Resource International, Inc.

MOT-JOHNSON STATION ROAD
BRIDGE REPLACEMENT
PID 120484
VANDALIA, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT

Prepared For:
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Rii Project No. W-24-093

June 2026

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June 9, 2026

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Re: Structure Foundation Exploration Report
MOT-Johnson Station Road Bridge Replacement
PID 120484
Vandalia, Ohio
Rii Project No. W-24-093

Mr. Ava:

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 MOT-Jonson Station Road Bridge carrying Johnson Station Road over Poplar Creek in Vandalia, Ohio.

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.

Daniel K. Hayes, E.I.
Staff Engineer – Geotechnical Services

Daniel E Karch, P.E.
Director – Geotechnical Services

Enclosure: Structure Foundation Exploration Report

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EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration performed for the design and construction of the proposed replacement of the existing MOT-Johnson Station Road Bridge carrying Johnson Station Road over Poplar Creek in Vandalia, Ohio.

Foundation loads for the proposed structure were not available at the time of this report. It is understood that the vertical and horizontal alignments of the proposed bridge will approximately match those of the existing. Therefore, Rii has considered that minimal (less than 1 foot) cut/fill will be required to bring the site to the proposed roadway grade.

Exploration and Findings

Between August 28 and 30, 2024, a total of four (4) borings, designated as B-001-0-24 through B-003-0-24, and B-002-1-24 were performed for this project. The borings ranged in depth from 7.0 to 63.6 feet below the existing grade.

All of the borings were drilled through the existing roadway surface of Johnson Station Road and encountered asphalt pavement with thicknesses ranging from 3.5 to 5.5 inches, overlaying aggregate base with thicknesses ranging from 6.5 to 12.0 inches.

Below the surficial materials, the soil borings encountered existing fill to depths of 2.5 and 9.0 feet below the existing ground surface in borings B-001-0-24 and B-002-0-24, respectively. The fill was described as gravel with sand, and silt and clay (ODOT A-1-b, A-6a) and contained asphalt fragments.

Underlying the surficial material and existing fill, the borings generally encountered layers of natural granular and natural cohesive soils to boring termination depths. The natural granular soils were described as gravel, gravel with sand, gravel with sand and silt, and course and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a) were encountered. The natural cohesive soils were described as sandy silt and silty clay (ODOT A-4a, A-6b).

Natural moisture contents of the soil samples tested ranged from 3 to 20 percent. The natural moisture contents of the cohesive soil samples tested for plasticity index ranged from 1 percent to 3 percent below their corresponding plastic limits. In general, the soils exhibited natural moisture contents estimated to be slightly to moderately above their optimum moisture levels.

Many cobbles were encountered in borings B-001-0-24, B-002-0-24 and B-002-1-24 starting at depths of approximately 19.0 feet below the existing ground surface. A limestone boulder was encountered in boring B-002-0-24 at a depth of 21.8 below the existing ground surface. Heaving sands were encountered in boring B-002-1-24 at a depth of 31.0 below the existing ground surface.

Analyses and Recommendations

It is recommended that the proposed bridge be supported on a deep foundation system. Rii recommends that steel CIP pipe piles (ODOT Item 507.06), driven to the depth of the ultimate bearing value (UBV), be employed for foundation support. Rii recommends the use of conical tips to protect the piles due to cobbles and boulders encountered in the borings.

Driven Pile Recommendations

For the replacement of the existing single span bridge carrying Johnson Station Road over Poplar Creek, given the subsurface conditions encountered, Rii recommends that steel CIP pipe piles (ODOT Item 507.06), driven to the depth of the ultimate bearing value (UBV), be employed for foundation support. The geotechnical/structural resistance recommendations for the piles are provided in Table 6. If higher loading per pile is anticipated for the proposed foundation, then Rii should be provided the information for our analyses and our recommendations should be revised.

The table below shows the recommended pile lengths and the corresponding ultimate bearing value (UBV) of the steel CIP pipe piles. Rii recommends the use of conical tips to protect the piles due to cobbles and boulders encountered in the borings.

Driven Pile Recommendations

Substructure/ Boring Reference	Bottom of Footing (feet)	Pile Size / Type	Min. Req. Pile Wall Thickness (inch)	Pile Elevation (feet)		Est. Pile Length [2] (feet)	Scour Friction (kips)	UBV [3] (kips/pile)	φ_{dyn} [4]
				Top [1]	Tip				
Forward Abutment (B-001-0-24)	765.0	12” CIP	0.375	766.0	729.5	40.0	-	257.0	0.7
Rear Abutment (B-002-0-24)	765.0	12” CIP	0.375	766.0	735.7	35.0	-	257.0	0.7

1. *The top of pile elevation corresponds to the pile cutoff elevation, which is considered to be 1.0-foot above the bottom of footing elevation.*
2. *Per Section 305.3.5.2 of the 2023 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.*
3. *UBV is the required resistance that an individual pile is expected to provide based on the structural loading and accounting for the applicable geotechnical resistance factor.*
4. *The resistance factor listed assumes dynamic testing of the pile elements per Section 305.7.1 of the 2023 ODOT BDM.*

Scour Findings

Soil borings performed for the proposed bridge replacement encountered granular and cohesive soils consisting of gravel and / or stone fragments, gravel and / or stone fragments with sand, gravel and / or stone fragments with sand and silt, course and fine sand, sandy silt, and silt and clay (ODOT A-1-a, A-1-b, A-2-4, A-3a, A-4a, A-6a) at or near level where the existing soil in front of the abutments meet the abutment face. Classification tests were performed on the soil samples recovered from the ground surface elevation at the face of the abutment for the scour considerations. A summary of soil parameters for scour analysis are tabulated in Table 8.

Parameters for Scour Analysis

Boring Number	Sample	Elevation, (feet)	Soil Type	D_{50} (mm)	Design D_{50} (mm)
B-001-0-24 (Forward Abutment)	SS-5 & SS-6	771.5-768.5	A-2-4	3.0600	3.0600
	SS-7	768.5-767.0	A-1-a	3.6200	3.6200
	SS-8	767.0-765.5	A-2-4	0.1800	0.2000
	SS-9	765.5-764.0	A-1-a	3.6200	3.6200
	SS-10	764.0-762.5	A-1-b	2.7300	2.7300
B-002-2-24 (Rear Abutment)	SS-5	771.2-769.7	A-6a	0.2500	0.2500
	SS-6	769.7-768.2	A-1-a	3.6200	3.6200
	SS-7	768.2-766.7	A-4a	0.0800	0.2000
	SS-8	766.7-765.2	A-4a	0.0500	
	SS-9	765.2-763.7	A-3a	0.1500	
	SS-10	763.7-762.2	A-1-b	0.6800	0.6800

Subgrade Recommendations

Per ODOT subgrade analysis, overall average site parameters are included in the following table.

Average Site Parameters

Average N60L	Average PI	Average Moisture	Average Optimum Moisture	Average Group Index	Average CBR
11	8	10	11	4	8

Based on the results of the subgrade analysis of the borings, Rii does not anticipate the need for subgrade stabilization. However, the entire subgrade should be proof rolled to verify that stability has been achieved in accordance with ODOT CMS 204.

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 MOT-Johnson Station Road Bridge carrying Johnson Station Road over Poplar Creek in Vandalia, Ohio.

Rii understands the existing structure is a single-span steel girder superstructure on reinforced concrete wall abutments. The span of the existing bridge is 44 feet with a total bridge width of approximately 22 feet from curb to curb with a 2.5-inch wearing surface. Based on the information provided by Prime AE Group, Inc., it is understood that the proposed bridge will consist of single-span prestressed concrete adjacent box beam with composite reinforced concrete deck on semi-integral abutments. The length of the proposed bridge is 57.0 feet with a total width of 33.0 feet form one face of rail to the other. Proposed structural loading information was not available at the time of this report. In addition, the existing approach pavements are planned to be replaced. The total project length is estimated to be 350 feet.

It is understood that the vertical and horizontal alignments of the proposed bridge will approximately match those of the existing. Therefore, Rii has considered that minimal (less than 1 foot) cut/fill will be required to bring the site to the proposed roadway grade.

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Site Geology

Physiographically, the project area lies within the Southern Ohio Loamy Till Plain of the Till Plains Region, north of the glaciation border. The Southern Ohio Loamy Till Plain is described as a surface of loamy till with 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 are common in this region. The Southern Ohio Loamy Till Plain has moderate relief, with an elevation ranging from 530 feet to 1,150 feet.

Based on the Bedrock Geology and Topography Maps obtained from the Ohio Department of Natural Resources (ODNR), the bedrock underlying these deposits consists of the Ordovician Undivided formation. The Ordovician Undivided formation consists of various shades of gray shale with interbedded dolomite and limestone, with thin to medium bedding. This formation is generally over 145 feet in thickness. The bedrock depth in this area ranges from 30 to 60 feet below ground surface.

2.2 Existing Conditions

The site of the proposed structure replacement is located on Johnson Station Road in the south eastern area of Vandalia, Ohio, approximately 30 feet south of the entrance to Unibilt Industries. The existing structure is a single-span steel girder superstructure on reinforced concrete wall abutments. The span of the existing bridge is 44 feet with a total bridge width of approximately 22 feet from curb to curb with a 2.5-inch wearing surface that is aligned north to south. Within the project limits, the roadway traverses primarily along wooded area with some commercial purpose. Overhead electric lines aligned north to south were observed along the west side of Johnson Station Road. The pavements within the project area appeared to be in fair to good condition, and the existing bridge deck appear to be in good condition.

3.0 EXPLORATION

Between August 28 and 30, 2024, a total of four (4) borings, designated as B-001-0-24 through B-003-0-24, and B-002-1-24 were performed for this project. The borings ranged in depth from 7.0 to 63.6 feet below the existing grade.

The soil borings were performed at the locations shown on the boring plan provided in Appendix I of this report. A summary of soil borings information is provided in Table 1.

Table 1. Test Boring Summary

Boring Number	Station [1]	Offset [1]	Latitude	Longitude	Ground Elevation [1] (feet)	Boring Depth (feet)
B-001-0-24	7+96	4' RT	39.864625°	-84.171170°	778.5	51.6
B-002-0-24	7+40	6’ RT	39.864472°	-84.171193°	778.7	21.8
B-002-1-24	7+22	6’ RT	39.864499°	-84.170999°	778.7	63.6
B-003-0-24	6+11	4' RT	39.864123°	-84.171262°	778.3	7.0

1. *Stations, offsets and ground surface elevations were interpolated from basemapping provided by Prime AE Group, Inc.*

The boring 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 locations. Stations, offsets and ground surface elevations were interpolated from basemapping provided by Prime AE Group, Inc.

The borings were drilled using a Diedrich D-50 track mounted rotary drilling machine. The borings were advanced utilizing a 3.25-inch inside diameter, hollow stem augers or 4.5-inch outside diameter, continuous flight augers. Standard penetration testing (SPT) and split spoon sampling were performed at 1.5-foot intervals to a depth of 6.0 feet below the top of the proposed subgrade, followed by 2.5-foot intervals to a depth of 40 feet below

existing grade, followed by a 5-foot sampling interval to boring termination depths. In addition, continuous (1.5-foot) SPT sampling was performed beginning where the existing stream channel meets the existing abutment to 6 feet below in both structure borings 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. A calibrated automatic drop hammer was utilized 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 Diedrich D-50 drill rig was calibrated on March 25, 2024 and has a drill rod energy ratio of 91.1 percent. However, per Section 404.3 of the ODOT SGE, the energy ratio is limited to 90 percent for determination of the N_{60} values.

At the completion of drilling in borings, the boreholes were backfilled with a mixture of soil cuttings and bentonite chips. The pavement was patched with an equivalent thickness of 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 detailing the encountered subsurface conditions. Soil samples obtained from the drilling operation were preserved and sealed in glass jars and delivered to the soil laboratory. In the laboratory, the soil 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	56
Plastic and Liquid Limits	AASHTO T89, T90	23
Gradation – Sieve/Hydrometer	AASHTO T88	23
Gradation – Sieve Only	AASHTO T88	1
Sulfate Content – Colorimetric Method	ODOT S1122	3

The tests performed are necessary to classify the existing soil 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.

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 terms used throughout this report is presented in Appendix II.

4.1 Surface Materials

All of the borings were drilled through the existing roadway surface of Johnson Station Road and encountered asphalt pavement with thicknesses ranging from 3.5 to 5.5 inches overlaying aggregate base with thicknesses ranging from 6.5 to 12.0 inches. A summary of the encountered pavement material thicknesses at each boring location is provided in Table 3.

Table 3. Surface Material Summary

Boring	Asphalt Thickness (in)	Aggregate Base Thickness (in)
B-001-0-24	3.5	8.5
B-002-0-24	5.5	12.0
B-003-0-24	5.5	6.5

4.2 Subsurface Soils

Below the surficial materials, the soil borings encountered existing fill to depths of 2.5 and 9.0 feet below the existing ground surface in borings B-001-0-24 and B-002-0-24, respectively. The fill was described as gravel with sand and silt and clay (ODOT A-1-b, A-6a) and contained asphalt fragments throughout.

Underlying the surficial material and existing fill, the borings generally encountered layers of natural granular soils either to boring termination depths. However, thin layers of natural cohesive soil were encountered in the borings to depths ranging from 7.0 to 13.5 feet below the existing ground surface.

