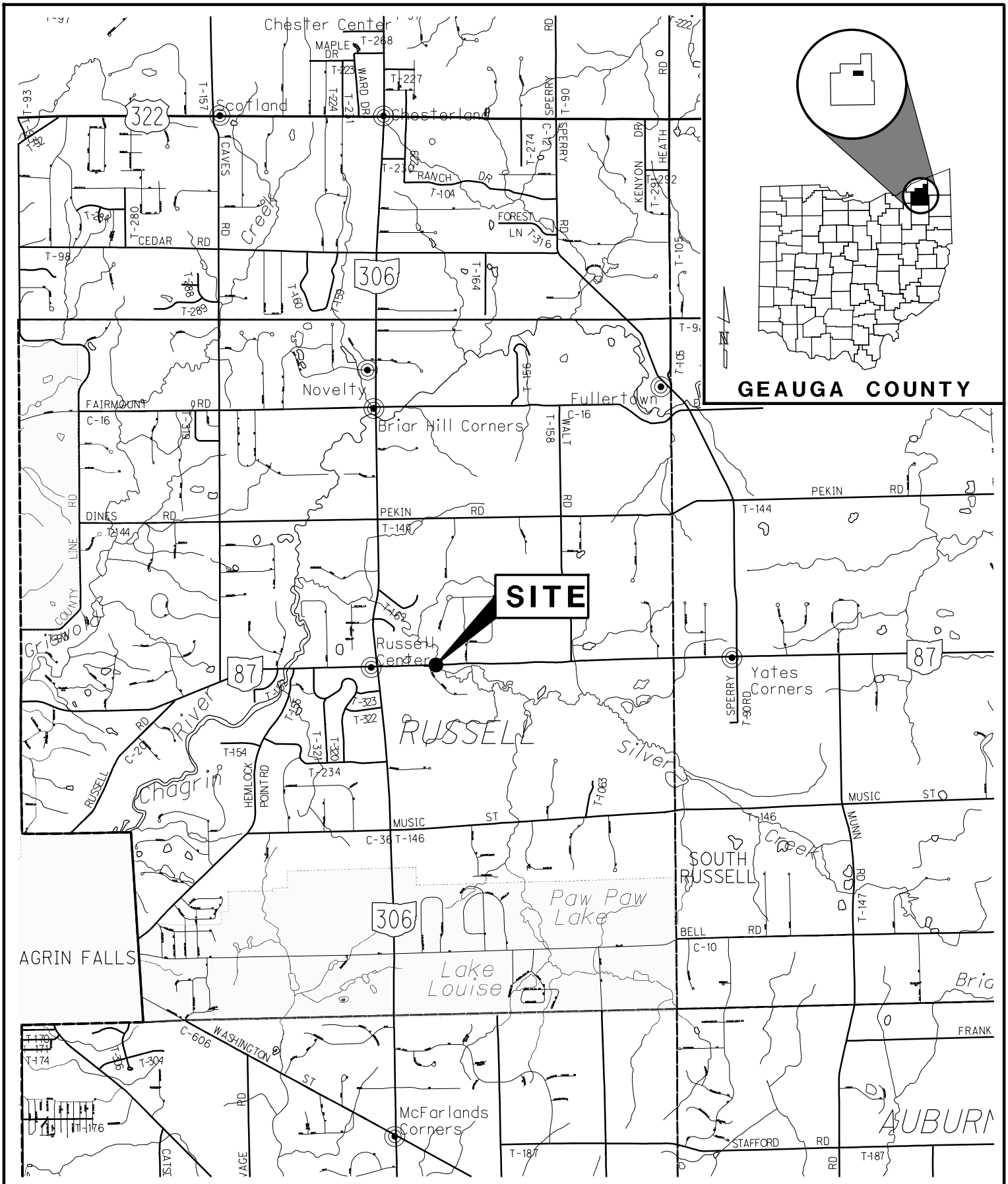
The conclusions and recommendations herein have been based upon the available soil and bedrock information and the design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be brought to the attention of the geotechnical engineer to determine whether any changes in the foundation or earthwork recommendations are necessary. If deviations from the noted subsurface conditions are encountered during construction, they should also be brought to the attention of the geotechnical engineer.

The scope of our services does not include any environmental assessment or investigation for the presence or absence of hazardous or toxic materials in the soil, groundwater or surface water within or beyond the site studied. Any statements in this report or on the test boring logs regarding odors, staining of soils or other unusual conditions observed are strictly for the information of our client.

Our professional services have been performed, our findings obtained and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. Resource International is not responsible for the conclusions, opinions or recommendations made by others based upon the data included.

APPENDIX I

VICINITY MAP AND BORING PLAN



VICINITY MAP

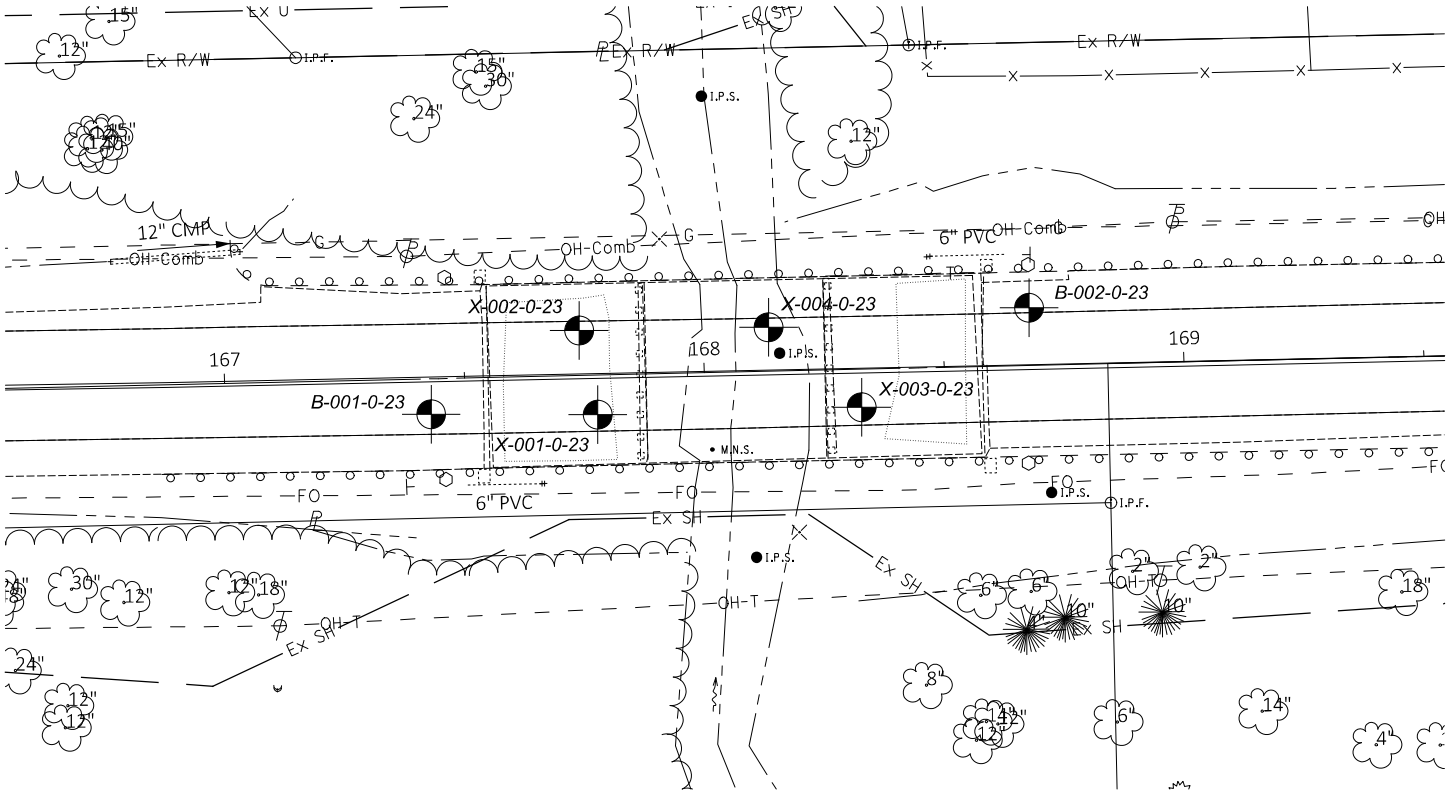
GEA-087-03.18 BRIDGE REPLACEMENT

PID 110999

GEAUGA COUNTUY, OHIO

RII PROJECT NO. N-23-023	DRAWN JAS
SCALE: 1"=5000' (0, 2500, 5000)	REVIEWED AG
	DATE 8/14/2023

RESOURCE INTERNATIONAL Rii



BORING PLAN

GEA-087-03.18 BRIDGE REPLACEMENT PID 110999

GEAUGA COUNTUY, OHIO

RII PROJECT NO. N-23-023	DRAWN JAS
SCALE: 1"=20' (0 10 20) N	REVIEWED AG
	DATE 8/14/2023

APPENDIX II

DESCRIPTION OF SOIL TERMS

CLASSIFICATION OF SOILS

Ohio Department of Transportation

(The classification of a soil is found by proceeding from top to bottom of the chart.
The first classification that the test data fits is the correct classification.)