The natural granular soils were described as gravel, gravel with sand, gravel with sand and silt, and course and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a) were encountered. The relative density of granular soils is primarily derived from SPT blow counts (N_{60}). Based on the SPT blow counts obtained, the relative density of the granular soils encountered ranged from loose ($5 < N_{60} < 10$) to very dense ($N_{60} > 50$ bpf). Blow counts recorded from the SPT ranged from 8 to SPT sampling refusal. SPT sampling refusal is defined as exceeding 50 blows with less than 6 inches of penetration by the split spoon sampler.

The natural cohesive soils were described as sandy silt and silty clay (ODOT A-4a, A-6b). The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soils encountered generally ranged from soft ($0.25 < HP \leq 0.5$ tsf) to hard ($HP > 4.5$ tsf). The unconfined compressive strength of the natural cohesive soil samples tested, obtained from the hand penetrometer, ranged from 0.25 to over 4.5 tsf (limit of the instrument).

Natural moisture contents of the soil samples tested ranged from 3 to 20 percent. The natural moisture contents of the cohesive soil samples tested for plasticity index ranged from 1 percent to 3 percent below their corresponding plastic limits. In general, the soils exhibited natural moisture contents estimated to be slightly to moderately above their optimum moisture levels.

Many cobbles were encountered in borings B-001-0-24, B-002-0-24 and B-002-1-24 starting at depths of approximately 19.0 feet below the existing ground surface. A limestone boulder was encountered in boring B-002-0-24 at a depth of 21.8 below the existing ground surface. Heaving sands were encountered in boring B-002-1-24 at a depth of 31.0 below the existing ground surface.

4.3 Bedrock

Bedrock was not encountered in the borings performed for this investigation.

4.4 Groundwater

Groundwater was encountered in the borings as shown in Table 4 below.

Table 4. Groundwater Levels

Boring Number	Ground Elevation (feet)	During Drilling		Upon Completion [1]	
		Depth (feet)	Elevation (feet)	Depth (feet)	Elevation (feet)
B-001-0-24	778.5	24.5	764.0	N/A	N/A
B-002-1-24	778.7	24.0	763.7	N/A	N/A

1. *Groundwater at completion was not able to be measured due to the introduction of drilling fluid to counteract heave.*

During drilling groundwater was encountered in borings B-001-0-24 and B-002-2-24 at depths of 24.5 and 24.0 feet below the existing ground surface, respectively. Groundwater was not able to be measured due to the introduction of water or drilling mud during the drilling process.

Please note that short-term water level readings 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 soil encountered at the site. These parameters have been used to provide guidelines for the design of foundation systems for the subject 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 Prime AE Group, Inc. Based on the information provided, it is understood that the proposed bridge will consist of a single-span prestressed concrete spread box beam with composite reinforced concrete deck on semi-integral abutments on CIP-piles. The length of the proposed bridge is 57.0 feet with a total width of 33.0 feet from one face of rail to the other.

If the design details of the proposed structure and/or proposed site grading differs from what is described in this report, Rii should be provided the information for our report revised or amended, as necessary.

Table 5. Bridge Design Elevations

Substructure Unit (Boring)	Structure Component	Elevation (feet)	Design Maximum Factored Load (kip)
Forward Abutment (B-001-0-24)	Bottom of Footing	765.0	179.8
Rear Abutment (B-002-0-24)	Bottom of Footing	765.0	179.8

5.1 Driven Pile Recommendations

For the replacement of the existing single span bridge carrying Johnson Station Road over Poplar Creek, given the subsurface conditions encountered, Rii recommends that steel CIP pipe piles (ODOT Item 507.06), driven to the depth of the ultimate bearing value (UBV), be employed for foundation support. The geotechnical/structural resistance recommendations for the piles are provided in Table 6. If higher loading per pile is anticipated for the proposed foundation, then Rii should be provided the information for our analyses and our recommendations should be revised.

Table 6 shows the recommended pile lengths and the corresponding ultimate bearing value (UBV) of the steel CIP pipe piles. Rii recommends the use of conical tips to protect the piles due to cobbles and boulders encountered in the borings.

Table 6. Driven Pile Recommendations

Substructure/ Boring Reference	Bottom of Footing (feet)	Pile Size / Type	Min. Req. Pile Wall Thickness (inch)	Pile Elevation (feet)		Est. Pile Length [2] (feet)	Scour Friction (kips)	UBV [3] (kips/pile)	φ_{dyn} [4]
				Top [1]	Tip				
Forward Abutment (B-001-0-24)	765.0	12” CIP	0.375	766.0	729.5	40.0	-	257.0	0.7
Rear Abutment (B-002-0-24)	765.0	12” CIP	0.375	766.0	735.7	35.0	-	257.0	0.7

1. *The top of pile elevation corresponds to the pile cutoff elevation, which is considered to be 1.0-foot above the bottom of footing elevation.*
2. *Per Section 305.3.5.2 of the 2023 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.*
3. *UBV is the required resistance that an individual pile is expected to provide based on the structural loading and accounting for the applicable geotechnical resistance factor.*
4. *The resistance factor listed assumes dynamic testing of the pile elements per Section 305.7.1 of the 2023 ODOT BDM.*

The factored structural axial resistances listed in Table 6 consider an axially loaded pile with negligible moment, no appreciable loss of section due to deterioration throughout the life of the structure, no capacity reduction due to scour, Grade 3 steel for CIP piles with a yield strength of 45 ksi, and piles fully braced along their length.

The piles were analyzed using the DrivenPiles software program. The ultimate bearing values listed in Table 6 were calculated in accordance with Section 305.3.2 and 305.3.4 of the ODOT BDM and Section 1304.1 of the ODOT GDM.

The UBVs listed in Table 6 represent the calculated values after soil setup has occurred, following a specified waiting period (at restrike). Based on the subsurface conditions encountered, it is recommended that a minimum hold period of one (1) day be specified between the end of driving the pile and the time of restrike to allow adequate soil setup to occur. However, if dynamic testing indicates that the required UBV is achieved at the end of driving the pile, a restrike of the pile will not be required. It is recommended that a minimum of one (1) dynamic load test or restrike shall be performed at each substructure for each phase of construction.

Settlement is estimated to be less than 1.0 inch for CIP pipe piles driven to the resistances provided in Table 6.

It should be noted that the pile lengths and ultimate bearing values presented Table 6. are estimates using empirical equations based on the derived characteristics of the soils encountered in the subject borings drilled. The actual pile capacities should be verified using static or dynamic pile load testing as detailed in Sections 305.7.1 and 305.7.2 of the ODOT BDM. The most accurate method for determining pile capacities and lengths is to drive test piling at the site and perform static load testing in accordance with ASTM D1143. Dynamic pile load testing should be performed in accordance with ASTM D4945. Further installation considerations are presented in Section 5.1.2.

5.1.1 Drivability

Drivability analyses were 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 V In the drivability analysis. A **Delmag 19-42** hammer with a rated energy of approximately 44,000 ft-lbs was used in conjunction with the CIP pipe pile sections. Based on the results of this analysis, driving stresses induced on the CIP piles **would not exceed** 90 percent of the yield stress of the steel (f_y = 45 ksi, 0.9f_y = 40.5 ksi) if driven to the elevations provided in Table 6. Care should be taken during pile driving operations 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 from the pile hammer with an inch or less of penetration to reduce the possibility of damaging the pile element.

5.1.2 Driven Pile Considerations

Proper pile installation is as important as pile design in order to obtain a cost effective and safe product. Driven piles must be installed to develop adequate soil resistance without structural damage. Because piles cannot be visually inspected after installation, direct quality control of the finished product is impossible. Consequently, substantial control must be exercised over peripheral operations leading to the pile placement within the foundation. It is essential that installation be considered during the design stage to ensure that piles shown on the plans can be installed. Construction monitoring should be employed in (1) pile materials, (2) installation equipment, and (3) the estimation of the static load capacity.

It is recommended that the contractor submit a wave equation analysis (bearing graph) of their pile driving equipment, or the necessary pile driving and equipment data to perform the wave equation analysis, for hammer approval. A constant capacity wave equation analysis (inspector's chart) should also be performed to assist field personnel during inspection in accordance with the ODOT BDM.

5.1.3 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 that should be used for lateral loading design is provided in Appendix VI. 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 7 lists the eleven 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 VI.

Table 7. 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 Scour Data

Soil borings performed for the proposed bridge replacement encountered granular and cohesive soils consisting of gravel and/or stone fragments, gravel and/or stone fragments with sand, gravel and/or stone fragments with sand and silt, course and fine sand, sandy silt, and silt and clay (ODOT A-1-a, A-1-b, A-2-4, A-3a, A-4a, A-6a) at or near level where the existing soil in front of the abutments meet the abutment face. Classification tests were performed on each of these soil samples recovered for scour considerations. A summary of soil parameters for scour analysis are tabulated in Table 8.

Table 8. Parameters for Scour Analysis

Boring Number	Sample	Elevation, (feet)	Soil Type	D_{50} (mm)	Design D_{50} (mm)
B-001-0-24 (Forward Abutment)	SS-5 & SS-6	771.5-768.5	A-2-4	3.0600	3.0600
	SS-7	768.5-767.0	A-1-a	3.6200	3.6200
	SS-8	767.0-765.5	A-2-4	0.1800	0.2000
	SS-9	765.5-764.0	A-1-a	3.6200	3.6200
	SS-10	764.0-762.5	A-1-b	2.7300	2.7300
B-002-2-24 (Rear Abutment)	SS-5	771.2-769.7	A-6a	0.2500	0.2500
	SS-6	769.7-768.2	A-1-a	3.6200	3.6200
	SS-7	768.2-766.7	A-4a	0.0800	0.2000
	SS-8	766.7-765.2	A-4a	0.0500	
	SS-9	765.2-763.7	A-3a	0.1500	
	SS-10	763.7-762.2	A-1-b	0.6800	0.6800

5.3 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 9 and Table 10.

Table 9. Estimated Undrained (Short-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	c (psf)	φ	k_a	k_o	k_p
Medium Stiff to Stiff Cohesive Soil	115	1,000	0°	N/A	N/A	N/A
Hard Cohesive Soil	125	2,000	0°	N/A	N/A	N/A
Loose to Medium Dense Granular Soil	120	0	28°	0.36	0.53	2.77
Dense to Very Dense Granular Soil	125	0	36°	0.31	0.47	3.25
Compacted Cohesive Engineered Fill	120	2,000	0°	N/A	N/A	N/A
Compacted Granular Engineered Fill	130	0	32°	0.31	0.47	3.25

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

Table 10. Estimated Drained (Long-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	c' (psf)	φ'	k_a	k_o	k_p
Medium Stiff to Stiff Cohesive Soil	115	0	27°	0.38	0.55	2.66
Hard Cohesive Soil	120	0	28°	0.36	0.53	2.77
Loose to Medium Dense Granular Soil	120	0	28°	0.36	0.53	2.77
Dense to Very Dense Granular Soil	125	0	36°	0.31	0.47	3.25
Compacted Cohesive Engineered Fill	120	0	28°	0.36	0.53	2.77
Compacted Granular Engineered Fill	130	0	32°	0.31	0.47	3.25

1. *When below groundwater table, use effective unit weight, γ' = γ - 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 a sheet pile system, should be designed using the undrained soil parameters provided in Table 9, 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 10. Regardless of whether the retaining structure is temporary or permanent, the effective unit weight (γ' = γ - 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.

5.4 Pavement Subgrade Recommendations

The subgrade soils along the alignment are anticipated to consist of cohesive and granular materials. The cohesive materials are comprised of sandy silt and silty clay (ODOT A-4a, A-6b), and the granular materials are comprised of gravel, gravel with sand, gravel with sand and silt, and course and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a). Based on the soil conditions encountered during the drilling phase, it is estimated that the subgrade soils within the upper portions of the proposed subgrade will not require stabilization per ODOT subgrade analysis. Proposed grading information was not available at the time of this report. It is understood that the proposed subgrade will generally match the existing subgrade within the existing roadways, and that minor amounts of earthwork cut or fill will be required outside the limits of the existing pavement to achieve the proposed subgrade elevations in the vicinity of the proposed bridge replacement.

5.4.1 Subgrade Stabilization

Per ODOT subgrade analysis, the overall average subgrade parameters are noted in Table 8 below.

Table 8. Average Site Parameters

Average N_{60L}	Average PI	Average Moisture	Average Optimum Moisture	Average Group Index	Average CBR
11	8	10	11	4	8

Based on the results of the subgrade analysis for the borings performed, Rii does not anticipate the need for subgrade stabilization. However, the subgrade should be prepared in accordance with ODOT CMS Item 200 (Earthwork).

5.4.2 Subgrade Design Considerations

Based on the conditions encountered across the subject site, **it is recommended that pavement design be based on a CBR value of 8** with a corresponding resilient modulus, M_R, of 9,600 psi. Correlation charts indicate a modulus of subgrade reaction (K) of 180 pci and a soil support value (SSV) of 5.4.

Per ODOT GDM, soils with sulfate content in excess of 5,000 ppm cannot be chemically stabilized due to the potential for sulfate heave in the soil. Based on the results of the testing, the sulfate contents of the subgrade soils range from 100 to 160 ppm. Therefore, soil with sulfate content greater than 5,000 ppm was not encountered in any boring.

Please note that the recommended CBR values assume that the materials utilized for the subgrade in fill areas are equivalent to, or better than materials at the existing subgrade elevation. Sources of borrow material should be designated in advance of construction. The material should be tested in the laboratory to verify the soil exhibits a minimum design CBR value of 9.

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 CMS 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.

5.5.2 Groundwater Considerations

Groundwater should be anticipated at or near the elevation as indicated in Table 4. Groundwater should be anticipated within the upper granular soils at the creek elevation when the creek level is above the normal pool elevation. 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. If excavation encounter such layers, temporary dewatering with localized sumps and pumps will likely not be sufficient and more robust dewatering measures such as cofferdams or well points may be needed adequately maintain dry excavations.