SYMBOL	DESCRIPTION	Classifcation		LL_O/LL x 100*	% Pass #40	% Pass #200	Liquid Limit (LL)	Plastic Index (PI)	Group Index Max.	REMARKS
		AASHTO	OHIO							
	Gravel and/or Stone Fragments	A-1-a			30 Max.	15 Max.		6 Max.	0	Min. of 50% combined gravel, cobble and boulder sizes
	Gravel and/or Stone Fragments with Sand	A-1-b			50 Max.	25 Max.		6 Max.	0	
	Fine Sand	A-3			51 Min.	10 Max.	NON-PLASTIC		0	
	Coarse and Fine Sand	--	A-3a			35 Max.		6 Max.	0	Min. of 50% combined coarse and fine sand sizes
	Gravel and/or Stone Fragments with Sand and Silt	A-2-4				35 Max.	40 Max.	10 Max.	0	
		A-2-5					41 Min.			
	Gravel and/or Stone Fragments with Sand, Silt and Clay	A-2-6				35 Max.	40 Max.	11 Min.	4	
		A-2-7					41 Min.			
	Sandy Silt	A-4	A-4a	76 Min.		36 Min.	40 Max.	10 Max.	8	Less than 50% silt sizes
	Silt	A-4	A-4b	76 Min.		50 Min.	40 Max.	10 Max.	8	50% or more silt sizes
	Elastic Silt and Clay	A-5		76 Min.		36 Min.	41 Min.	10 Max.	12	
	Silt and Clay	A-6	A-6a	76 Min.		36 Min.	40 Max.	11 - 15	10	
	Silty Clay	A-6	A-6b	76 Min.		36 Min.	40 Max.	16 Min.	16	
	Elastic Clay	A-7-5		76 Min.		36 Min.	41 Min.	$\leq$LL-30	20	
	Clay	A-7-6		76 Min.		36 Min.	41 Min.	>LL-30	20	
	Organic Silt	A-8	A-8a	75 Max.		36 Min.				W/o organics would classify as A-4a or A-4b
	Organic Clay	A-8	A-8b	75 Max.		36 Min.				W/o organics would classify as A-5, A-6a, A-6b, A-7-5 or A-7-6

MATERIAL CLASSIFIED BY VISUAL INSPECTION

 Sod and Topsoil

 Pavement or Base

 Uncontrolled Fill (Describe)

 Bouldery Zone

Peat

* Only perform the oven-dried liquid limit test and this calculation if organic material is present in the sample.

DESCRIPTION OF SOIL TERMS

The following terminology was used to describe soils throughout this report and is generally adapted from ASTM 2487/2488 and ODOT Specifications for Geotechnical Explorations.

Granular Soils - The relative compactness of granular soils is described as:
ODOT A-1, A-2, A-3, A-4 (non-plastic) or USCS GW, GP, GM, GC, SW, SP, SM, SC, ML (non-plastic)

Description	Blows per foot – SPT (N_{60})		
Very Loose	Below		5
Loose	5	-	10
Medium Dense	11	-	30
Dense	31	-	50
Very Dense	Over		50

Cohesive Soils - The relative consistency of cohesive soils is described as:
ODOT A-4, A-5, A-6, A-7, A-8 or USCS ML, CL, OL, MH, CH, OH, PT

Description	Unconfined Compression (tsf)		
Very Soft	Less than		0.25
Soft	0.25	-	0.5
Medium Stiff	0.5	-	1.0
Stiff	1.0	-	2.0
Very Stiff	2.0	-	4.0
Hard	Over		4.0

Gradation - The following size-related denominations are used to describe soils:

Soil Fraction		USCS Size	ODOT Size
Boulders		Larger than 12”	Larger than 12”
Cobbles		12” to 3”	12” to 3”
Gravel	coarse	3” to ¾”	3” to ¾“
	fine	¾” to 4.75 mm (¾” to #4 Sieve)	¾” to 2.0 mm (¾” to #10 Sieve)
Sand	coarse	4.75 mm to 2.0 mm (#4 to #10 Sieve)	2.0 mm to 0.42 mm (#10 to #40 Sieve)
	medium	2.0 mm to 0.42 mm (#10 to #40 Sieve)	-
	fine	0.42 mm to 0.074 mm (#40 to #200 Sieve)	0.42 mm to 0.074 mm (#40 to #200 Sieve)
Silt		0.074 mm to 0.005 mm (#200 to 0.005 mm)	0.074 mm to 0.005 mm (#200 to 0.005 mm)
Clay		Smaller than 0.005 mm	Smaller than 0.005 mm

Modifiers of Components - Modifiers of components are as follows:

Term	Range		
Trace	0%	-	10%
Little	10%	-	20%
Some	20%	-	35%
And	35%	-	50%

Moisture Table - The following moisture-related denominations are used to describe cohesive soils:

Term	Range - USCS	Range - ODOT
Dry	0% to 10%	Well below Plastic Limit
Damp	>2% below Plastic Limit	Below Plastic Limit
Moist	2% below to 2% above Plastic Limit	Above PL to 3% below LL
Very Moist	>2% above Plastic Limit	
Wet	≥ Liquid Limit	3% below LL to above LL

Organic Content – The following terms are used to describe organic soils:

Term	Organic Content (%)
Slightly organic	2-4
Moderately organic	4-10
Highly organic	>10

Bedrock – The following terms are used to describe the relative strength of bedrock:

Description	Field Parameter
Very Weak	Can be carved with knife and scratched by fingernail. Pieces 1 in. thick can be broken by finger pressure.
Weak	Can be grooved or gouged with knife readily. Small, thin pieces can be broken by finger pressure.
Slightly Strong	Can be grooved or gouged 0.05 in deep with knife. 1 in. size pieces from hard blows of geologist hammer.
Moderately Strong	Can be scratched with knife or pick. 1/4 in. size grooves or gouges from blows of geologist hammer.
Strong	Can be scratched with knife or pick with difficulty. Hard hammer blows to detach hand specimen.
Very Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to detach hand specimen.
Extremely Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to chip hand specimen.

DESCRIPTION OF ROCK TERMS

The following terminology was used to describe the rock throughout this report and is generally adapted from ASTM D5878 and the ODOT Specifications for Geotechnical Explorations.

Weathering – Describes the degree of weathering of the rock mass:

Description	Field Parameter
Unweathered	No evidence of any chemical or mechanical alteration of the rock mass. Mineral crystals have a right appearance with no discoloration. Fractures show little or not staining on surfaces.
Slightly Weathered	Slight discoloration of the rock surface with minor alterations along discontinuities. Less than 10% of the rock volume presents alteration.
Moderately Weathered	Portions of the rock mass are discolored as evident by a dull appearance. Surfaces may have a pitted appearance with weathering "halos" evident. Isolated zones of varying rock strengths due to alteration may be present. 10 to 15% of the rock volume presents alterations.
Highly Weathered	Entire rock mass appears discolored and dull. Some pockets of slightly to moderately weathered rock may be present and some areas of severely weathered materials may be present.
Severely Weathered	Majority of the rock mass reduced to a soil-like state with relic rock structure discernable. Zones of more resistant rock may be present but the material can generally be molded and crumbled by hand pressures.

Strength of Bedrock – The following terms are used to describe the relative strength of bedrock:

Description	Field Parameter
Very Weak	Can be carved with knife and scratched by fingernail. Pieces 1 in. thick can be broken by finger pressure.
Weak	Can be grooved or gouged with knife readily. Small, thin pieces can be broken by finger pressure.
Slightly Strong	Can be grooved or gouged 0.05 in deep with knife. 1 in. size pieces from hard blows of geologist hammer.
Moderately Strong	Can be scratched with knife or pick. 1/4 in. size grooves or gouges from blows of geologist hammer.
Strong	Can be scratched with knife or pick with difficulty. Hard hammer blows to detach hand specimen.
Very Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to detach hand specimen.
Extremely Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to chip hand specimen.

Bedding Thickness – Description of bedding thickness as the average perpendicular distances between bedding surfaces:

Description	Thickness
Very Thick	Greater than 36 inches
Thick	18 to 36 inches
Medium	10 to 18 inches
Thin	2 to 10 inches
Very Thin	0.4 to 2 inches
Laminated	0.1 to 0.4 inches
Thinly Laminated	Less than 0.1 inches

Fracturing – Describes the degree and condition of fracturing (fault, joint, or shear):

Degree of Fracturing

Description	Spacing
Unfractured	Greater than 10 feet
Intact	3 to 10 feet
Slightly Fractured	1 to 3 feet
Moderately Fractured	

Aperture Width

Description	Width
Open	Greater than 0.2 inches
Narrow	0.05 to 0.2 inches
Tight	Less than 0.05 inches

Surface Roughness

Description	Criteria
Very Rough	Near vertical steps and ridges occur on surface
Slightly Rough	Asperities on the surfaces distinguishable
Slickensided	Surface has smooth, glassy finish, evidence of Striations

RQD – Rock Quality Designation (calculation shown in report) and Rock Quality (ODOT, GB 3, January 13, 2006):

RQD %	Rock Index Property Classification (based on RQD, not slake durability index)
0 – 25%	Very Poor
26 – 50%	Poor
51 – 70%	Fair
71 – 85%	Good
86 – 100%	Very Good

APPENDIX III

BORING LOGS: B-001-0-23 and B-002-0-23

ROCK CORE PHOTOGRAPHS

BORING LOGS

Definitions of Abbreviations

AS = Auger sample

GI = Group index as determined from the Ohio Department of Transportation classification system

HP = Unconfined compressive strength as determined by a hand penetrometer (tons per square foot)

LL_o = Oven-dried liquid limit as determined by ASTM D4318. Per ASTM D2487, if LL_o/LL is less than 75 percent, soil is classified as "organic".

LOI = Percent organic content (by weight) as determined by ASTM D2974 (loss on ignition test)

PID = Photo-ionization detector reading (parts per million)

QR = Unconfined compressive strength of intact rock core sample as determined by ASTM D2938 (pounds per square inch)

QU = Unconfined compressive strength of soil sample as determined by ASTM D2166 (pounds per square foot)

RC = Rock core sample

REC = Ratio of total length of recovered soil or rock to the total sample length, expressed as a percentage

RQD = Rock quality designation – estimate of the degree of jointing or fracture in a rock mass, expressed as a percentage:

$$\frac{\sum \text{segments equal to or longer than 4.0 inches}}{\text{core run length}} \times 100$$

S = Sulfate content (parts per million)

SPT = Standard penetration test blow counts, per ASTM D1586. Driving resistance recorded in terms of blows per 6-inch interval while letting a 140-pound hammer free fall 30 inches to drive a 2-inch outer diameter (O.D.) split spoon sampler a total of 18 inches. The second and third intervals are added to obtain the number of blows per foot (N_m).

N_{60} = Measured blow counts corrected to an equivalent (60 percent) energy ratio (ER) by the following equation: $N_{60} = N_m*(ER/60)$

SS = Split spoon sample

2S = For instances of no recovery from standard SS interval, a 2.5 inch O.D. split spoon is driven the full length of the standard SS interval plus an additional 6.0 inches to obtain a representative sample. Only the final 6.0 inches of sample is retained. Blow counts from 2S sampling are not correlated with N_{60} values.

3S = Same as 2S, but using a 3.0 inch O.D. split spoon sampler.

TR = Top of rock

W = Initial water level measured during drilling

▼ = Water level measured at completion of drilling

Classification Test Data

Gradation (as defined on Description of Soil Terms):

GR = % Gravel
SA = % Sand
SI = % Silt
CL = % Clay

Atterberg Limits:

LL = Liquid limit
PL = Plastic limit
PI = Plasticity Index

WC = Water content (%)

RESOURCE INTERNATIONAL, INC.

PROJECT: GEA-087-03.18	DRILLING FIRM / OPERATOR: RII / LH/SD	DRILL RIG: CME 55 (386345)	STATION / OFFSET: 167+43 / 7' RT	EXPLORATION ID B-001-0-23
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: RII / KC	HAMMER: AUTOMATIC	ALIGNMENT: EX. CL GEA 87	
PID: 110999 SFN:	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 3/21/22	ELEVATION: 1043.7 (MSL) EOB: 101.0 ft.	PAGE 1 OF 4
START: 7/19/23 END: 7/19/23	SAMPLING METHOD: SPT	ENERGY RATIO (%): 87	LAT / LONG: 40.238705, -89.098415	

MATERIAL DESCRIPTION AND NOTES	ELEV. 1043.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.8' - ASPHALT (10.0")	1042.9																	
MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, SOME FINE GRAVEL, LITTLE SILT, TRACE CLAY, MOIST.			6 6 6	17	78	SS-1	-	-	-	-	-	-	-	-	-	7	A-3a (V)	
			7 6 4	15	78	SS-2	-	-	-	-	-	-	-	-	-	7	A-3a (V)	
			9 5 7	17	67	SS-3	-	25	21	29	19	6	NP	NP	NP	7	A-3a (0)	
	1035.7																	
LOOSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET.	1034.2	W 1034.2	6 3 2	7	0	SS-4	-	-	-	-	-	-	-	-	-	-		
			2	-	100	2S-4A	-	40	16	20	18	6	18	17	1	12	A-1-b (0)	
SOFT TO MEDIUM STIFF, GRAYISH BROWN **SANDY SILT**, LITTLE CLAY, LITTLE FINE GRAVEL, MOIST.			1 1 1	3	61	SS-5	0.75	15	19	27	26	13	19	14	5	15	A-4a (1)	
			2 3 2	7	67	SS-6	0.50	16	17	25	28	14	19	14	5	16	A-4a (1)	
	1030.7																	
SOFT TO STIFF, GRAY **CLAY**, SOME SILT, TRACE FINE SAND, TRACE FINE GRAVEL, DAMP TO MOIST.			3 3 5	12	67	SS-7	0.50	-	-	-	-	-	-	-	-	14	A-7-6 (V)	
			4 3 3	9	67	SS-8	1.75	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
-QU @ 19.0' = 0.54 TSF					100	ST-9	2.00	1	0	1	23	75	45	22	23	28	A-7-6 (14)	
	1023.2																	
MEDIUM DENSE TO DENSE, GRAY **GRAVEL WITH SAND AND SILT**, WET.			8 11 14	36	89	SS-10	-	-	-	-	-	-	-	-	-	14	A-2-4 (V)	
			10 7 9	23	78	SS-11	-	-	-	-	-	-	-	-	-	20	A-2-4 (V)	

PID: 110999	SFN:	PROJECT: GEA-087-03.18	STATION / OFFSET: 16743, 7' RT.	START: 7/19/23	END: 7/19/23	PG 2 OF 4	B-001-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM DENSE TO DENSE, GRAY **GRAVEL WITH SAND AND SILT**, WET. *(continued)*	1018.7	26																
		27	12 13 13	38	100	SS-12	-	-	-	-	-	-	-	-	-	18	A-2-4 (V)	
	1015.7	28																
MEDIUM STIFF TO STIFF, GRAY **SILT AND CLAY**, TRACE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP TO MOIST.		29	3 3 3	9	89	SS-13	1.50	-	-	-	-	-	-	-	-	25	A-6a (V)	
		30																
		31																
		32																
		33																
		34	2 3 4	10	89	SS-14	1.00	-	-	-	-	-	-	-	-	23	A-6a (V)	
		35																
		36																
		37																
-QU @ 38.0' = 0.17 TSF		38																
		39			100	ST-15	1.00	1	1	4	39	55	33	18	15	26	A-6a (10)	
	1001.7	40																
MEDIUM STIFF, GRAY **SANDY SILT**, TRACE CLAY, TRACE FINE GRAVEL, DAMP.		41																
		42																
		43																
		44	3 4 6	15	78	SS-16	1.00	-	-	-	-	-	-	-	-	12	A-6a (V)	
	996.7	45																
MEDIUM STIFF TO STIFF, GRAY **SILT AND CLAY**, TRACE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP TO MOIST.		46																
		47																
		48																
		49	3 3 5	12	94	SS-17	1.25	-	-	-	-	-	-	-	-	16	A-6a (V)	
		50																
		51																

PID: 110999	SFN:	PROJECT: GEA-087-03.18	STATION / OFFSET: 16743, 7' RT.	START: 7/19/23	END: 7/19/23	PG 3 OF 4	B-001-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV. 991.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM STIFF TO STIFF, GRAY **SILT AND CLAY**, TRACE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP TO MOIST. *(continued)*		52																
		53																
		54	5 5 6	16	100	SS-18	1.00	-	-	-	-	-	-	-	-	19	A-6a (V)	
		55																
		56																
		57																
		58																
		59	3 5 7	17	100	SS-19	1.25	-	-	-	-	-	-	-	-	20	A-6a (V)	
		60																
		61																
		62																
		63																
		64	1 4 6	15	89	SS-20	0.75	-	-	-	-	-	-	-	-	18	A-6a (V)	
		65																
		66																
		67																
		68																
		69	6 5 8	19	100	SS-21	1.25	-	-	-	-	-	-	-	-	18	A-6a (V)	
		70																
		71																
		72																
		73																
		74	5 5 6	16	100	SS-22	1.50	-	-	-	-	-	-	-	-	18	A-6a (V)	
		75																
		76																
		77																
		78																

PID: 110999	SFN:	PROJECT: GEA-087-03.18	STATION / OFFSET: 16743, 7' RT.	START: 7/19/23	END: 7/19/23	PG 4 OF 4	B-001-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV. 965.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM STIFF TO STIFF, GRAY **SILT AND CLAY**, TRACE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP TO MOIST. *(continued)*		79	3 4 4	12	94	SS-23	2.00	-	-	-	-	-	-	-	-	18	A-6a (V)	
	961.7	80																
VERY DENSE, GRAY **SANDY SILT**, TRACE CLAY, TRACE FINE GRAVEL, MOIST.		81																
		82																
		83																
		84	5 11 31	61	83	SS-24	0.75	3	13	40	35	9	NP	NP	NP	17	A-4a (2)	
		85																
		86																
		87																
		88																
	954.7	89	22 50/5"	-	155	SS-25A	0.75	-	-	-	-	-	-	-	-	14	A-4a (V)	
SANDSTONE : GRAY, HIGHLY WEATHERED. AUGER REFUSAL @ 90.0'	953.7	TR				SS-25B	-	-	-	-	-	-	-	-	-	9	Rock (V)	
SANDSTONE : GRAY, SLIGHTLY WEATHERED, STRONG, VERY FINE TO FINE GRAINED, MEDIUM BEDDED, MODERATELY FRACTURED, NARROW TO OPEN APERTURE WIDTH, SLIGHTLY ROUGHSURFACE ROUGHNESS. -QU @ 90.5' = 7,820 PSI -1" SHALE SEAM @ 91.0'		90	50		58	NQ-1												CORE
		91																
		92																
		93	68		100	NQ-2												CORE
		94																
-2" SHALE SEAM @ 93.5', 94.0' AND 95.8'	947.7	95																
SHALE : BLACK, SLIGHTLY WEATHERED, SLIGHTLY STRONG, VERY THIN, FRACTURED TO MODERATELY FRACTURED, NARROW APERATURE WIDTH, SLIGHTLY ROUGH SURFACE ROUGHNESS.		96																
		97																
		98	43		95	NQ-3												CORE
		99																
		100																
	942.7	EOB 101																

NOTES: SEEPAGE @ 9.0'; GROUNDWATER ENCOUNTERED INITIALLY @ 9.5'; CAVE-IN DEPTH @ 5.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 50 LBS BENTONITE CHIPS AND SOIL CUTTINGS. PAVEMENT PATCHED WITH CONCRETE. .

RESOURCE INTERNATIONAL, INC.