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.

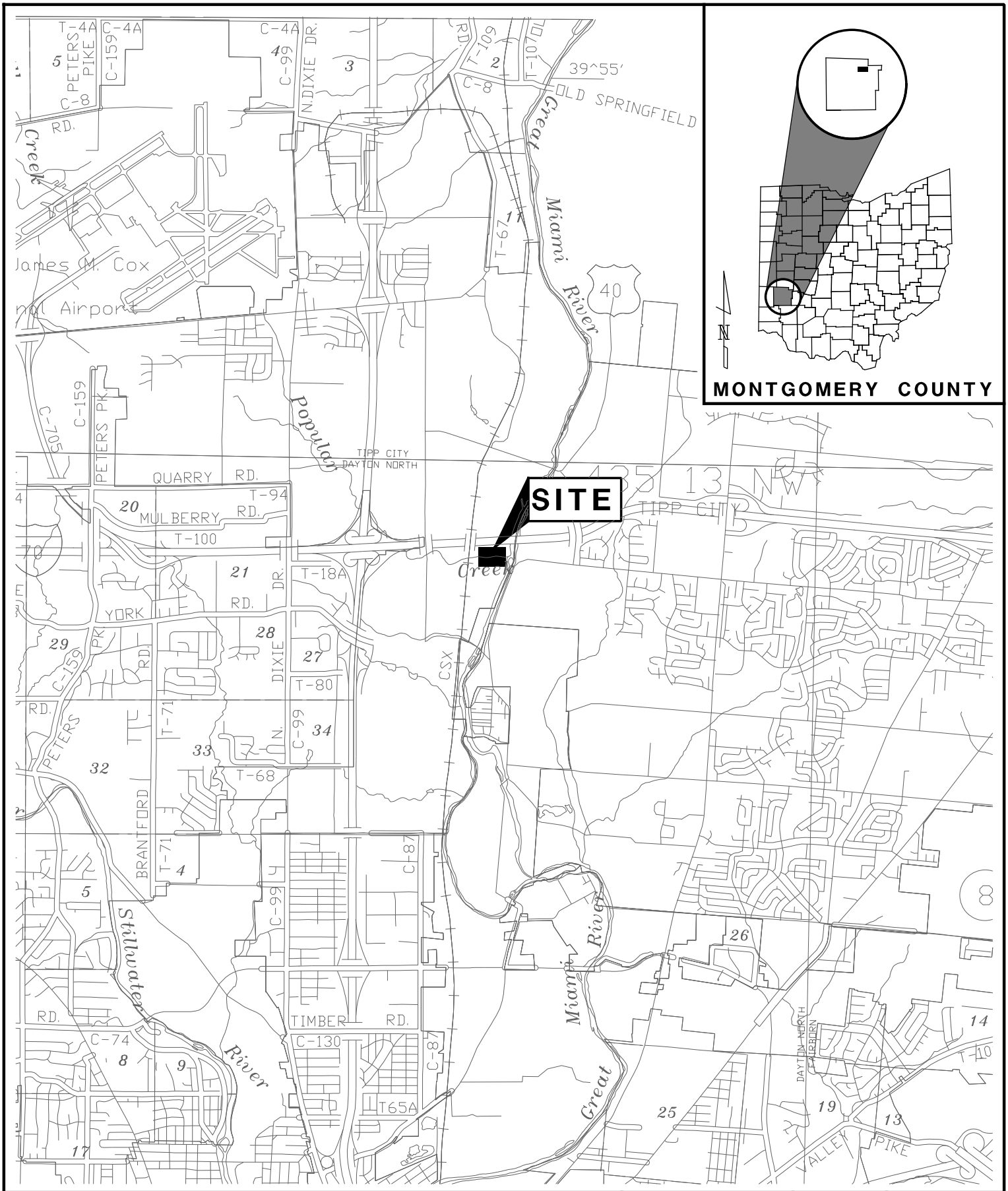
The conclusions and recommendations herein have been based upon the available soil and bedrock information and the design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be 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
JOHNSON STATION ROAD BRIDGE REPLACEMENT MONTGOMERY COUNTY, OHIO

RII PROJECT NO. W-24-093	DRAWN ALF
SCALE: 1"=5000' (0, 2500, 5000)	REVIEWED DEK
	DATE 12/4/2024

RESOURCE INTERNATIONAL Rii

BORING PLAN
JOHNSON STATION ROAD BRIDGE REPLACEMENT
MONTGOMERY COUNY, OHIO

RII PROJECT NO. W-24-093		DRAWN ALF
SCALE: 1"=30' (0 15 30)	N	REVIEWED DEK
		DATE 12/4/2024

RESOURCE INTERNATIONAL Rii

APPENDIX II

DESCRIPTION OF SOIL TERMS

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 – ODOT A-1, A-2, A-3, A-4 (non-plastic)
The relative compactness of granular soils is described as:

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 – ODOT A-4, A-5, A-6, A-7, A-8
The relative consistency of cohesive soils is described as:

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		Size
Boulders		Larger than 12”
Cobbles		12” to 3”
Gravel	coarse	3” to ¾“
	fine	¾” to 2.0 mm (¾” to #10 Sieve)
Sand	coarse	2.0 mm to 0.42 mm (#10 to #40 Sieve)
	fine	0.42 mm to 0.074 mm (#40 to #200 Sieve)
Silt		0.074 mm to 0.005 mm (#200 to 0.005 mm)
Clay		Smaller than 0.005 mm

Modifiers of Components - The following modifiers indicate the range of percentages of the minor soil components:

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 - ODOT
Dry	Well below Plastic Limit
Damp	Below Plastic Limit
Moist	Above PL to 3% below LL
Wet	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.

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.

APPENDIX III

BORING LOGS:

B-001-0-24 through B-003-0-24, B-002-1-24

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: MOT-JOHNSON STATION RD REPL.	DRILLING FIRM / OPERATOR: RII / IS	DRILL RIG: DIEDRICH D-50	STATION / OFFSET: 7+96 / 4' RT	**EXPLORATION ID**	
TYPE: STRUCTURE FOUNDATION	SAMPLING FIRM / LOGGER: RII / DB	HAMMER: AUTOMATIC	ALIGNMENT: JOHNSON STATION ROAD	**B-001-0-24**	
PID: 120484 SFN: NA	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 3/25/24	ELEVATION: 778.5 (MSL) EOB: 51.6 ft.	PAGE	
START: 8/30/24 END: 8/30/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 90	LAT / LONG: 39.864625, -84.171170	1 OF 2	

MATERIAL DESCRIPTION AND NOTES	ELEV. 778.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
0.3' - ASPHALT (3.5")	778.2																		
0.7' - BASE (8.5")	777.5																		
FILL: DENSE, BROWN TO BLACK **GRAVEL WITH SAND**, TRACE SILT, DRY. -ASPHALT FRAGMENTS PRESENT THROUGHOUT	776.0	1	11 12 13	38	44	SS-1	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	120	
MEDIUM DENSE, GRAYISH BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST.	774.5	3	7 7 7	21	78	SS-2	-	-	-	-	-	-	-	-	-	8	A-2-6 (V)	-	
HARD, BROWN TO LIGHT BROWN **SANDY SILT**, SOME CLAY, SOME FINE GRAVEL, DAMP.	771.5	5	7 8 4	18	58	SS-3	4.50	26	10	9	26	29	23	14	9	11	A-4a (4)	-	
		6	6 11 11	33	61	SS-4	-	-	-	-	-	-	-	-	-	6	A-4a (V)	-	
MEDIUM DENSE, BROWN TO DARK BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP.	768.5	8	6 7 6	20	47	SS-5	-	-	-	-	-	-	-	-	-	3	A-2-4 (V)	-	
		9	10 6 6	18	58	SS-6	-	56	13	12	12	7	22	14	8	8	A-2-4 (0)	-	
MEDIUM DENSE, GRAY **GRAVEL**, MOIST. -COBBLES PRESENT @ 10.5'	767.0	11	12 9 6	23	39	SS-7	-	-	-	-	-	-	-	-	-	5	A-1-a (V)	-	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND AND SILT**, LITTLE CLAY, DAMP.	765.5	12	6 4 5	14	47	SS-8	-	14	19	34	21	12	20	13	7	10	A-2-4 (0)	-	
DENSE, LIGHT BROWN TO BROWN **GRAVEL**, "AND" FINE TO COARSE SAND, TRACE SILT, TRACE CLAY, DAMP TO WET.	764.0	14	7 8 14	33	58	SS-9	-	61	17	11	8	3	NP	NP	NP	4	A-1-a (0)	-	
DENSE TO VERY DENSE, LIGHT BROWN TO BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST. -COBBLES PRESENT @ 16.0'			8 8 14	33	44	SS-10	-	54	19	9	13	5	NP	NP	NP	5	A-1-b (0)	-	
		16	60/3"	-	0	SS-11	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	-	
		18	16 17 31	72	67	SS-12	-	55	20	9	10	6	18	14	4	6	A-1-b (0)	-	
-COBBLES PRESENT @ 19.0'		20	5 25 22	71	67	SS-13	-	62	12	9	11	6	NP	NP	NP	6	A-1-b (0)	-	
		22	19 33 47	120	56	SS-14	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	-	
W 754.0		24	10 13 15	42	0	SS-15	-	-	-	-	-	-	-	-	-	-		-	
-FLUID ADDED TO AUGERS @ 25.0'	752.7	25	14	-	100	2S-15A	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	-	
VERY DENSE, LIGHT BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST TO WET.		27	15 21 24	68	64	SS-16	-	59	20	9	9	3	NP	NP	NP	10	A-1-a (0)	-	
-COBBLES PRESENT @ 29.0'		29	33 48 46	141	72	SS-17	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	-	

PID: 120484	SFN: NA	PROJECT: ODOT-JOHNSON STATION RD REPL	STATION / OFFSET: 796, 4' RT.	START: 8/30/24	END: 8/30/24	PG 2 OF 2	B-001-0-24

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)	SO4 ppm	BACK FILL
VERY DENSE, LIGHT BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST TO WET. *(continued)*	748.5	31																	
-HEAVING SANDS @ 31.0'		32	30 50/5"	-	91	SS-18	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	-	
		33																	
	744.2	34	30 43 24	101	83	SS-19A	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	-	
VERY DENSE, BROWN **COARSE AND FINE SAND**, SOME COARSE TO FINE GRAVEL, LITTLE SILT, TRACE CLAY, WET.	743.0	35				SS-19B	-	22	26	33	13	6	NP	NP	NP	14	A-3a (0)	-	
DENSE TO VERY DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, WET.		36	16 25 35	90	50	SS-20	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	-	
		37																	
		38																	
		39	11 20 33	80	53	SS-21	-	-	-	-	-	-	-	-	-	18	A-1-b (V)	-	
		40																	
		41																	
		42																	
		43																	
		44	18 28 24	78	61	SS-22	-	47	31	12	7	3	NP	NP	NP	12	A-1-b (0)	-	
-COBBLES PRESENT @ 46.0'		45																	
		46																	
		47																	
		48																	
		49	50/3"	-	100	SS-23	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	-	
		50																	
AUGER REFUSAL @ 51.6'	726.9	51 EOB	50/4"	-	0	SS-24	-	-	-	-	-	-	-	-	-	-		-	

NOTES: GROUNDWATER ENCOUNTERED @ 24.5' AND COULD NOT BE DETERMINED UPON COMPLETION DUE TO ADDITION OF MUD; CAVE-IN DEPTH @ 6.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH BENTONITE CHIPS AND SOIL CUTTINGS. PAVEMENT PATCHED WITH CONCRETE. .

RESOURCE INTERNATIONAL, INC.

PROJECT: MOT-JOHNSON STATION RD REPL.	DRILLING FIRM / OPERATOR: RII / IS	DRILL RIG: DIEDRICH D-50	STATION / OFFSET: 7+40 / 6' RT	**EXPLORATION ID**	
TYPE: STRUCTURE FOUNDATION	SAMPLING FIRM / LOGGER: RII / BG	HAMMER: AUTOMATIC	ALIGNMENT: JOHNSON STATION ROAD	**B-002-0-24**	
PID: 120484 SFN: NA	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 3/25/24	ELEVATION: 778.7 (MSL) EOB: 25.2 ft.	PAGE	
START: 8/28/24 END: 8/28/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 90	LAT / LONG: 39.864472, -84.171193	1 OF 1	

MATERIAL DESCRIPTION AND NOTES	ELEV. 778.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
0.5' - ASPHALT (5.5")	778.2																		
1.0' - BASE (12.0")	777.2																		
FILL: MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP. -ASPHALT FRAGMENTS PRESENT THROUGHOUT	775.7	1	6 6 5	17	83	SS-1	-	32	26	18	15	9	16	12	4	8	A-1-b (0)	100	
FILL: MEDIUM STIFF TO STIFF, BROWN TO DARK BROWN **SILT AND CLAY**, "AND" COARSE AND FINE SAND, SOME FINE GRAVEL, MOIST. -2S SAMPLER USED WITHIN THE SAME INTERVAL AS SS-2; 2S-2A WITH 100% RECOVERY. -ASPHALT FRAGMENTS PRESENT THROUGHOUT		2	3 4 4	12	0	SS-2	2.00	-	-	-	-	-	-	-	-	-	A-6a (V)	-	
		3	3 4 4	12	33	SS-3	0.50	-	-	-	-	-	-	-	-	11	A-6a (V)	-	
		4	4 2 2	6	61	SS-4	1.50	27	18	17	22	16	25	14	11	15	A-6a (1)	-	
		5	2 3 4	11	72	SS-5	1.00	-	-	-	-	-	-	-	-	14	A-6a (V)	-	
	769.7																		
-2S SAMPLER USED WITHIN THE SAME INTERVAL AS SS-6; 2S-6A WITH 50% RECOVERY.	768.2	6	5 11 13	36	33	SS-6	-	-	-	-	-	-	-	-	-	5	A-1-a (V)	-	
DENSE, GRAY **GRAVEL**, DAMP.																			
SOFT TO MEDIUM STIFF, BROWN **SANDY SILT**, LITTLE CLAY, TRACE FINE GRAVEL, MOIST.		7	7 4 4	12	61	SS-7	0.75	13	6	31	33	17	24	14	10	13	A-4a (3)	-	
	765.2	8	3 2 3	8	94	SS-8	0.25	4	4	36	41	15	20	14	6	13	A-4a (4)	-	
LOOSE, BROWN **COARSE AND FINE SAND**, SOME FINE GRAVEL, LITTLE TO TRACE SILT, DAMP.	764.7					SS-9A	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	-	
	763.7	9	3 3 1	6	69	SS-9B	-	3	11	58	13	15	19	14	5	18	A-3a (0)	-	
LOOSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT AND CLAY, TRACE FINE GRAVEL, VERY MOIST.	762.2	10	5 8 9	26	56	SS-10	-	36	20	21	14	9	18	14	4	7	A-1-b (0)	-	
MEDIUM DENSE, BROWN TO LIGHT BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP.		11	13 16 17	50	69	SS-11	-	60	18	8	8	6	23	13	10	5	A-2-4 (0)	-	
		12																	
DENSE TO VERY DENSE, BROWN TO LIGHT BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP. -FLUID ADDED TO AUGERS @ 21.3' AUGER REFUSAL @ 21.8'		13	14 12 11	35	89	SS-12	-	-	-	-	-	-	-	-	-	9	A-2-4 (V)	-	
		14																	
	756.9	15	25 50/4"	-	100	SS-13	-	-	-	-	-	-	-	-	-	6	A-2-4 (V)	-	
LIMESTONE BOULDER -VERY LOW RECOVERY IN NQ2-1	753.5	16 EOB	0		16	NQ2-1											CORE		

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING; CAVE-IN DEPTH @ 14.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH BENTONITE CHIPS AND SOIL CUTTINGS. PAVEMENT PATCHED WITH CONCRETE. .

000-23 RII STA ODOT LOG SUL(8.5 X 11) - OH DOT.GDT - 1/13/25 14:08 - U:\GI8\PROJECTS\2024\W-24-093.GPJ

RESOURCE INTERNATIONAL, INC.

PROJECT: MOT-JOHNSON STATION RD REPL.	DRILLING FIRM / OPERATOR: RII / IS	DRILL RIG: DIEDRICH D-50	STATION / OFFSET: 7+22 / 6' RT	**EXPLORATION ID**	
TYPE: STRUCTURE FOUNDATION	SAMPLING FIRM / LOGGER: RII / DB	HAMMER: AUTOMATIC	ALIGNMENT: JOHNSON STATION ROAD	**B-002-1-24**	
PID: 120484 SFN: NA	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 3/25/24	ELEVATION: 778.7 (MSL) EOB: 63.6 ft.	PAGE	
START: 8/28/24 END: 8/29/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 90	LAT / LONG: 39.864499, -84.170999	1 OF 3	

MATERIAL DESCRIPTION AND NOTES	ELEV. 778.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
-BLANK DRILL TO 21.0', BOTTOM DEPTH OF B-002		1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20																	
	757.7	21																	
DENSE TO VERY DENSE, GRAY TO BROWN **GRAVEL**, SOME COARSE AND FINE SAND, LITTLE SILT AND TRACE CLAY, MOIST.		22	10 22 30	78	56	SS-1	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	-	
		23																	
	W 754.7	24	29 29 16	68	39	SS-2	-	59	16	10	11	4	NP	NP	NP	9	A-1-a (0)	-	
		25																	
		26	16 15 14	44	44	SS-3	-	-	-	-	-	-	-	-	-	10	A-1-a (V)	-	
		27																	
		28																	
	749.3	29	38 35 44	119	86	SS-4A	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	-	
						SS-4B	-	-	-	-	-	-	-	-	-	7	A-2-4 (V)	-	

PID: 120484	SFN: NA	PROJECT: ODOT-JOHNSON STATION RD REPL	STATION / OFFSET: 722, 6' RT.	START: 8/28/24	END: 8/29/24	PG 2 OF 3	B-002-1-24

MATERIAL DESCRIPTION AND NOTES	ELEV. 748.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
VERY DENSE, DARK BROWN TO BROWN **GRAVEL WITH SAND AND SILT**, MOIST. *(continued)*	748.2																		
VERY DENSE, BROWN **GRAVEL**, SOME COARSE AND FINE SAND, TRACE SILT AND CLAY, MOIST TO WET. -HEAVING SANDS @ 31.0' -FLUID ADDED TO AUGERS @ 33.5'		31–32	25 19 21	60	86	SS-5	-	57	21	10	8	4	NP	NP	NP	10	A-1-a (0)	-	
		33–34	49 24 27	77	78	SS-6	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	-	
		35–36	21 50/0"	-	40	SS-7	-	-	-	-	-	-	-	-	-	13	A-1-a (V)	-	
	739.2	37–38																	
VERY DENSE, BROWN **GRAVEL WITH SAND**, LITTLE TO TRACE SILT, MOIST.		39	22 20 24	66	67	SS-8A	-	-	-	-	-	-	-	-	-	10	A-1-a (V)	-	
						SS-8B	-	-	-	-	-	-	-	-	-	17	A-1-b (V)	-	
	735.2	40–43																	
VERY DENSE, LIGHT BROWN **GRAVEL WITH SAND AND SILT**, WET. -COBBLES PRESENT @ 46.5'		44–45	25 20 28	72	56	SS-9	-	54	20	15	-	11 -	-	-	-	11	A-2-4 (V)	-	
-COBBLES PRESENT @ 49.0'		49–50	5 30 13	65	44	SS-10	-	-	-	-	-	-	-	-	-	11	A-2-4 (V)	-	
	725.2	51–53																	
VERY DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET. -COBBLES PRESENT @ 56.0'		54	50/5"	-	100	SS-11	-	54	14	12	14	6	NP	NP	NP	9	A-1-b (0)	-	
		55–58																	
		59	50/4"	-	100	SS-12	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	-	
		60–61																	

PID: 120484	SFN: NA	PROJECT: DOT-JOHNSON STATION RD REPL	STATION / OFFSET: 722, 6' RT.	START: 8/28/24	END: 8/29/24	PG 3 OF 3	B-002-1-24

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)	SO4 ppm	BACK FILL
VERY DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET. *(continued)*	716.6																		
	715.1	63 EOB	50/1"	-	100	SS-13	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	-	

NOTES: GROUNDWATER ENCOUNTERED @ 24.0' AND COULD NOT BE DETERMINED UPON COMPLETION DUE TO ADDITION OF MUD; CAVE-IN DEPTH @ 7.7'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH BENTONITE CHIPS AND SOIL CUTTINGS. PAVEMENT PATCHED WITH CONCRETE. .

RESOURCE INTERNATIONAL, INC.

PROJECT: MOT-JOHNSON STATION RD REPL.	DRILLING FIRM / OPERATOR: RII / IS	DRILL RIG: DIEDRICH D-50	STATION / OFFSET: 6+11 / 4' RT	**EXPLORATION ID B-003-0-24**
TYPE: STRUCTURE FOUNDATION	SAMPLING FIRM / LOGGER: RII / DB	HAMMER: AUTOMATIC	ALIGNMENT: JOHNSON STATION ROAD	
PID: 120484 SFN: NA	DRILLING METHOD: 4.5" CFA	CALIBRATION DATE: 3/25/24	ELEVATION: 778.3 (MSL) EOB: 7.0 ft.	PAGE 1 OF 1
START: 8/29/24 END: 8/29/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 90	LAT / LONG: 39.864123, -84.171262	

MATERIAL DESCRIPTION AND NOTES	ELEV. 778.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
0.5' - ASPHALT (5.5")	777.8																		
0.5' - BASE (6.5")	777.3																		
DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST.	775.8	1	11 11 11	33	89	SS-1	-	38	29	19	9	5	NP	NP	NP	6	A-1-b (0)	160	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND AND SILT**, LITTLE CLAY, DAMP TO MOIST.	772.8	2 3 4 5	6 6 5	17	78	SS-2	-	24	21	22	20	13	18	12	6	11	A-2-4 (0)	-	
			4 6 4	15	100	SS-3	-	-	-	-	-	-	-	-	-	7	A-2-4 (V)	-	
STIFF, BROWN **SILTY CLAY**, LITTLE TO TRACE COARSE AND FINE SAND, MOIST.	771.3	6 EOB 7	3 2 4	9	100	SS-4	1.75	-	-	-	-	-	-	-	-	20	A-6b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH BENTONITE CHIPS AND SOIL CUTTINGS. PAVEMENT PATCHED WITH CONCRETE. .

APPENDIX IV

PAVEMENT CORE DATA SHEETS

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

Pavement Core Data Summary

PROJECT: MOT-Johnson Station Road Bridge Replacement
LOCATION: Vandalia, Ohio
JOB No.: W-24-093

BORING/CORE No.: B-003-0-24
DATE CORE OBTAINED: 8/29/2024
CORE OBTAINED BY: IS

Core Composition

Core Number	Lift Thickness (in.)	Lift Number	Asphalt: Surface Binder	Asphalt: Intermediate Binder	Asphalt: Base Binder	Concrete	Aggregate/Granular Base	Other		
B-003-0-24	1.25	3		✓						
	1.75	2		✓						
	2.50	1		✓						
	6.50						✓			

Comments/Remarks

- Layer 1 is disintegrated.
- Layers 1 & 2 are separated.
- Layer 2 is deteriorating and has voids.
- Layer 3 has voids.
- Aggregate Base: Gravel and Sand
  ODOT A-1-b

Total Pavement Thickness =	5.50	in.	Total Asphalt Thickness =	5.50	in.	Total Concrete Thickness =	0.00	in.	Total Base Thickness =	6.50	in.

APPENDIX V

PILE BEARING AND DRIVABILITY ANALYSIS

DrivenPiles - Report

General Project Information

Filename: C:\Users\Legacy\Documents\W-24-093\Forward Abutment B-001.dvn
Project Name: MOT-Johnson Station Rd Bridge Replacement
Project Client: Prime AE Group
Prepared By: DEK
Project Manager: DEK

Pile Information

Pile Type: Pipe Pile - Closed End
Top of Pile: 0.00 ft
Diameter of Pile: 14.00 in

Nominal Considerations

Water Table Depth At Time Of:

Drilling:	0.00 ft
Driving/Restrike:	0.00 ft
Nominal:	0.00 ft

Nominal Considations:

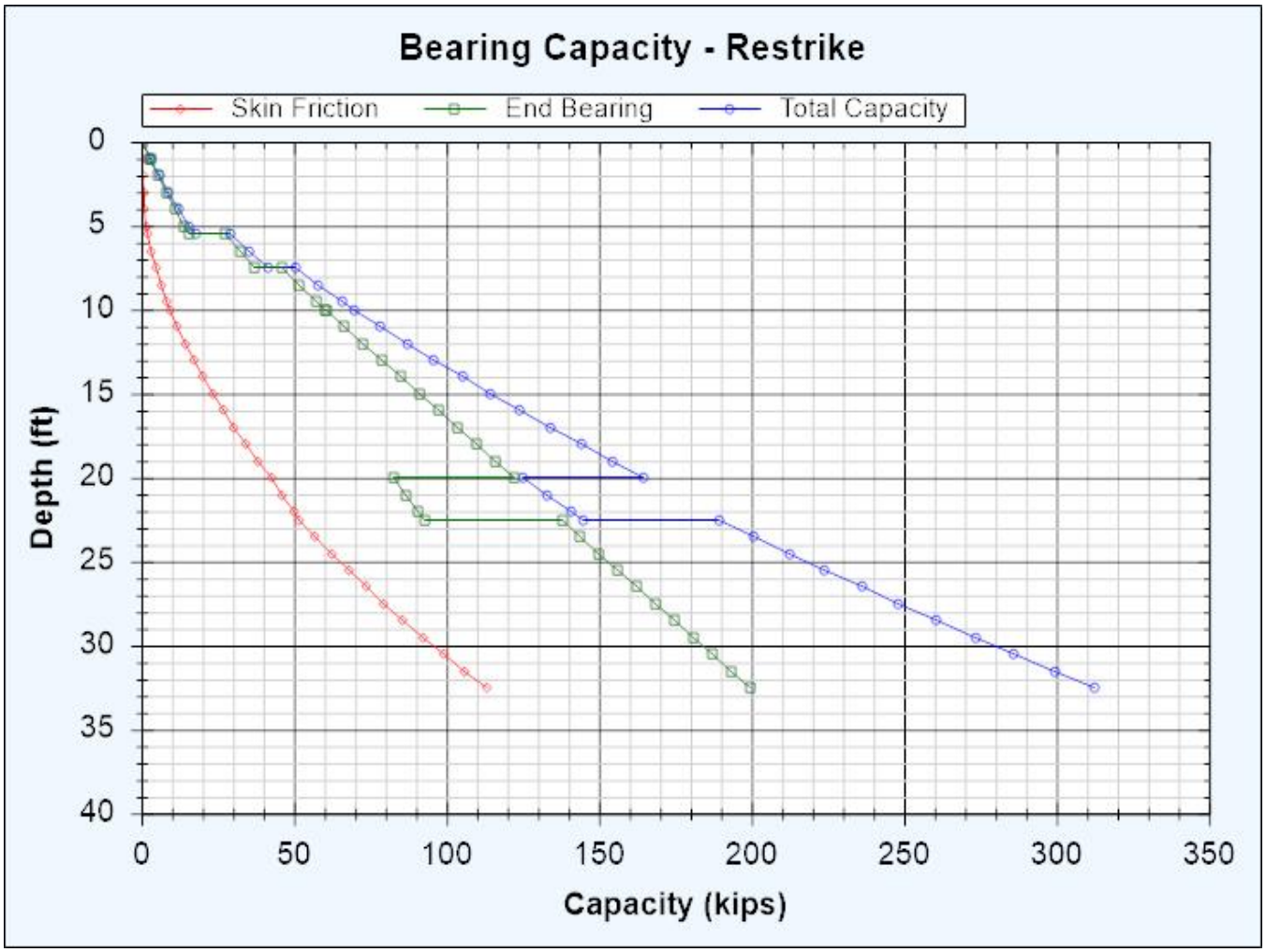
Local Scour:	0.00 ft
Long Term Scour:	0.00 ft
Soft Soil:	0.00 ft