PROJECT: GEA-087-03.18	DRILLING FIRM / OPERATOR: RII / LH/SD	DRILL RIG: CME 55 (386345)	STATION / OFFSET: 168+68 / 12' LT	EXPLORATION ID B-002-0-23
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: RII / KC	HAMMER: AUTOMATIC	ALIGNMENT: EX. CL GEA 87	
PID: 110999 SFN:	DRILLING METHOD: 3.25" HSA / NQ	CALIBRATION DATE: 3/21/22	ELEVATION: 1038.6 (MSL) EOB: 95.5 ft.	PAGE 1 OF 4
START: 7/17/23 END: 7/18/23	SAMPLING METHOD: SPT	ENERGY RATIO (%): 87	LAT / LONG: 40.238792, -89.097976	

MATERIAL DESCRIPTION AND NOTES	ELEV. 1038.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
1.5' - ASPHALT (18.5")	1037.1																	
MEDIUM DENSE, BROWN AND GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST.	1031.1		3 4 5	13	56	SS-1	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
			6 5 5	15	89	SS-2	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
			8 3 5	12	72	SS-3	-	39	21	23	13	4	NP	NP	NP	7	A-1-b (0)	
STIFF, GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.	1029.6		9 4 5	13	100	SS-4	1.75	8	11	20	36	25	26	15	11	16	A-6a (6)	
MEDIUM STIFF, BROWN **SILTY CLAY**, SOME FINE TO COARSE SAND, TRACE FINE GRAVEL, MOIST.	1028.1		2 2 2	6	61	SS-5	0.75	2	5	23	39	31	32	16	16	24	A-6b (9)	
SOFT, BROWN TO GRAY **SILT AND CLAY**, "AND" COARSE TO FINE SAND, MOIST.		W 1025.6	2 1 2	4	89	SS-6	0.50	0	2	40	35	23	29	17	12	17	A-6a (5)	
-QU @ 13.5' = 0.24 TSF					100	ST-7	0.50	-	-	-	-	-	-	-	-	18	A-6a (V)	
			2 2 3	7	72	SS-8	0.50	-	-	-	-	-	-	-	-	21	A-6a (V)	
	1018.1		4 1 7	12	61	SS-9	0.50	-	-	-	-	-	-	-	-	17	A-6a (V)	
MEDIUM DENSE TO DENSE, GRAYISH BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, WET.			5 7 7	20	78	SS-10	-	13	35	37	9	6	29	17	12	19	A-2-6 (0)	
			11 9 13	32	100	SS-11	-	-	-	-	-	-	-	-	-	11	A-2-6 (V)	

PID: 110999	SFN:	PROJECT: GEA-087-03.18	STATION / OFFSET: 16868, 12' LT.	START: 7/17/23	END: 7/18/23	PG 2 OF 4	B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
	1013.6																	
MEDIUM STIFF TO STIFF, GRAY **SANDY SILT**, LITTLE CLAY, TRACE FINE GRAVEL, WET.	1013.1	26																
		27	10 8 6	20	89	SS-12	1.00	-	-	-	-	-	-	-	-	20	A-4a (V)	
		28																
		29	3 3 4	10	94	SS-13	1.25	2	1	40	37	20	15	12	3	20	A-4a (4)	
		30																
		31																
	1006.6	32																
SOFT TO STIFF, BROWN TO GRAY **SILT**, SOME CLAY, TRACE FINE SAND, MOIST.		33																
		34	5 2 4	9	83	SS-14	1.50	-	-	-	-	-	-	-	-	19	A-4b (V)	
		35																
		36																
		37																
		38	4 3 3	9	83	SS-15	0.50	-	-	-	-	-	-	-	-	22	A-4b (V)	
		39																
		40																
		41																
		42																
		43																
		44	2 1 1	3	72	SS-16	-	0	0	1	66	33	26	18	8	21	A-4b (8)	
		45																
		46																
		47																
		48																
		49	0 1 3	6	100	SS-17	0.50	-	-	-	-	-	-	-	-	17	A-4b (V)	
		50																
		51																

PID: 110999	SFN:	PROJECT: GEA-087-03.18	STATION / OFFSET: 16868, 12' LT.	START: 7/17/23	END: 7/18/23	PG 3 OF 4	B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV. 986.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SOFT TO STIFF, BROWN TO GRAY **SILT**, SOME CLAY, TRACE FINE SAND, MOIST. *(continued)*		52																
		53																
		54	0 0 3	4	78	SS-18	0.50	-	-	-	-	-	-	-	-	16	A-4b (V)	
		55																
		56																
		57																
		58																
		59	3 4 4	12	89	SS-19	1.50	-	-	-	-	-	-	-	-	16	A-4b (V)	
		60																
		61																
		62																
		63																
		64	4 4 7	16	100	SS-20	1.00	-	-	-	-	-	-	-	-	13	A-4b (V)	
		65																
	972.1	66																
SOFT TO VERY STIFF, GRAY **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, DAMP TO MOIST.		67																
		68																
		69	3 5 6	16	89	SS-21	0.50	2	6	17	42	33	23	14	9	14	A-4a (8)	
		70																
		71																
		72																
		73																
		74	4 4 7	16	89	SS-22	0.50	-	-	-	-	-	-	-	-	15	A-4a (V)	
		75																
		76																
		77																
		78																

PID: 110999	SFN:	PROJECT: GEA-087-03.18	STATION / OFFSET: 16868, 12' LT.	START: 7/17/23	END: 7/18/23	PG 4 OF 4	B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV. 960.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SOFT TO VERY STIFF, GRAY **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, DAMP TO MOIST. *(continued)*		79	4 1 2	4	72	SS-23	-	-	-	-	-	-	-	-	-	17	A-4a (V)	
		80																
		81																
		82																
		83																
		84	22 34 37	103	83	SS-24	4.00	-	-	-	-	-	-	-	-	9	A-4a (V)	
		85																
		86																
		87																
		88																
	950.1	TR																
SANDSTONE : GRAY, HIGHLY WEATHERED. AUGER REFUSAL @ 89.0'	949.6	89	50/0"	-		SS-25	-	-	-	-	-	-	-	-	-	-		
SANDSTONE : GRAY, SLIGHTLY WEATHERED, STRONG, VERY FINE TO FINE GRAINED, MEDIUM BEDDED, MODERATELY FRACTURED, NARROW APERTURES, SLIGHTLY ROUGH SURFACE CONDITION. -QU @ 90.0' = 9,782 PSI		90	33		56	NQ-1												CORE
	947.1	91																
SHALE : BLACK, SLIGHTLY WEATHERED, SLIGHTLY STRONG, VERY THIN BEDDED, FRACTURED TO MODERATELY FRACTURED, NARROW APERATURE WIDTH, SLIGHTLY ROUGH SURFACE CONDITION.		92																
		93	25		83	NQ-2												CORE
		94																
	943.1	95 EOB																

NOTES: SEEPAGE @ 10.5'; GROUNDWATER ENCOUNTERED INITIALLY @ 13.0'; CAVE-IN DEPTH @ 17.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 94 LBS CEMENT / 25 LBS BENTONITE POWDER / 40 GAL WATER. PAVEMENT PATCHED WITH CONCRETE .

Project Name: GEA-087-3.18 Structure Replacement	Location: Geauga County, Ohio	Project No.: RII. N-23-023

Photo No. 1	
Boring: B-001-0-23	
RC-1: 90.0'-91.0' REC (%):58 RQD (%):50	
RC-2: 91.0'-96.0' REC (%):100 RQD (%):68	

Project Name: GEA-087-3.18 Structure Replacement	Location: Geauga County, Ohio	Project No.: RII. N-23-023

Photo No. 2	
Boring: B-001-0-23	
RC-3: 96'-101' REC (%):95 RQD (%):43	

Project Name: GEA-087-3.18 Structure Replacement	Location: Geauga County, Ohio	Project No.: RII. N-23-023

Photo No. 3	
Boring: B-002-0-23	
RC-1: 89.0'-90.5' REC (%):56 RQD (%):33	
RC-2: 90.5'-95.5' REC (%):83 RQD (%):25	

APPENDIX IV

LABORATORY TEST RESULTS

6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

UNCONFINED COMPRESSION

ASTM D2166

PROJECT	GEA-087-3.18
JOB No.	N-23-023
BORING	B-001-0-23
STATION / OFFSET	167+43; 7 ft Rt
SAMPLE No. / DEPTH	ST-9/19'-19.5'
DATE OF TESTING	07/26/2023
TESTED BY	ML

Soil Description: Gray Clay
Soil Classification: A-7-6

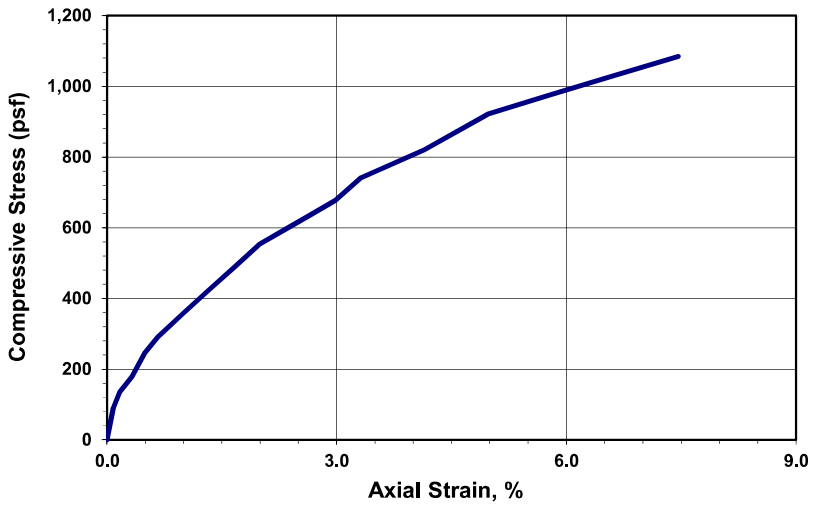
Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	Sand%	Silt%	Clay%
	45	22	23	1	1	23	75

DIAMETER, D_0	2.852 in	72.4 mm	STRAIN RATE	2.00	%/min
AREA, A_0	6.390 in^2	41.2 cm^2	WET SOIL + PAN MASS	1423.8	g
HEIGHT, L_0	6.032 in	153.22 mm	PAN MASS	179.8	g
VOLUME, V_0	38.546 in^3	631.65 cm^3	DRY SOIL + PAN MASS	1136.3	g
MACH. RATE	0.121 in/min		WET DENSITY	122.94	lb/ft^3
WATER CONT.	30.05 %		DRY DENSITY	94.53	lb/ft^3

UNCONFINED COMPRESSION STRESS, q_u	**1,084** psf	0.54	tsf
AXIAL STRAIN @ FAILURE		7.46	%
HAND PENETROMETER		1.25	tsf

Failure Sketch

Unconfined Compression Test



6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

UNCONFINED COMPRESSION

ASTM D2166

PROJECT	GRA-087-3.18
JOB No.	N-23-023
BORING	B-001-0-23
STATION / OFFSET	167+43; 12' Lt
SAMPLE No. / DEPTH	ST-15/38'-38.5'
DATE OF TESTING	07/26/2023
TESTED BY	ML

Soil Description: Gray Silt and Clay
Soil Classification: A-6a

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	Sand%	Silt%	Clay%
	33	18	15	1	5	39	55

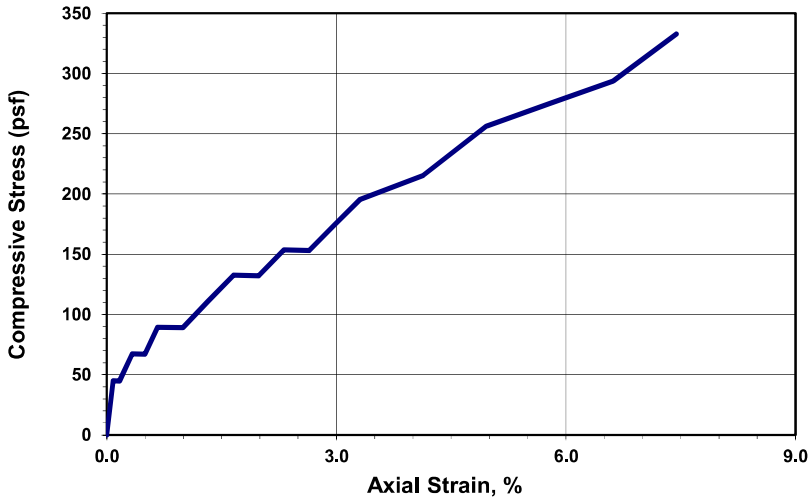
DIAMETER, D_0	2.856	in	72.6	mm		
AREA, A_0	6.408	in^2	41.3	cm^2		
HEIGHT, L_0	6.047	in	153.59	mm		
VOLUME, V_0	38.7479	in^3	634.96	cm^3		
MACH. RATE	0.121	in/min				
WATER CONT.	29.83	%				

STRAIN RATE	2.00	%/min		
WET SOIL + PAN MASS	1412.0	g		
PAN MASS	177.9	g		
DRY SOIL + PAN MASS	1128.4	g		
WET DENSITY	121.32	lb/ft^3		
DRY DENSITY	93.45	lb/ft^3		

UNCONFINED COMPRESSION STRESS, q_u	**333**	**psf**	0.17	tsf
AXIAL STRAIN @ FAILURE			7.44	%
HAND PENETROMETER			3.00	tsf

Failure Sketch

Unconfined Compression Test



6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

UNCONFINED COMPRESSION

ASTM D2166

PROJECT	GEA-087-3.18
JOB No.	N-23-023
BORING	B-002-023
STATION / OFFSET	168+68
SAMPLE No. / DEPTH	ST-7/13.5'-14'
DATE OF TESTING	07/26/2023
TESTED BY	ML

Soil Description: Gray Sandy Silt
Soil Classification: A-4a

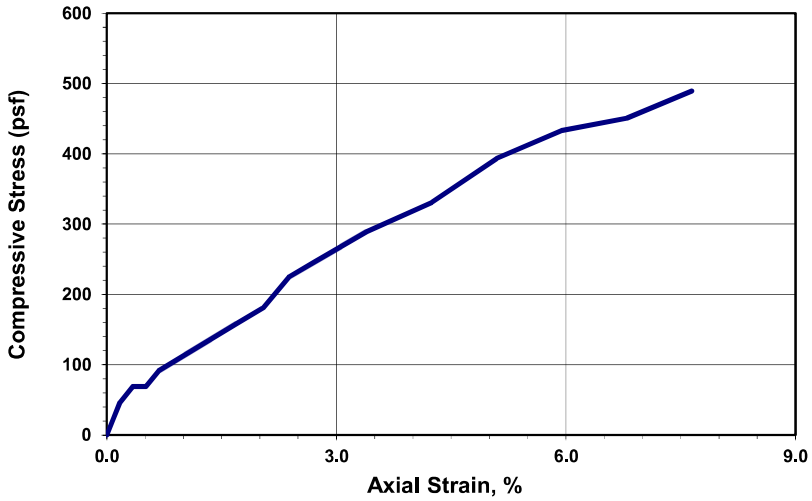
Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	Sand%	Silt%	Clay%

DIAMETER, D_0	2.821 in	71.7 mm	STRAIN RATE	2.00	%/min
AREA, A_0	6.252 in^2	40.3 cm^2	WET SOIL + PAN MASS	1382.9	g
HEIGHT, L_0	5.887 in	149.52 mm	PAN MASS	178.7	g
VOLUME, V_0	36.8017 in^3	603.07 cm^3	DRY SOIL + PAN MASS	1154.5	g
MACH. RATE	0.118	in/min	WET DENSITY	124.65	lb/ft^3
WATER CONT.	23.41	%	DRY DENSITY	101.00	lb/ft^3

UNCONFINED COMPRESSION STRESS, q_u	**489**	**psf**	0.24	tsf
AXIAL STRAIN @ FAILURE			7.64	%
HAND PENETROMETER			0.75	tsf

Failure Sketch

Unconfined Compression Test



RESOURCE INTERNATIONAL, INC.
Engineering Consultants

6350 Presidential Gatew.
Columbus, OH 43231
Phone (614) 823-4949

9885 Rockside Road
Cleveland, OH 44125
Phone (216) 573-0955

4480 Lake Forest Drive
Cincinnati, Ohio 45242
Phone (513) 769-6998

Unconfined Compressive Strength of Intact Rock Core Specimens

(ASTM D 7012-14)

Project: GEA-87-03.18 Bridge Replacement
Project No.: N-23-023
Date of Testing: 7/28/2023
Test Performed by: KL/EM

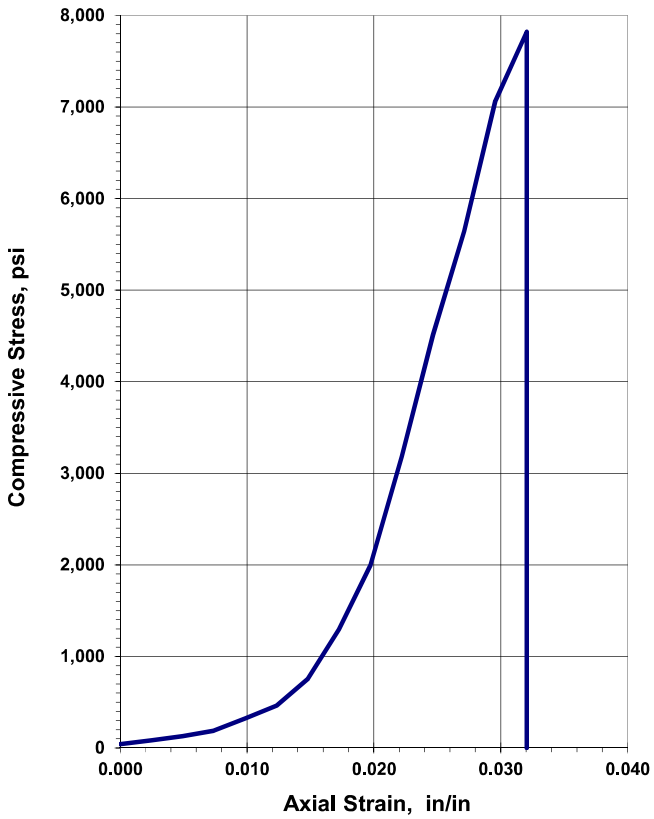
Rock Description: Gray Sandstone
Rock Formation:

Boring No.:	B-001-0-23		Average Length:	4.057	in
Sample No:	RC-1		Average Diameter:	1.967	in
Depth (ft):	90.50	feet	Length to diameter ratio:	2.063	
Moisture condition:	As received		Cross Sectional Area:	3.039	in^2
Sample Mass:	494.15	grams	Volume:	0.0071	ft^3
Testing Temperature:	23	°C	Unit Weight (sample specimen)*:	152.70	lbs/ft3
Rate of Loading:	100.3	lbs/sec	Failure Load:	23,764	lbs
Testing Time:	237	sec	Axial Strain at Failure:	0.0320	in/in
(Rate 2-15 min			Compressive Strength:	7,820	psi

Sample Preparation: Per ASTM D4543

**Actual test sample used for unit weight prior to testing.*

Unconfined Compression Test



Before Testing

After Failure

REMARKS:

RESOURCE INTERNATIONAL, INC.
Engineering Consultants

6350 Presidential Gatew.
Columbus, OH 43231
Phone (614) 823-4949

9885 Rockside Road
Cleveland, OH 44125
Phone (216) 573-0955

4480 Lake Forest Drive
Cincinnati, Ohio 45242
Phone (513) 769-6998

Unconfined Compressive Strength of Intact Rock Core Specimens

(ASTM D 7012-14)

Project: GEA-87-03.18 Bridge Replacement
Project No.: N-23-023
Date of Testing: 7/28/2023
Test Performed by: KL/EM