Nominal Profile

Layer	Soil Type	Thickness	Setup Factor	Unit Weight	Strength	Nominal Curve
1	Cohesionless	1.00 ft	1.000	130.00 pcf	35.0/35.0	Nordlund
2	Cohesionless	4.50 ft	1.000	135.00 pcf	34.0/34.0	Nordlund
3	Cohesionless	2.00 ft	1.000	135.00 pcf	37.0/37.0	Nordlund
4	Cohesionless	2.50 ft	1.000	130.00 pcf	38.0/38.0	Nordlund
5	Cohesionless	10.00 ft	1.000	135.00 pcf	38.0/38.0	Nordlund
6	Cohesionless	2.50 ft	1.000	135.00 pcf	36.0/36.0	Nordlund
7	Cohesionless	10.00 ft	1.000	135.00 pcf	38.0/38.0	Nordlund

Restrike - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.03 kips	0.03 kips
0.99 ft	0.07 kips	3.11 kips	3.18 kips
1.01 ft	0.07 kips	2.69 kips	2.76 kips
2.00 ft	0.27 kips	5.52 kips	5.79 kips
3.00 ft	0.60 kips	8.38 kips	8.99 kips
4.00 ft	1.08 kips	11.24 kips	12.32 kips
5.00 ft	1.69 kips	14.10 kips	15.80 kips
5.49 ft	2.04 kips	15.50 kips	17.55 kips
5.51 ft	2.06 kips	27.25 kips	29.31 kips
6.50 ft	3.23 kips	32.21 kips	35.44 kips
7.49 ft	4.60 kips	37.16 kips	41.77 kips
7.51 ft	4.63 kips	46.03 kips	50.66 kips
8.50 ft	6.39 kips	51.73 kips	58.12 kips
9.50 ft	8.37 kips	57.49 kips	65.86 kips
9.99 ft	9.42 kips	60.31 kips	69.73 kips
10.01 ft	9.46 kips	60.43 kips	69.90 kips
11.00 ft	11.75 kips	66.56 kips	78.30 kips
12.00 ft	14.27 kips	72.74 kips	87.02 kips
13.00 ft	17.03 kips	78.93 kips	95.96 kips
14.00 ft	20.00 kips	85.12 kips	105.12 kips
15.00 ft	23.21 kips	91.30 kips	114.51 kips
16.00 ft	26.63 kips	97.49 kips	124.12 kips
17.00 ft	30.28 kips	103.67 kips	133.96 kips
18.00 ft	34.16 kips	109.86 kips	144.02 kips
19.00 ft	38.26 kips	116.05 kips	154.31 kips
19.99 ft	42.54 kips	122.17 kips	164.71 kips
20.01 ft	42.62 kips	82.55 kips	125.17 kips
21.00 ft	46.13 kips	86.68 kips	132.81 kips
22.00 ft	49.85 kips	90.86 kips	140.70 kips
22.49 ft	51.73 kips	92.90 kips	144.64 kips
22.51 ft	51.82 kips	137.76 kips	189.58 kips
23.50 ft	56.88 kips	143.89 kips	200.77 kips
24.50 ft	62.22 kips	150.07 kips	212.29 kips
25.50 ft	67.78 kips	156.26 kips	224.03 kips
26.50 ft	73.56 kips	162.44 kips	236.00 kips
27.50 ft	79.57 kips	168.63 kips	248.20 kips
28.50 ft	85.80 kips	174.82 kips	260.62 kips
29.50 ft	92.26 kips	181.00 kips	273.26 kips
30.50 ft	98.94 kips	187.19 kips	286.13 kips
31.50 ft	105.85 kips	193.38 kips	299.22 kips
32.49 ft	112.91 kips	199.50 kips	312.41 kips


Bearing Capacity - Restrike
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
5
10
15
20
25
30
35
40
0
50
100
150
200
250
300
350
Capacity (kips)

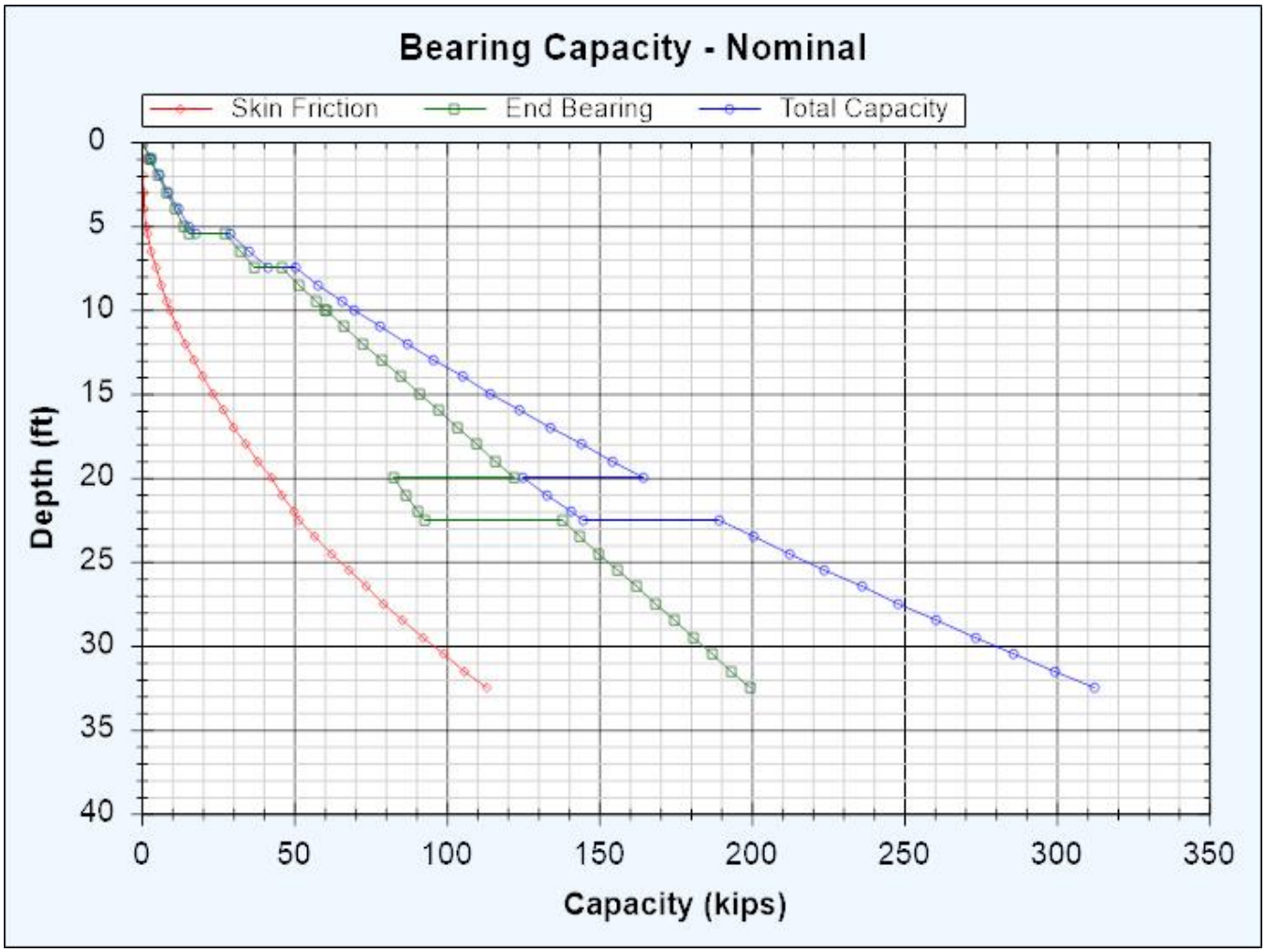
Driving - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.03 kips	0.03 kips
0.99 ft	0.07 kips	3.11 kips	3.18 kips
1.01 ft	0.07 kips	2.69 kips	2.76 kips
2.00 ft	0.27 kips	5.52 kips	5.79 kips
3.00 ft	0.60 kips	8.38 kips	8.99 kips
4.00 ft	1.08 kips	11.24 kips	12.32 kips
5.00 ft	1.69 kips	14.10 kips	15.80 kips
5.49 ft	2.04 kips	15.50 kips	17.55 kips
5.51 ft	2.06 kips	27.25 kips	29.31 kips
6.50 ft	3.23 kips	32.21 kips	35.44 kips
7.49 ft	4.60 kips	37.16 kips	41.77 kips
7.51 ft	4.63 kips	46.03 kips	50.66 kips
8.50 ft	6.39 kips	51.73 kips	58.12 kips
9.50 ft	8.37 kips	57.49 kips	65.86 kips
9.99 ft	9.42 kips	60.31 kips	69.73 kips
10.01 ft	9.46 kips	60.43 kips	69.90 kips
11.00 ft	11.75 kips	66.56 kips	78.30 kips
12.00 ft	14.27 kips	72.74 kips	87.02 kips
13.00 ft	17.03 kips	78.93 kips	95.96 kips
14.00 ft	20.00 kips	85.12 kips	105.12 kips
15.00 ft	23.21 kips	91.30 kips	114.51 kips
16.00 ft	26.63 kips	97.49 kips	124.12 kips
17.00 ft	30.28 kips	103.67 kips	133.96 kips
18.00 ft	34.16 kips	109.86 kips	144.02 kips
19.00 ft	38.26 kips	116.05 kips	154.31 kips
19.99 ft	42.54 kips	122.17 kips	164.71 kips
20.01 ft	42.62 kips	82.55 kips	125.17 kips
21.00 ft	46.13 kips	86.68 kips	132.81 kips
22.00 ft	49.85 kips	90.86 kips	140.70 kips
22.49 ft	51.73 kips	92.90 kips	144.64 kips
22.51 ft	51.82 kips	137.76 kips	189.58 kips
23.50 ft	56.88 kips	143.89 kips	200.77 kips
24.50 ft	62.22 kips	150.07 kips	212.29 kips
25.50 ft	67.78 kips	156.26 kips	224.03 kips
26.50 ft	73.56 kips	162.44 kips	236.00 kips
27.50 ft	79.57 kips	168.63 kips	248.20 kips
28.50 ft	85.80 kips	174.82 kips	260.62 kips
29.50 ft	92.26 kips	181.00 kips	273.26 kips
30.50 ft	98.94 kips	187.19 kips	286.13 kips
31.50 ft	105.85 kips	193.38 kips	299.22 kips
32.49 ft	112.91 kips	199.50 kips	312.41 kips