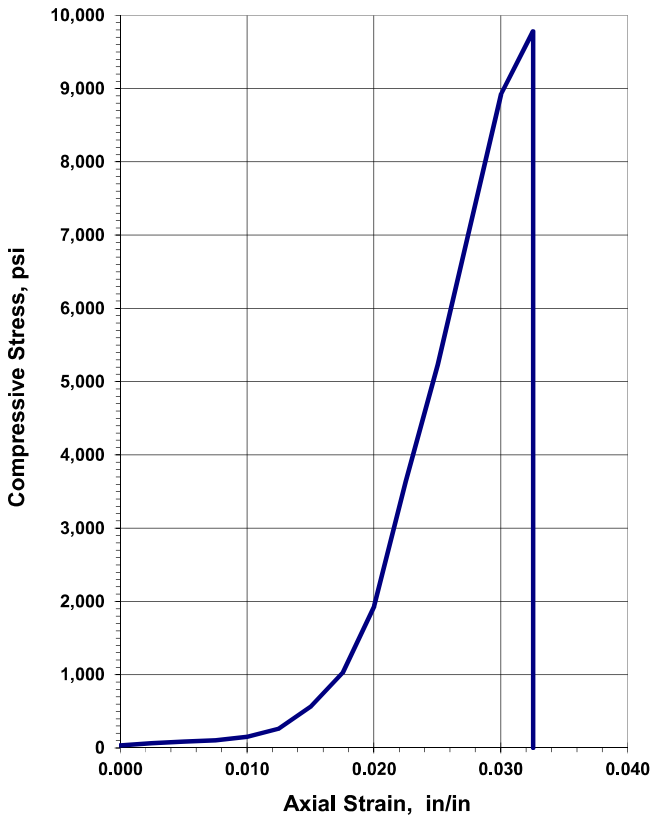
Rock Description: Gray Sandstone
Rock Formation:

Boring No.:	B-002-0-23		Average Length:	3.995	in
Sample No:	RC-1		Average Diameter:	1.976	in
Depth (ft):	90.0	feet	Length to diameter ratio:	2.022	
Moisture condition:	As received		Cross Sectional Area:	3.067	in^2
Sample Mass:	498.74	grams	Volume:	0.0071	ft^3
Testing Temperature:	23	°C	Unit Weight (sample specimen)*:	155.08	lbs/ft3
Rate of Loading:	105.6	lbs/sec	Failure Load:	29,998	lbs
Testing Time:	284	sec	Axial Strain at Failure:	0.0325	in/in
(Rate 2-15 min			Compressive Strength:	9,782	psi

Sample Preparation: Per ASTM D4543

**Actual test sample used for unit weight prior to testing.*

Unconfined Compression Test



Before Testing

After Failure

REMARKS:

APPENDIX V

PAVEMENT CORE DATA SHEETS

6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

Pavement Core Data Summary

PROJECT	GEA-087-3.18 Bridge Replacement
LOCATION	Geauga County, OH
JOB No.	N-23-023
BORING/CORE No.	B-001-0-23
DATE CORE OBTAINED	7/19/2023
CORE OBTAINED BY	LH, KC, SD

Core Composition

Core Number	Layer Thickness (in.)	Pavement Layer Number	Asphalt: Surface Binder	Asphalt: Intermediate Binder	Asphalt: Base Binder	Concrete	Aggregate/Granular Base	Other		
B-001-0-23	1.25	2	✓							
	8.75	1		✓						

Comments/Remarks

- Core is broken at 2.25" and 4.00"
- Layer 1 has trace voids
- Layer 2 has trace voids
- Aggregate Base:

*Sand and gravel layer encountered to a depth of 9.5 feet below the existing grade

Total Pavement Thickness =	10.00	in.	Total Asphalt Thickness =	10.00	in.	Total Concrete Thickness =	0.00	in.	Total Base Thickness =	*	in.

6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

Pavement Core Data Summary

PROJECT	GEA-087-3.18 Bridge Replacement
LOCATION	Geauga County, OH
JOB No.	N-23-023
BORING/CORE No.	B-002-0-23
DATE CORE OBTAINED	7/17/2023
CORE OBTAINED BY	LH, KC, SD

Core Composition

Core Number	Layer Thickness (in.)	Pavement Layer Number	Asphalt: Surface Binder	Asphalt: Intermediate Binder	Asphalt: Base Binder	Concrete	Aggregate/Granular Base	Other		
B-002-0-23	2.00	4	✓							
	6.00	3	✓							
	4.00	2		✓						
	6.50	1		✓						

Comments/Remarks

- Core is separated at 2" and 12"
  Layer 1 has some voids
  Layer 2 has some voids
  Layer 3 has trace voids
  Layer 4 has trace voids

- Aggregate Base:
- *Sand and gravel layer encountered to a depth of 7.5 feet below the existing grade

Total Pavement Thickness =	18.50	in.	Total Asphalt Thickness =	18.50	in.	Total Concrete Thickness =	0.00	in.	Total Base Thickness =	*	in.

6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

Pavement Core Data Summary

PROJECT	GEA-087-3.18 Bridge Replacement
LOCATION	Geauga County, OH
JOB No.	N-23-023
BORING/CORE No.	X-001-0-23
DATE CORE OBTAINED	7/17/2023
CORE OBTAINED BY	LH, KC, SD

Core Composition

Core Number	Layer Thickness (in.)	Pavement Layer Number	Asphalt: Surface Binder	Asphalt: Intermediate Binder	Asphalt: Base Binder	Concrete	Aggregate/Granular Base	Other		
X-001-0-23	2.75	4				✓				
	1.25	3				✓				
	14.25	2				✓				
	0.25	1				✓				

Comments/Remarks

- Core is broken at 12.75"
  Layer 1 has trace voids
  Layer 2 has some voids, reinforcement at 16.0"
  Layer 3 has some voids
  Layer 4 has some voids

Total Pavement Thickness =	18.50	in.	Total Asphalt Thickness =	0.00	in.	Total Concrete Thickness =	18.50	in.	Total Base Thickness =	NA

6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

Pavement Core Data Summary

PROJECT	GEA-087-3.18 Bridge Replacement
LOCATION	Geauga County, OH
JOB No.	N-23-023
BORING/CORE No.	X-002-0-23
DATE CORE OBTAINED	7/17/2023
CORE OBTAINED BY	LH, KC, SD

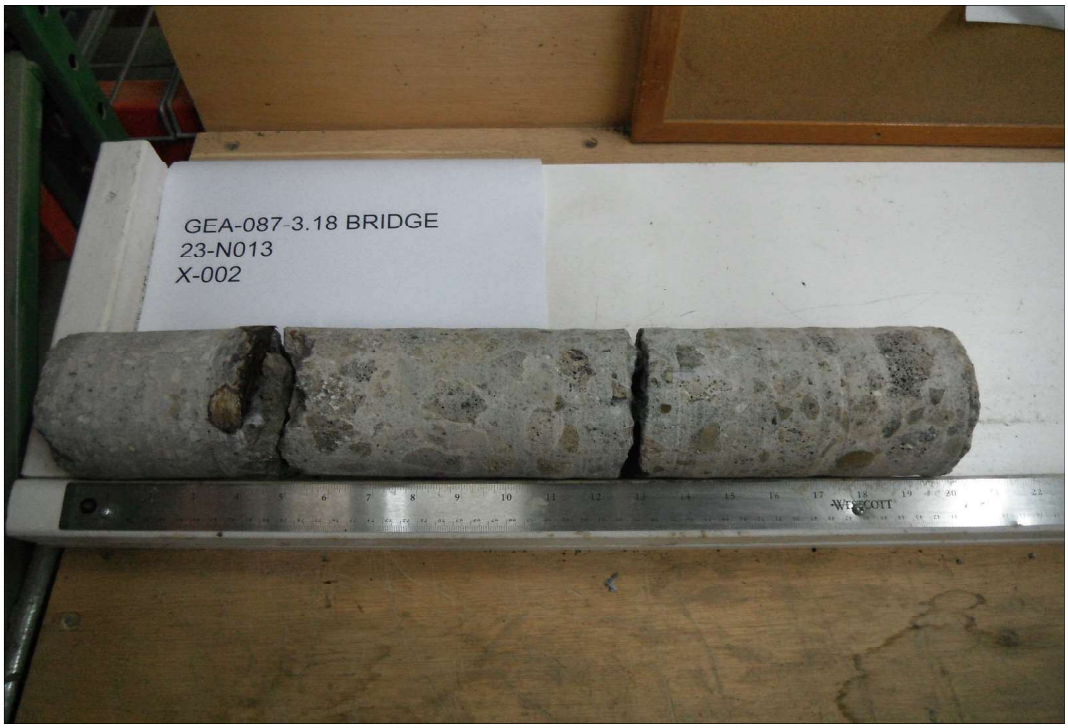
Core Composition

Core Number	Layer Thickness (in.)	Pavement Layer Number	Asphalt: Surface Binder	Asphalt: Intermediate Binder	Asphalt: Base Binder	Concrete	Aggregate/Granular Base	Other		
X-002-0-23	5.00	3				✓				
	14.75	2				✓				
	0.25	1				✓				

Comments/Remarks

- Core is broken at 5" and 12.75"
  Core is broken at 12.75" in layer 2
  Layer 1 has trace voids
  Layer 2 has some voids, reinforcement at 17.5"
  Layer 3 has some voids, reinforcement at 4.5"

Total Pavement Thickness =	20.00	in.	Total Asphalt Thickness =	0.00	in.	Total Concrete Thickness =	20.00	in.	Total Base Thickness =	NA



6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

Pavement Core Data Summary

PROJECT	GEA-087-3.18 Bridge Replacement
LOCATION	Geauga County, OH
JOB No.	N-23-023
BORING/CORE No.	X-003-0-23
DATE CORE OBTAINED	7/17/2023
CORE OBTAINED BY	LH, KC, SD

Core Composition

Core Number	Layer Thickness (in.)	Pavement Layer Number	Asphalt: Surface Binder	Asphalt: Intermediate Binder	Asphalt: Base Binder	Concrete	Aggregate/Granular Base	Other		
X-003-0-23	4.50	3				✓				
	13.25	2				✓				
	0.25	1				✓				

Comments/Remarks

- Core is broken at 4.5" and 13.25"
  Core is broken in layer 2 at 13.0"
  Layer 1 has trace voids
  Layer 2 is a slag mix with some voids
  Layer 3 has some voids with reinforcement at 4.5"

Total Pavement Thickness =	18.00	in.	Total Asphalt Thickness =	0.00	in.	Total Concrete Thickness =	18.00	in.	Total Base Thickness =	NA