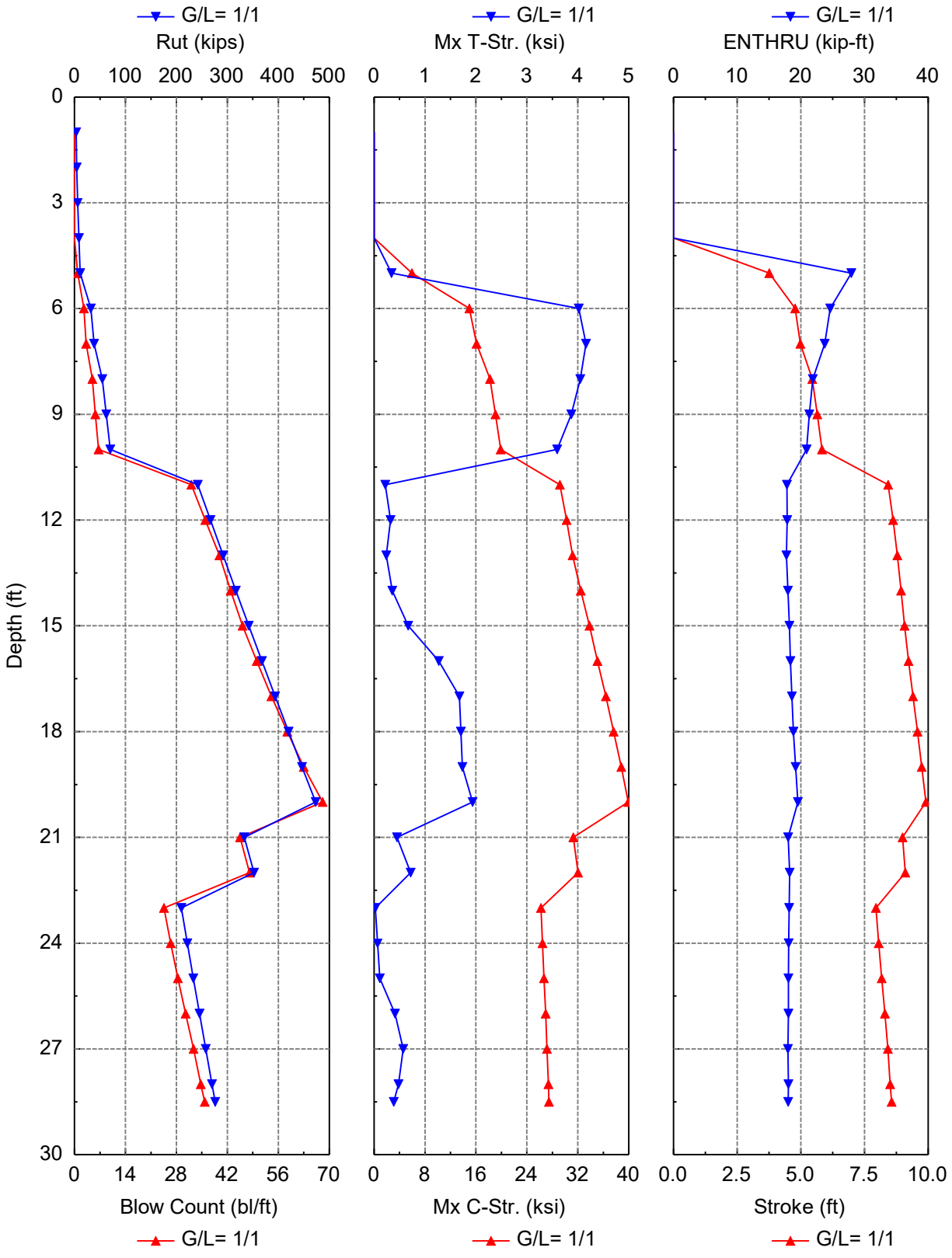

Bearing Capacity - Driving
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
5
10
15
20
25
30
35
40
0
50
100
150
200
250
300
350
Capacity (kips)

Nominal - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.03 kips	0.03 kips
0.99 ft	0.07 kips	3.11 kips	3.18 kips
1.01 ft	0.07 kips	2.69 kips	2.76 kips
2.00 ft	0.27 kips	5.52 kips	5.79 kips
3.00 ft	0.60 kips	8.38 kips	8.99 kips
4.00 ft	1.08 kips	11.24 kips	12.32 kips
5.00 ft	1.69 kips	14.10 kips	15.80 kips
5.49 ft	2.04 kips	15.50 kips	17.55 kips
5.51 ft	2.06 kips	27.25 kips	29.31 kips
6.50 ft	3.23 kips	32.21 kips	35.44 kips
7.49 ft	4.60 kips	37.16 kips	41.77 kips
7.51 ft	4.63 kips	46.03 kips	50.66 kips
8.50 ft	6.39 kips	51.73 kips	58.12 kips
9.50 ft	8.37 kips	57.49 kips	65.86 kips
9.99 ft	9.42 kips	60.31 kips	69.73 kips
10.01 ft	9.46 kips	60.43 kips	69.90 kips
11.00 ft	11.75 kips	66.56 kips	78.30 kips
12.00 ft	14.27 kips	72.74 kips	87.02 kips
13.00 ft	17.03 kips	78.93 kips	95.96 kips
14.00 ft	20.00 kips	85.12 kips	105.12 kips
15.00 ft	23.21 kips	91.30 kips	114.51 kips
16.00 ft	26.63 kips	97.49 kips	124.12 kips
17.00 ft	30.28 kips	103.67 kips	133.96 kips
18.00 ft	34.16 kips	109.86 kips	144.02 kips
19.00 ft	38.26 kips	116.05 kips	154.31 kips
19.99 ft	42.54 kips	122.17 kips	164.71 kips
20.01 ft	42.62 kips	82.55 kips	125.17 kips
21.00 ft	46.13 kips	86.68 kips	132.81 kips
22.00 ft	49.85 kips	90.86 kips	140.70 kips
22.49 ft	51.73 kips	92.90 kips	144.64 kips
22.51 ft	51.82 kips	137.76 kips	189.58 kips
23.50 ft	56.88 kips	143.89 kips	200.77 kips
24.50 ft	62.22 kips	150.07 kips	212.29 kips
25.50 ft	67.78 kips	156.26 kips	224.03 kips
26.50 ft	73.56 kips	162.44 kips	236.00 kips
27.50 ft	79.57 kips	168.63 kips	248.20 kips
28.50 ft	85.80 kips	174.82 kips	260.62 kips
29.50 ft	92.26 kips	181.00 kips	273.26 kips
30.50 ft	98.94 kips	187.19 kips	286.13 kips
31.50 ft	105.85 kips	193.38 kips	299.22 kips
32.49 ft	112.91 kips	199.50 kips	312.41 kips


Bearing Capacity - Nominal
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
5
10
15
20
25
30
35
40
0
50
100
150
200
250
300
350
Capacity (kips)

Driveability Analysis Summary



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

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	-
1.0	3.2	0.1	3.1	0.3	0.000	0.000	10.81	0.0	D 19-42
2.0	4.0	0.2	3.8	0.3	0.000	0.000	10.81	0.0	D 19-42
3.0	6.3	0.5	5.8	0.0	0.000	0.000	0.00	0.0	D 19-42
4.0	8.7	0.9	7.8	0.0	0.000	0.000	0.00	0.0	D 19-42
5.0	11.1	1.4	9.7	0.9	5.945	0.343	3.76	27.9	D 19-42
6.0	32.1	2.3	29.8	2.6	14.971	4.018	4.78	24.6	D 19-42
7.0	38.5	3.6	34.9	3.2	16.088	4.162	4.98	23.7	D 19-42
8.0	54.4	5.2	49.2	4.9	18.224	4.047	5.45	21.9	D 19-42
9.0	62.1	7.1	55.0	5.7	19.086	3.872	5.64	21.3	D 19-42
10.0	70.1	9.2	60.8	6.6	19.874	3.594	5.83	20.9	D 19-42
11.0	242.1	12.1	230.0	32.1	29.180	0.221	8.43	17.8	D 19-42
12.0	266.7	15.3	251.4	35.9	30.240	0.325	8.62	17.9	D 19-42
13.0	291.5	18.7	272.8	39.8	31.155	0.243	8.79	17.7	D 19-42
14.0	316.6	22.5	294.2	42.9	32.452	0.358	8.93	17.9	D 19-42
15.0	342.0	26.5	315.5	46.2	33.831	0.673	9.07	18.2	D 19-42
16.0	367.7	30.8	336.9	50.1	35.074	1.269	9.22	18.4	D 19-42
17.0	393.7	35.4	358.3	54.1	36.420	1.677	9.40	18.6	D 19-42
18.0	420.0	40.3	379.7	58.5	37.614	1.707	9.57	18.8	D 19-42
19.0	446.5	45.4	401.1	63.0	38.813	1.734	9.74	19.2	D 19-42
20.0	473.3	50.9	422.4	68.2	39.905	1.935	9.90	19.5	D 19-42
21.0	333.1	56.5	276.6	45.5	31.290	0.450	8.99	18.0	D 19-42
22.0	352.4	62.5	289.9	48.1	32.047	0.719	9.09	18.2	D 19-42
23.0	210.0	68.1	141.9	24.6	26.201	0.026	7.94	18.2	D 19-42
24.0	221.5	73.4	148.1	26.4	26.463	0.068	8.05	18.1	D 19-42
25.0	233.3	78.9	154.4	28.4	26.697	0.115	8.17	18.0	D 19-42
26.0	245.2	84.6	160.6	30.5	26.948	0.413	8.29	18.0	D 19-42
27.0	257.4	90.6	166.8	32.7	27.162	0.572	8.41	18.0	D 19-42
28.0	269.9	96.8	173.1	34.7	27.386	0.480	8.50	18.0	D 19-42
28.5	276.2	100.0	176.2	35.8	27.476	0.386	8.56	18.0	D 19-42

Total driving time: 20 minutes; Total Number of Blows: 786 (starting at penetration 1.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

MOT-Johnson Station Forward Abutment B-001 7/30/2025
RESOURCE INTERNATIONAL INC 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.

SOIL PROFILE

Depth	Soil Type	Spec. Wt	Su	Phi	Unit Rs	Unit Rt
ft	-	lb/ft³	ksf	°	ksf	ksf
0.0	Sand	130.0	0.0	35.0	0.00	0.00
1.0	Sand	130.0	0.0	35.0	0.03	2.94
1.0	Sand	135.0	0.0	32.0	0.02	1.72
5.5	Sand	135.0	0.0	32.0	0.14	10.02
5.5	Sand	135.0	0.0	37.0	0.23	25.57
7.5	Sand	135.0	0.0	37.0	0.31	34.98
7.5	Sand	130.0	0.0	38.0	0.35	43.34
10.0	Sand	130.0	0.0	38.0	0.46	56.91
10.0	Sand	135.0	0.0	43.0	0.56	195.17
20.0	Sand	135.0	0.0	43.0	1.13	395.17
20.0	Sand	135.0	0.0	41.0	1.13	246.26
22.5	Sand	135.0	0.0	41.0	1.27	277.42
22.5	Sand	135.0	0.0	38.0	1.05	129.81
32.5	Sand	135.0	0.0	38.0	1.53	188.13

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	40.000	Pile Penetration: (ft)	28.500
Pile Size: (ft)	1.17	Toe Area: (in²)	153.94

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	27.3	30,000.0	492.0	3.7	0
40.0	27.3	30,000.0	492.0	3.7	0

HAMMER INPUT

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

Hammer Data

ID	Ram Wt	Ram L.	Ram Ar.	Rtd. Stk	Effic.	Rtd. Energy
-	kips	in	in²	ft	-	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	E-Modulus	Thickness	COR	Round-out	Stiffness
-	in²	ksi	in	-	in	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	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	0.0	0.0	0.10	0.05	0.05	0.15	1.0	6.0	1.0	153.9
1.0	0.0	2.9	0.10	0.05	0.05	0.15	1.0	6.0	1.0	153.9
1.0	0.0	1.7	0.10	0.06	0.05	0.15	1.0	6.0	1.0	153.9
3.3	0.1	5.9	0.10	0.06	0.05	0.15	1.0	6.0	1.0	153.9
5.5	0.2	10.0	0.10	0.06	0.05	0.15	1.0	6.0	1.0	153.9
5.5	0.3	25.6	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
6.5	0.4	30.3	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
7.5	0.4	35.0	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
7.5	0.5	43.3	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
8.8	0.5	50.1	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
10.0	0.6	56.9	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
10.0	0.8	195.2	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
11.7	0.9	228.5	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
13.3	1.0	261.8	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
15.0	1.1	295.2	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
16.7	1.3	328.5	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
18.3	1.4	361.8	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
20.0	1.5	395.2	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
20.0	1.5	246.3	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
21.3	1.6	261.8	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
22.5	1.7	277.4	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
22.5	1.4	129.8	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
24.2	1.5	139.5	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
25.8	1.6	149.3	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
27.5	1.7	159.0	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
28.5	1.8	164.8	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9

DrivenPiles - Report

General Project Information

Filename: C:\Users\Legacy\Documents\W-24-093\Rear Abutment B-002.dvn
Project Name: MOT-Johnson Station Road Rear Abut B-002
Project Client: Prime AE Group
Prepared By: DEK
Project Manager: DEK

Pile Information

Pile Type: Pipe Pile - Closed End
Top of Pile: 0.00 ft
Diameter of Pile: 14.00 in

Nominal Considerations

Water Table Depth At Time Of:

Drilling:	0.00 ft
Driving/Restrike:	0.00 ft
Nominal:	0.00 ft

Nominal Considations:

Local Scour:	0.00 ft
Long Term Scour:	0.00 ft
Soft Soil:	0.00 ft

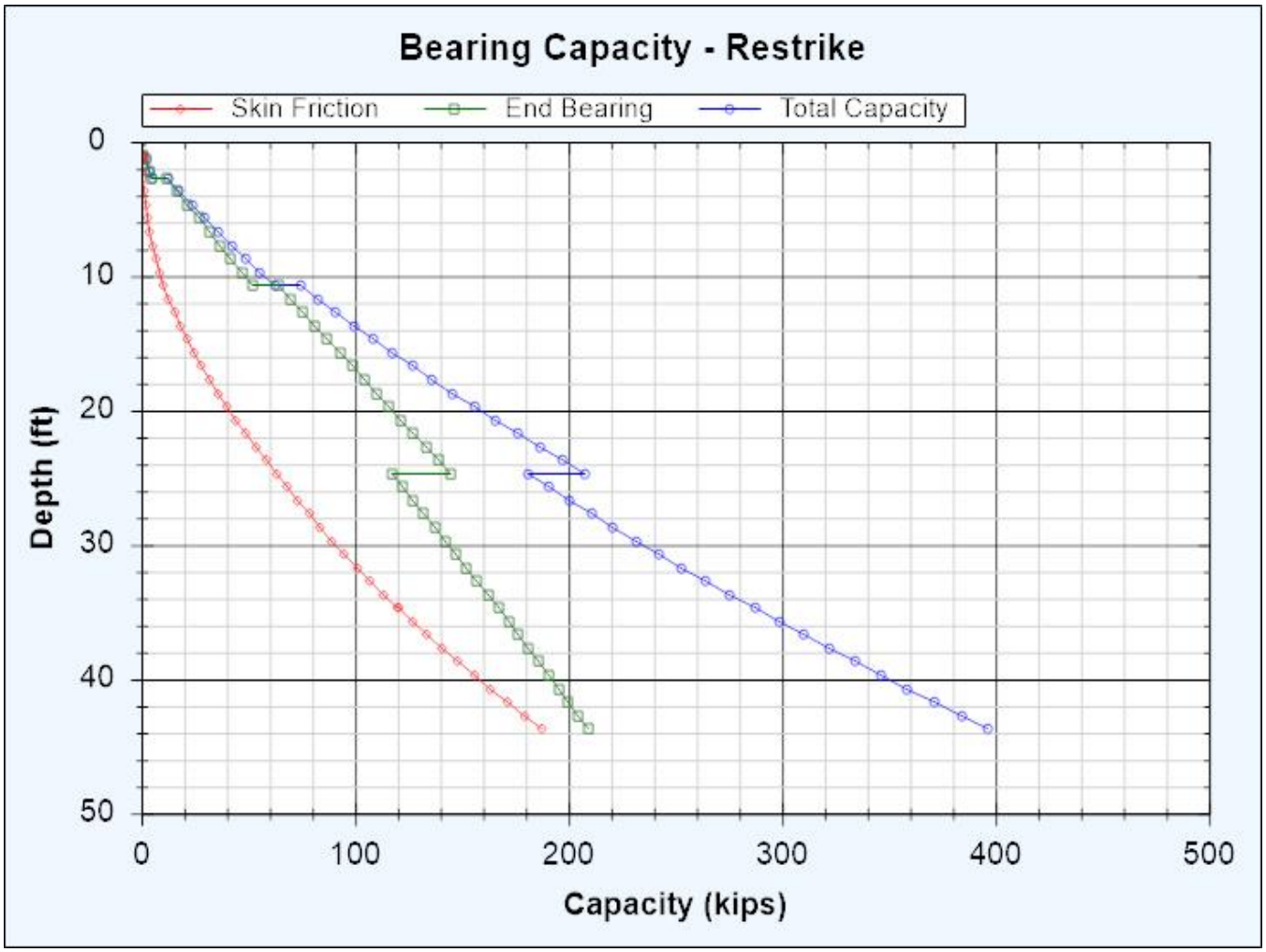
Nominal Profile

Layer	Soil Type	Thickness	Setup Factor	Unit Weight	Strength	Nominal Curve
1	Cohesionless	1.20 ft	1.000	120.00 pcf	27.0/27.0	Nordlund
2	Cohesionless	1.50 ft	1.000	130.00 pcf	32.0/32.0	Nordlund
3	Cohesionless	8.00 ft	1.200	135.00 pcf	37.0/37.0	Nordlund
4	Cohesionless	14.00 ft	1.000	130.00 pcf	38.0/38.0	Nordlund
5	Cohesionless	10.00 ft	1.000	135.00 pcf	37.0/37.0	Nordlund
6	Cohesionless	9.00 ft	1.200	130.00 pcf	37.0/37.0	Nordlund

Restrike - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.01 kips	0.01 kips
1.00 ft	0.03 kips	0.63 kips	0.65 kips
1.19 ft	0.04 kips	0.75 kips	0.79 kips
1.21 ft	0.04 kips	1.89 kips	1.93 kips
2.20 ft	0.20 kips	3.69 kips	3.90 kips
2.69 ft	0.32 kips	4.59 kips	4.91 kips
2.71 ft	0.33 kips	11.81 kips	12.14 kips
3.70 ft	0.89 kips	16.77 kips	17.66 kips
4.70 ft	1.66 kips	21.78 kips	23.44 kips
5.70 ft	2.63 kips	26.79 kips	29.41 kips
6.70 ft	3.79 kips	31.79 kips	35.59 kips
7.70 ft	5.16 kips	36.80 kips	41.96 kips
8.70 ft	6.73 kips	41.81 kips	48.53 kips
9.70 ft	8.49 kips	46.82 kips	55.31 kips
10.69 ft	10.44 kips	51.77 kips	62.21 kips
10.71 ft	10.48 kips	64.08 kips	74.56 kips
11.70 ft	12.89 kips	69.78 kips	82.67 kips
12.70 ft	15.52 kips	75.54 kips	91.06 kips
13.70 ft	18.37 kips	81.30 kips	99.67 kips
14.70 ft	21.42 kips	87.06 kips	108.49 kips
15.70 ft	24.69 kips	92.82 kips	117.51 kips
16.70 ft	28.16 kips	98.58 kips	126.74 kips
17.70 ft	31.85 kips	104.34 kips	136.19 kips
18.70 ft	35.74 kips	110.10 kips	145.84 kips
19.70 ft	39.84 kips	115.86 kips	155.70 kips
20.70 ft	44.15 kips	121.62 kips	165.77 kips
21.70 ft	48.67 kips	127.38 kips	176.05 kips
22.70 ft	53.40 kips	133.14 kips	186.54 kips
23.70 ft	58.33 kips	138.90 kips	197.24 kips
24.69 ft	63.43 kips	144.60 kips	208.03 kips
24.71 ft	63.53 kips	117.15 kips	180.68 kips
25.70 ft	68.25 kips	122.11 kips	190.36 kips
26.70 ft	73.21 kips	127.12 kips	200.33 kips
27.70 ft	78.38 kips	132.13 kips	210.50 kips
28.70 ft	83.74 kips	137.13 kips	220.88 kips
29.70 ft	89.31 kips	142.14 kips	231.45 kips
30.70 ft	95.07 kips	147.15 kips	242.22 kips
31.70 ft	101.03 kips	152.16 kips	253.19 kips
32.70 ft	107.20 kips	157.17 kips	264.36 kips
33.70 ft	113.56 kips	162.17 kips	275.73 kips
34.69 ft	120.05 kips	167.13 kips	287.18 kips
34.71 ft	120.19 kips	167.23 kips	287.41 kips

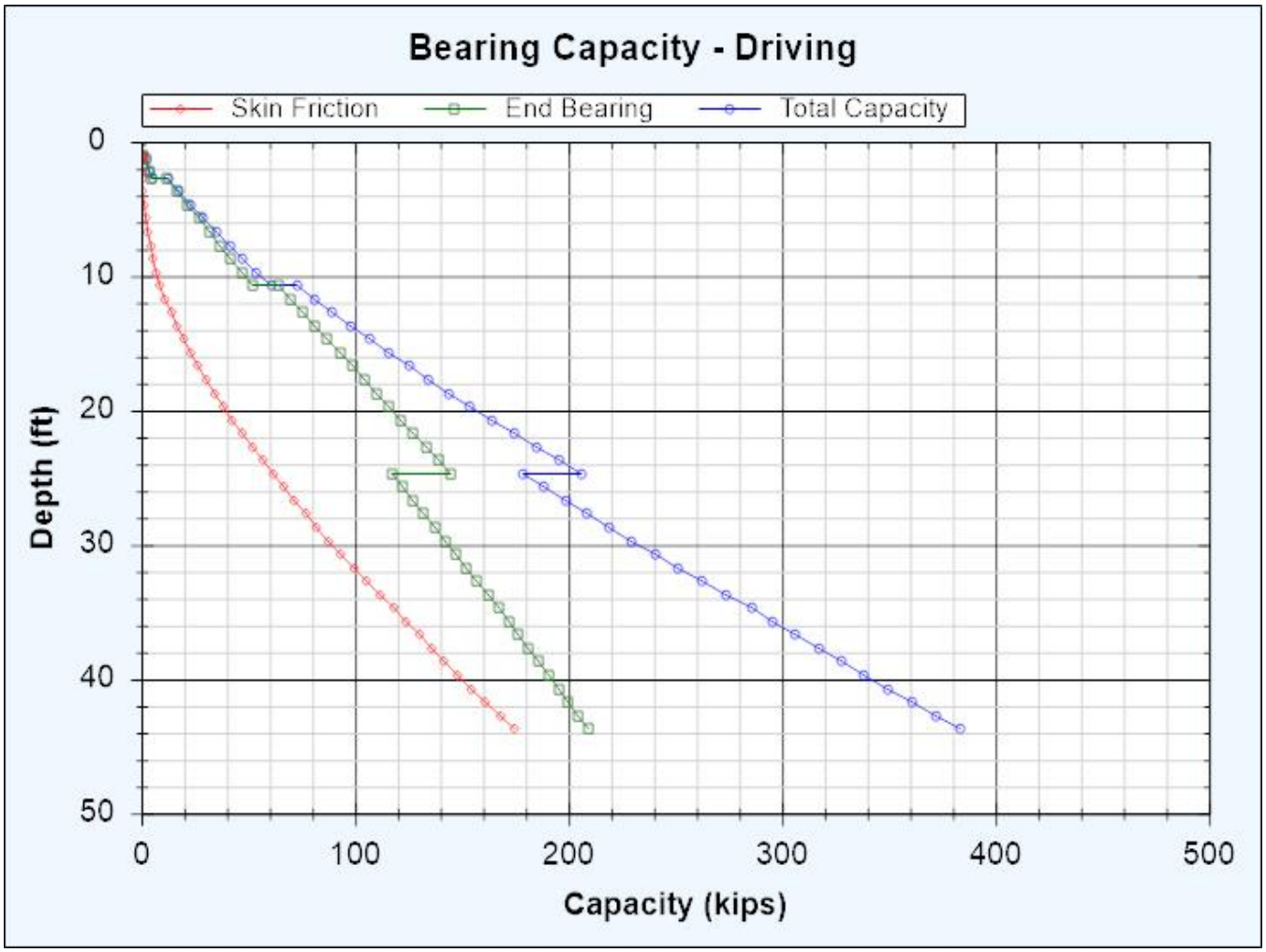
Depth	Skin Friction	End Bearing	Total Capacity
35.70 ft	126.87 kips	171.84 kips	298.72 kips
36.70 ft	133.81 kips	176.51 kips	310.32 kips
37.70 ft	140.94 kips	181.17 kips	322.11 kips
38.70 ft	148.25 kips	185.83 kips	334.09 kips
39.70 ft	155.75 kips	190.50 kips	346.25 kips
40.70 ft	163.43 kips	195.16 kips	358.59 kips
41.70 ft	171.30 kips	199.82 kips	371.12 kips
42.70 ft	179.36 kips	204.48 kips	383.84 kips
43.69 ft	187.52 kips	209.10 kips	396.62 kips


Bearing Capacity - Restrike
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
0
100
200
300
400
500
Capacity (kips)

Driving - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.01 kips	0.01 kips
1.00 ft	0.03 kips	0.63 kips	0.65 kips
1.19 ft	0.04 kips	0.75 kips	0.79 kips
1.21 ft	0.04 kips	1.89 kips	1.93 kips
2.20 ft	0.20 kips	3.69 kips	3.90 kips
2.69 ft	0.32 kips	4.59 kips	4.91 kips
2.71 ft	0.33 kips	11.81 kips	12.14 kips
3.70 ft	0.80 kips	16.77 kips	17.57 kips
4.70 ft	1.44 kips	21.78 kips	23.21 kips
5.70 ft	2.24 kips	26.79 kips	29.03 kips
6.70 ft	3.21 kips	31.79 kips	35.01 kips
7.70 ft	4.35 kips	36.80 kips	41.15 kips
8.70 ft	5.66 kips	41.81 kips	47.47 kips
9.70 ft	7.13 kips	46.82 kips	53.95 kips
10.69 ft	8.75 kips	51.77 kips	60.52 kips
10.71 ft	8.79 kips	64.08 kips	72.87 kips
11.70 ft	11.20 kips	69.78 kips	80.98 kips
12.70 ft	13.83 kips	75.54 kips	89.37 kips
13.70 ft	16.68 kips	81.30 kips	97.98 kips
14.70 ft	19.74 kips	87.06 kips	106.80 kips
15.70 ft	23.00 kips	92.82 kips	115.82 kips
16.70 ft	26.47 kips	98.58 kips	125.05 kips
17.70 ft	30.16 kips	104.34 kips	134.50 kips
18.70 ft	34.05 kips	110.10 kips	144.15 kips
19.70 ft	38.15 kips	115.86 kips	154.01 kips
20.70 ft	42.46 kips	121.62 kips	164.08 kips
21.70 ft	46.98 kips	127.38 kips	174.36 kips
22.70 ft	51.71 kips	133.14 kips	184.85 kips
23.70 ft	56.64 kips	138.90 kips	195.55 kips
24.69 ft	61.74 kips	144.60 kips	206.34 kips
24.71 ft	61.84 kips	117.15 kips	178.99 kips
25.70 ft	66.56 kips	122.11 kips	188.67 kips
26.70 ft	71.52 kips	127.12 kips	198.64 kips
27.70 ft	76.69 kips	132.13 kips	208.81 kips
28.70 ft	82.05 kips	137.13 kips	219.19 kips
29.70 ft	87.62 kips	142.14 kips	229.76 kips
30.70 ft	93.38 kips	147.15 kips	240.53 kips
31.70 ft	99.34 kips	152.16 kips	251.50 kips
32.70 ft	105.51 kips	157.17 kips	262.67 kips
33.70 ft	111.87 kips	162.17 kips	274.04 kips
34.69 ft	118.36 kips	167.13 kips	285.49 kips
34.71 ft	118.49 kips	167.23 kips	285.71 kips