6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

Pavement Core Data Summary

PROJECT	GEA-087-3.18 Bridge Replacement
LOCATION	Geauga County, OH
JOB No.	N-23-023
BORING/CORE No.	X-004-0-23
DATE CORE OBTAINED	7/17/2023
CORE OBTAINED BY	LH, KC, SD

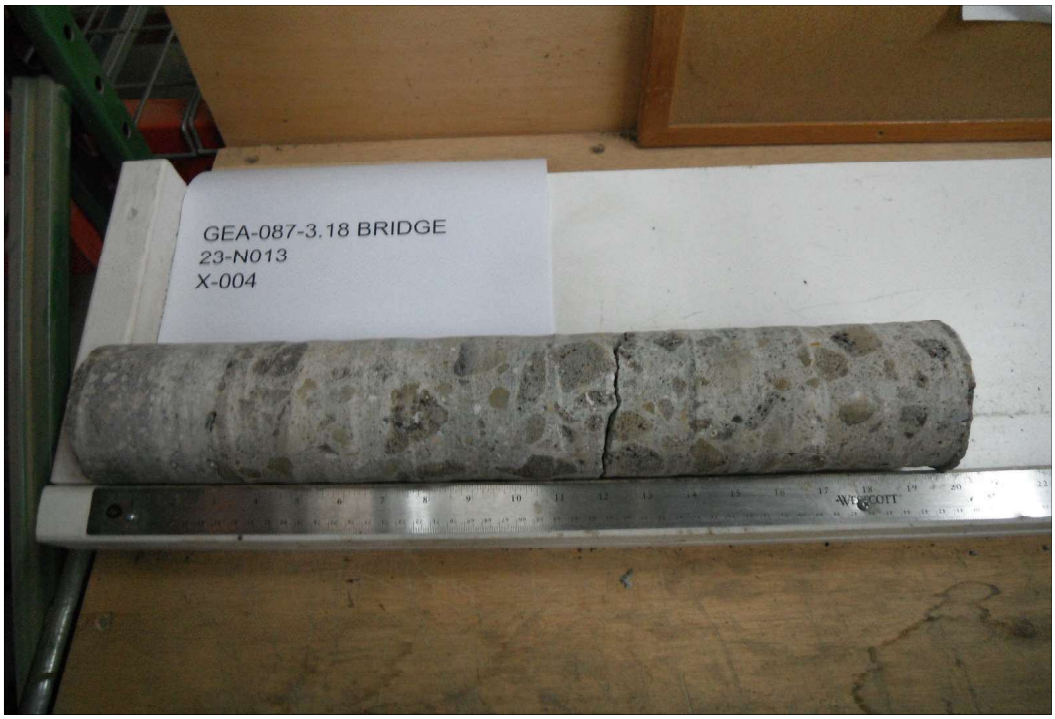
Core Composition

Core Number	Layer Thickness (in.)	Pavement Layer Number	Asphalt: Surface Binder	Asphalt: Intermediate Binder	Asphalt: Base Binder	Concrete	Aggregate/Granular Base	Other		
X-004-0-23	3.50	3				✓				
	16.25	2				✓				
	0.25	1				✓				

Comments/Remarks

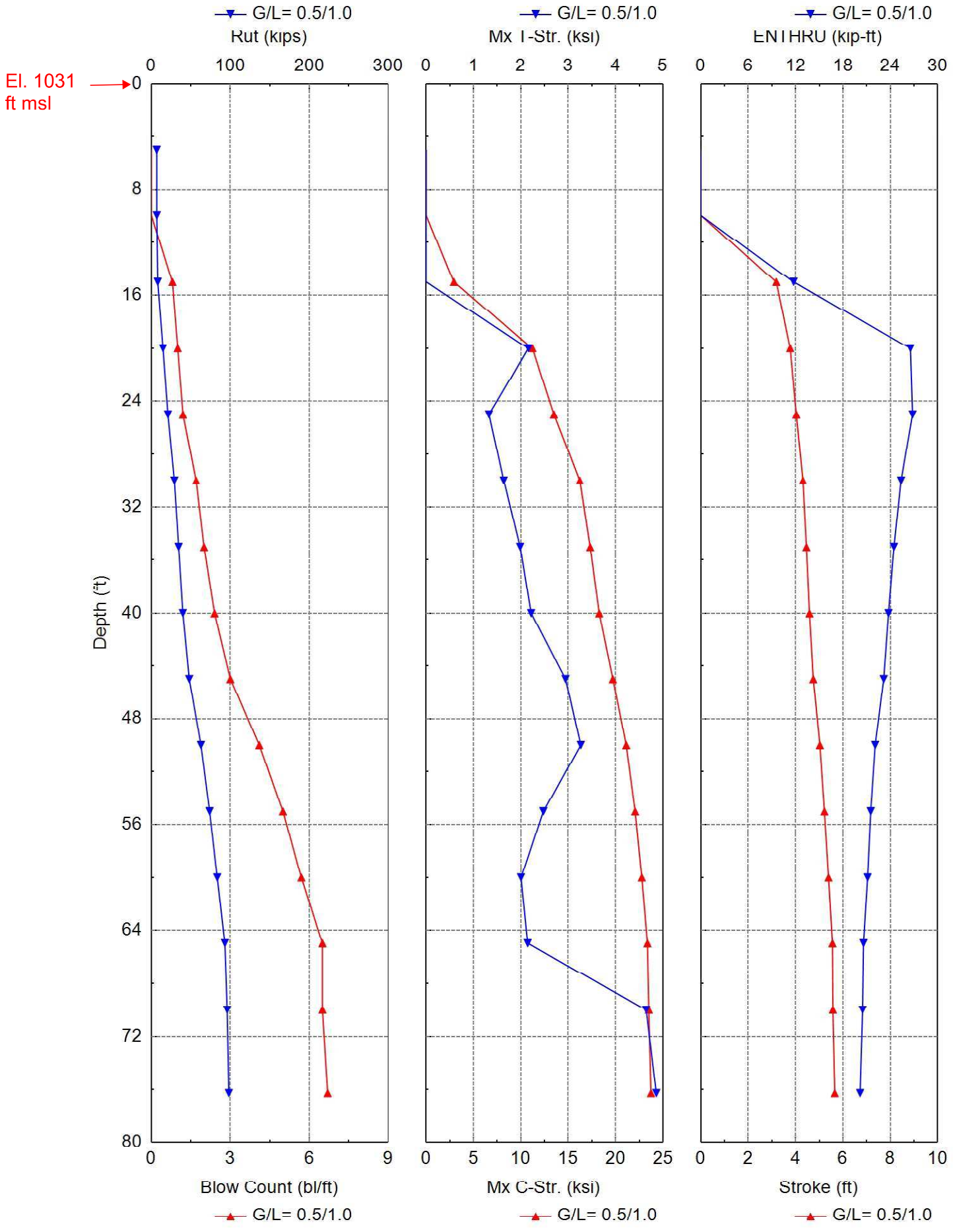
- Core is broken at 12.0"
  Layer 1 has trace voids
  Layer 2 has some voids, reinforcement at 17.5"
  Layer 3 has trace voids

Total Pavement Thickness =	20.00	in.	Total Asphalt Thickness =	0.00	in.	Total Concrete Thickness =	20.00	in.	Total Base Thickness =	NA



APPENDIX VI

GRL WEAP DRIVABILITY ANALYSIS OUTPUTS


G/L= 0.5/1.0
Rut (kips)
0
100
200
300
El. 1031
ft msl
0
8
16
24
32
40
48
56
64
72
80
Depth (ft)
0
3
6
9
Blow Count (bl/ft)
G/L= 0.5/1.0
G/L= 0.5/1.0
Mx T-Str. (ksi)
0
1
2
3
4
5
0
5
10
15
20
25
Mx C-Str. (ksi)
G/L= 0.5/1.0
G/L= 0.5/1.0
ENTHRU (kip-ft)
0
6
12
18
24
30
0
2
4
6
8
10
Stroke (ft)
G/L= 0.5/1.0

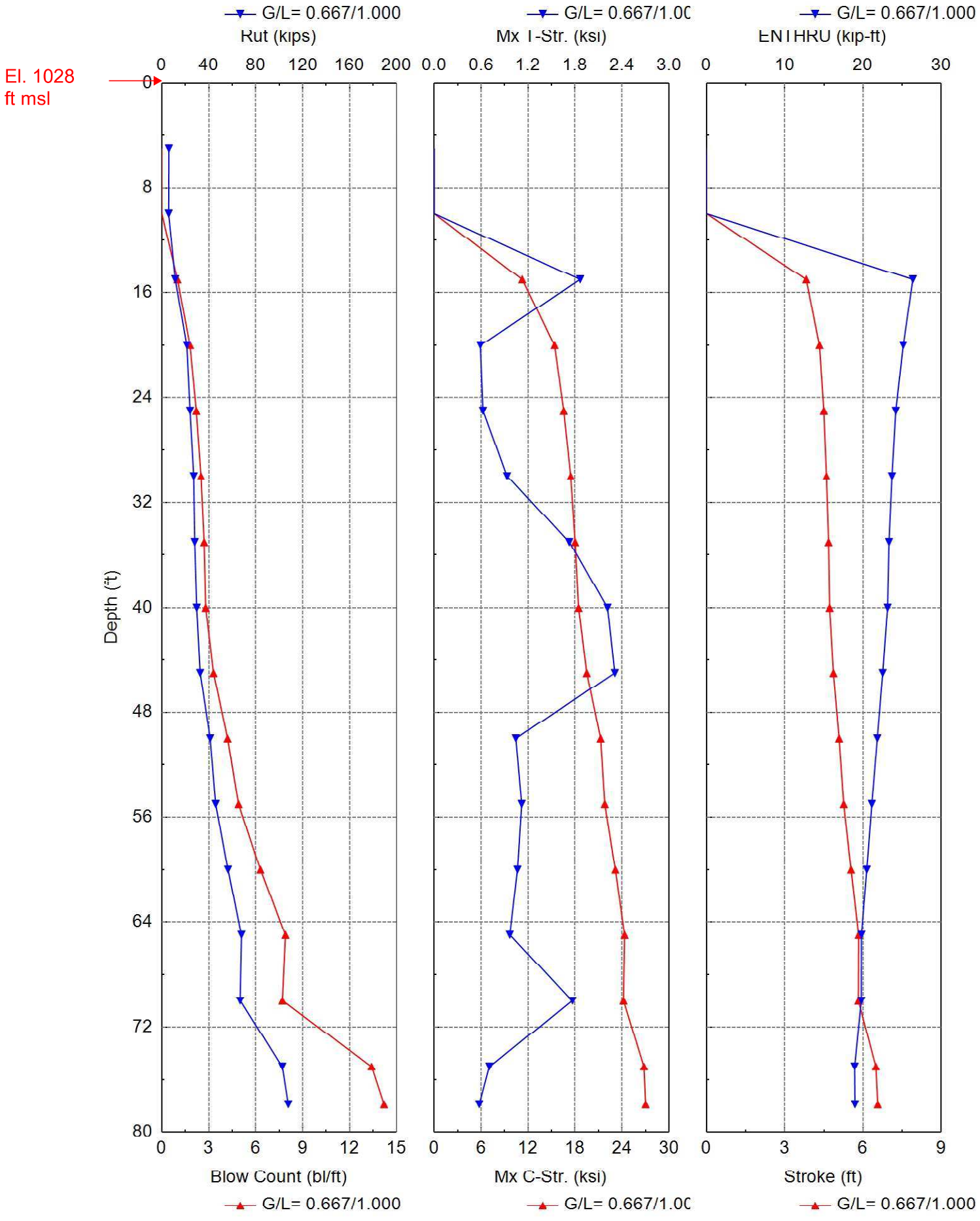
Gain/Loss Factor at Shaft/Toe = 0.500/1.000

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
5.0	6.7	2.9	3.8	0.0	0.000	0.000	0.00	0.0	D 19-42
10.0	6.9	4.6	2.3	0.0	0.000	0.000	0.00	0.0	D 19-42
15.0	8.0	5.3	2.8	0.8	2.931	0.000	3.19	11.7	D 19-42
20.0	14.7	11.2	3.5	1.0	11.223	2.160	3.77	26.5	D 19-42
25.0	20.9	17.5	3.5	1.2	13.489	1.326	4.03	26.8	D 19-42
30.0	29.1	23.6	5.5	1.7	16.220	1.639	4.31	25.4	D 19-42
35.0	34.5	28.9	5.6	2.0	17.315	1.985	4.46	24.5	D 19-42
40.0	39.8	34.2	5.6	2.4	18.272	2.217	4.59	23.8	D 19-42
45.0	48.0	42.3	5.6	3.0	19.713	2.943	4.75	23.2	D 19-42
50.0	62.8	57.2	5.6	4.1	21.123	3.266	5.03	22.1	D 19-42
55.0	73.7	68.1	5.6	5.0	22.064	2.475	5.22	21.5	D 19-42
60.0	83.4	77.8	5.6	5.7	22.770	2.003	5.39	21.1	D 19-42
65.0	93.1	87.5	5.6	6.5	23.362	2.144	5.56	20.6	D 19-42
70.0	96.0	95.8	0.2	6.5	23.505	4.646	5.57	20.5	D 19-42
76.3	98.1	96.1	2.0	6.7	23.737	4.860	5.65	20.2	D 19-42

Total driving time: 4 minutes; Total Number of Blows: 223 (starting at penetration 5.0 ft)

Forward Abutment

Bridge Replacement + B-002-0-23 (HP 10x42) RESOURCE INTERNATIONAL INC



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

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
5.0	6.0	2.5	3.5	0.0	0.000	0.000	0.00	0.0	D 19-42
10.0	5.8	5.6	0.2	0.0	0.000	0.000	0.00	0.0	D 19-42
15.0	11.4	5.9	5.5	1.0	11.252	1.865	3.82	26.4	D 19-42
20.0	21.3	15.8	5.5	1.8	15.386	0.590	4.33	25.1	D 19-42
25.0	24.0	20.7	3.3	2.2	16.555	0.623	4.50	24.2	D 19-42
30.0	27.1	23.8	3.3	2.5	17.443	0.931	4.60	23.7	D 19-42
35.0	28.0	26.5	1.5	2.7	18.009	1.726	4.68	23.3	D 19-42
40.0	29.7	28.1	1.5	2.8	18.451	2.216	4.72	23.1	D 19-42
45.0	32.7	31.1	1.5	3.3	19.498	2.309	4.86	22.5	D 19-42
50.0	41.2	35.3	5.9	4.2	21.271	1.044	5.08	21.8	D 19-42
55.0	45.8	40.0	5.9	4.9	21.802	1.118	5.26	21.1	D 19-42
60.0	56.4	50.5	5.9	6.3	23.152	1.064	5.54	20.5	D 19-42
65.0	67.8	62.0	5.9	7.9	24.334	0.966	5.83	19.8	D 19-42
70.0	66.7	65.3	1.4	7.7	24.191	1.767	5.82	19.8	D 19-42
75.0	102.6	72.1	30.5	13.4	26.811	0.706	6.49	18.9	D 19-42
77.9	107.7	77.2	30.5	14.2	27.017	0.575	6.56	19.0	D 19-42

Total driving time: 6 minutes; Total Number of Blows: 309 (starting at penetration 5.0 ft)

APPENDIX VII

LATERAL DESIGN PARAMETERS

Soil and Rock Parameters for Lateral Load Analysis
GEA-087-3.18 Bridge Replacement; PID 110999
Geauga County, Ohio
Rii Project Number: N-23-023

Substructure Unit (Boring)	Elevation (feet msl)	Soil Class.	Soil Type	Strata	N_{60}	γ (pcf)	γ' (pcf)	Strength Parameter	k (soil) k_{rm} (rock)	ε_{50} (soil) E_r (rock)	RQD (rock)
B-001-0-23	1043.7 to 1036.2	A-3a	G	4	16	125	125	φ = 29°	35 pci	-	-
	1036.2 to 1034.2	A-1-b	G	4	7	120	120	φ = 28°	20 pci	-	-
	1034.2 to 1030.2	A-4a	C	1	5	110	47.6	Su = 290 psf	35 pci	0.0192	-
	1030.2 to 1023.2	A-7-6	C	1	11	115	52.6	Su = 630 psf	85 pci	0.0124	-
	1023.2 to 1015.7	A-2-6	G	4	32	130	67.6	φ = 32°	60 pci	-	-
	1015.7 to 1001.7	A-6a	C	1	10	115	52.6	Su = 570 psf	75 pci	0.0136	-
	1001.7 to 996.7	A-4a	C	1	15	120	57.6	Su = 900 psf	180 pci	0.0094	-
	996.7 to 961.7	A-6a	C	1	15	120	57.6	Su = 920 psf	190 pci	0.0093	-
	961.7 to 954.7	A-4a	G	4	61	135	72.6	φ = 35°	125 pci	-	-
	954.7 to 953.7	Sandstone	R	9	-	140	77.6	Qu = 750 psi	0.0005	67,500 psi	0
	953.7 to 952.7	Sandstone	R	9	-	150	87.6	Qu = 7,820 psi	0.00005	680,000 psi	50
	952.7 to 947.7	Sandstone	R	9	-	150	87.6	Qu = 7,820 psi	0.00005	680,000 psi	68
	947.7 to 942.7	Shale	R	9	-	150	87.6	Qu = 3,000 psi	0.0005	270,000 psi	43

B-002-0-23	1038.6 to 1031.1	A-1-b	G	4	13	125	125	φ = 30°	35 pci	-	-
	1031.1 to 1028.1	A-6a	C	1	10	115	115	Su = 570 psf	75 pci	0.0136	-
	1028.1 to 1023.1	A-4a	C	1	4	110	47.6	Su = 230 psf	25 pci	0.0204	-
	1023.1 to 1018.1	A-4a	C	1	10	115	52.6	Su = 570 psf	75 pci	0.0136	-
	1018.1 to 1013.1	A-2-6	G	4	26	130	67.6	φ = 31°	50 pci	-	-
	1013.1 to 1006.6	A-4a	C	1	15	120	57.6	Su = 900 psf	180 pci	0.0094	-
	1006.6 to 996.6	A-4b	C	1	9	115	52.6	Su = 540 psf	70 pci	0.0142	-
	996.6 to 981.6	A-4b	C	1	4	110	47.6	Su = 250 psf	30 pci	0.0200	-
	981.6 to 961.6	A-4a	C	1	16	120	57.6	Su = 960 psf	210 pci	0.0092	-
	961.6 to 956.6	A-4a	C	1	4	110	47.6	Su = 230 psf	25 pci	0.0204	-
	956.6 to 950.1	A-4a	C	2	103	130	67.6	Su = 6,280 psf	2,095 pci	0.0039	-
	950.1 to 949.6	Sandstone	R	9	-	145	82.6	Qu = 750 psi	0.0005	67,500 psi	0
	949.6 to 947.1	Sandstone	R	9	-	150	87.6	Qu = 9,752 psi	0.00005	680,000 psi	33
	947.1 to 945.1	Shale	R	9	-	150	87.6	Qu = 3,000 psi	0.0005	270,000 psi	25

Soil and Rock Parameters for Lateral Load Analysis
GEA-087-3.18 Bridge Replacement; PID 110999
Geauga County, Ohio
Rii Project Number: N-23-023

Where,

1. *C = cohesive soil stratum; G = granular soil stratum*
2. *γ = total unit weight*
3. *γ' = effictive unit weight*
4. *S_u = average undrained shear strength (cohesive soil layers); φ = internal angle of friction (granular layers)*
5. *k = soil modulus parameter (static loading)*
6. *ε_{50} = strain factor*
7. *Er = Initial modulus of rock mass*