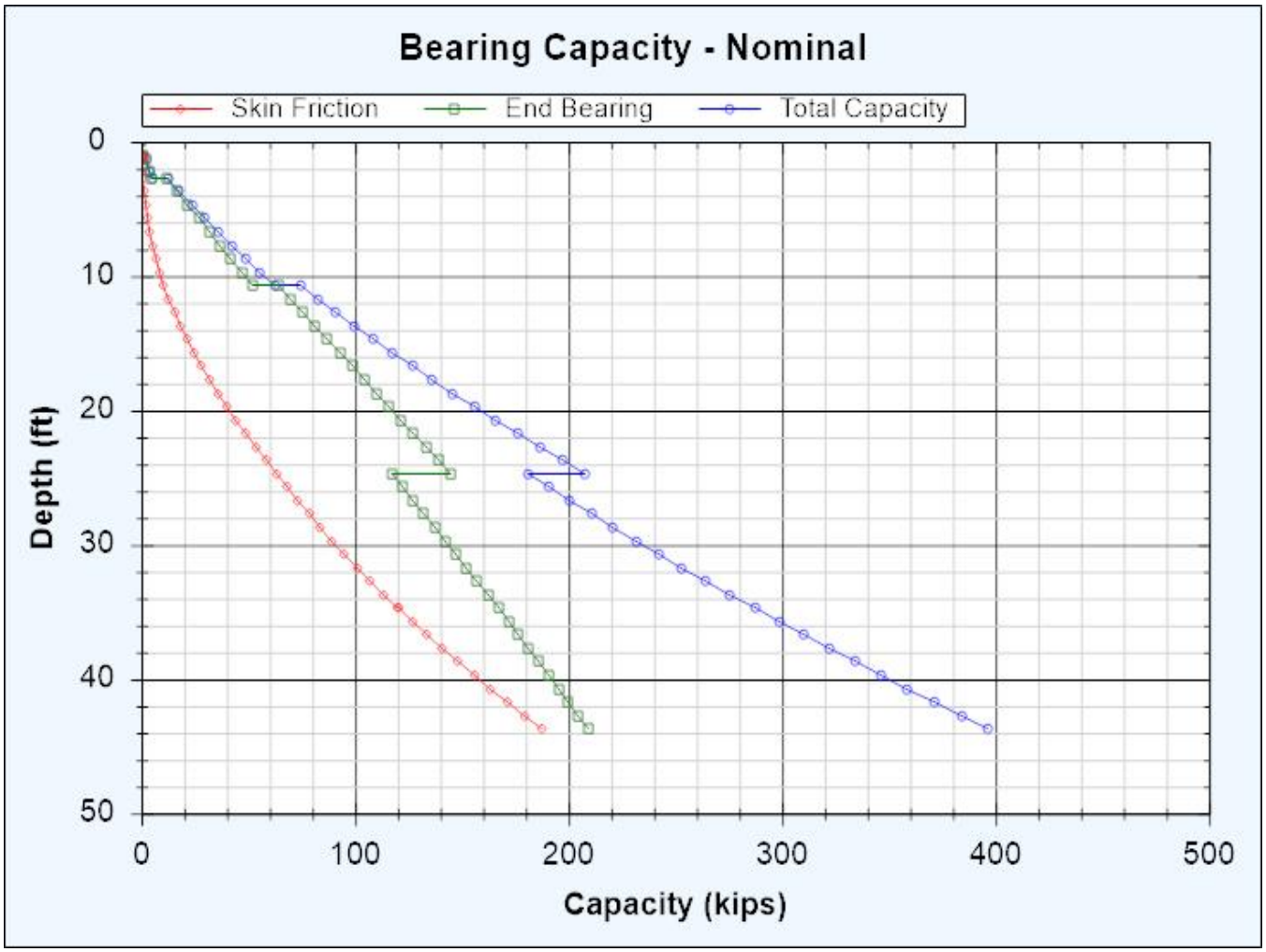
Depth	Skin Friction	End Bearing	Total Capacity
35.70 ft	124.06 kips	171.84 kips	295.90 kips
36.70 ft	129.84 kips	176.51 kips	306.35 kips
37.70 ft	135.78 kips	181.17 kips	316.95 kips
38.70 ft	141.87 kips	185.83 kips	327.71 kips
39.70 ft	148.12 kips	190.50 kips	338.62 kips
40.70 ft	154.52 kips	195.16 kips	349.68 kips
41.70 ft	161.08 kips	199.82 kips	360.90 kips
42.70 ft	167.79 kips	204.48 kips	372.28 kips
43.69 ft	174.59 kips	209.10 kips	383.69 kips


Bearing Capacity - Driving
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
0
100
200
300
400
500
Capacity (kips)

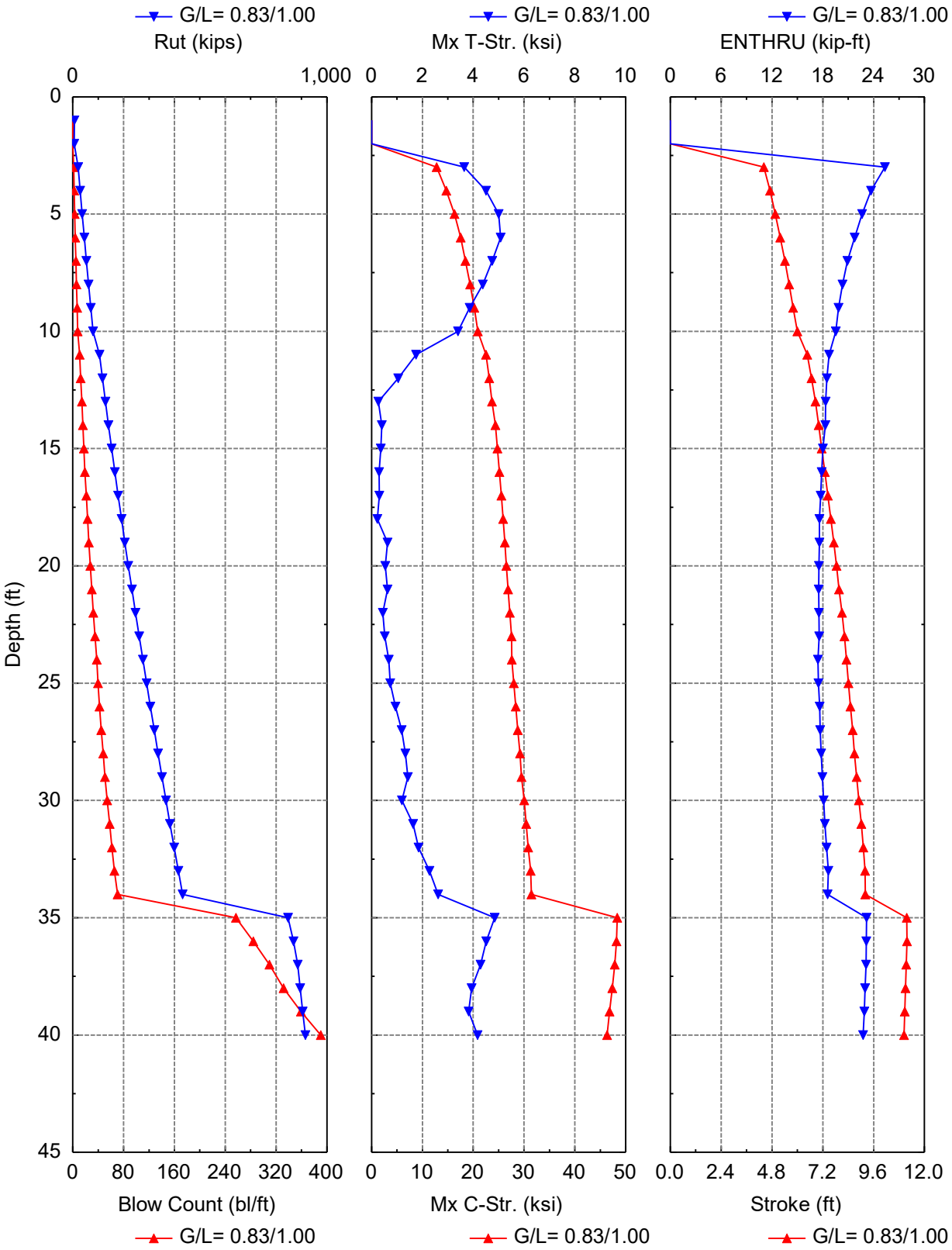
Nominal - Summary of Capacities

Depth	Skin Friction	End Bearing	Total Capacity
0.01 ft	0.00 kips	0.01 kips	0.01 kips
1.00 ft	0.03 kips	0.63 kips	0.65 kips
1.19 ft	0.04 kips	0.75 kips	0.79 kips
1.21 ft	0.04 kips	1.89 kips	1.93 kips
2.20 ft	0.20 kips	3.69 kips	3.90 kips
2.69 ft	0.32 kips	4.59 kips	4.91 kips
2.71 ft	0.33 kips	11.81 kips	12.14 kips
3.70 ft	0.89 kips	16.77 kips	17.66 kips
4.70 ft	1.66 kips	21.78 kips	23.44 kips
5.70 ft	2.63 kips	26.79 kips	29.41 kips
6.70 ft	3.79 kips	31.79 kips	35.59 kips
7.70 ft	5.16 kips	36.80 kips	41.96 kips
8.70 ft	6.73 kips	41.81 kips	48.53 kips
9.70 ft	8.49 kips	46.82 kips	55.31 kips
10.69 ft	10.44 kips	51.77 kips	62.21 kips
10.71 ft	10.48 kips	64.08 kips	74.56 kips
11.70 ft	12.89 kips	69.78 kips	82.67 kips
12.70 ft	15.52 kips	75.54 kips	91.06 kips
13.70 ft	18.37 kips	81.30 kips	99.67 kips
14.70 ft	21.42 kips	87.06 kips	108.49 kips
15.70 ft	24.69 kips	92.82 kips	117.51 kips
16.70 ft	28.16 kips	98.58 kips	126.74 kips
17.70 ft	31.85 kips	104.34 kips	136.19 kips
18.70 ft	35.74 kips	110.10 kips	145.84 kips
19.70 ft	39.84 kips	115.86 kips	155.70 kips
20.70 ft	44.15 kips	121.62 kips	165.77 kips
21.70 ft	48.67 kips	127.38 kips	176.05 kips
22.70 ft	53.40 kips	133.14 kips	186.54 kips
23.70 ft	58.33 kips	138.90 kips	197.24 kips
24.69 ft	63.43 kips	144.60 kips	208.03 kips
24.71 ft	63.53 kips	117.15 kips	180.68 kips
25.70 ft	68.25 kips	122.11 kips	190.36 kips
26.70 ft	73.21 kips	127.12 kips	200.33 kips
27.70 ft	78.38 kips	132.13 kips	210.50 kips
28.70 ft	83.74 kips	137.13 kips	220.88 kips
29.70 ft	89.31 kips	142.14 kips	231.45 kips
30.70 ft	95.07 kips	147.15 kips	242.22 kips
31.70 ft	101.03 kips	152.16 kips	253.19 kips
32.70 ft	107.20 kips	157.17 kips	264.36 kips
33.70 ft	113.56 kips	162.17 kips	275.73 kips
34.69 ft	120.05 kips	167.13 kips	287.18 kips
34.71 ft	120.19 kips	167.23 kips	287.41 kips

Depth	Skin Friction	End Bearing	Total Capacity
35.70 ft	126.87 kips	171.84 kips	298.72 kips
36.70 ft	133.81 kips	176.51 kips	310.32 kips
37.70 ft	140.94 kips	181.17 kips	322.11 kips
38.70 ft	148.25 kips	185.83 kips	334.09 kips
39.70 ft	155.75 kips	190.50 kips	346.25 kips
40.70 ft	163.43 kips	195.16 kips	358.59 kips
41.70 ft	171.30 kips	199.82 kips	371.12 kips
42.70 ft	179.36 kips	204.48 kips	383.84 kips
43.69 ft	187.52 kips	209.10 kips	396.62 kips


Bearing Capacity - Nominal
Skin Friction
End Bearing
Total Capacity
Depth (ft)
0
10
20
30
40
50
0
100
200
300
400
500
Capacity (kips)

Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.830/1.000

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	-
1.0	6.3	0.1	6.2	0.3	0.000	0.000	10.81	0.0	D 19-42
2.0	5.2	0.3	4.9	0.3	0.000	0.000	10.81	0.0	D 19-42
3.0	21.1	0.6	20.4	1.6	12.806	3.645	4.41	25.3	D 19-42
4.0	28.9	1.3	27.6	2.3	14.697	4.508	4.71	23.7	D 19-42
5.0	37.0	2.1	34.9	3.1	16.309	4.998	4.96	22.6	D 19-42
6.0	45.3	3.2	42.1	4.0	17.564	5.084	5.19	21.8	D 19-42
7.0	53.7	4.4	49.3	4.9	18.445	4.743	5.41	20.9	D 19-42
8.0	62.4	5.8	56.6	5.9	19.397	4.377	5.62	20.3	D 19-42
9.0	71.3	7.5	63.8	6.8	20.226	3.861	5.80	19.9	D 19-42
10.0	80.3	9.3	71.0	7.9	20.899	3.397	6.00	19.5	D 19-42
11.0	105.3	11.5	93.8	11.0	22.511	1.753	6.47	18.8	D 19-42
12.0	116.9	14.4	102.4	12.6	23.149	1.052	6.67	18.5	D 19-42
13.0	128.7	17.6	111.1	14.2	23.701	0.263	6.85	18.3	D 19-42
14.0	140.8	21.0	119.8	15.9	24.387	0.402	7.00	18.3	D 19-42
15.0	153.2	24.7	128.4	17.5	24.755	0.360	7.14	18.0	D 19-42
16.0	165.8	28.7	137.1	19.2	25.160	0.297	7.30	17.9	D 19-42
17.0	178.7	32.9	145.8	21.2	25.549	0.304	7.44	17.7	D 19-42
18.0	191.8	37.4	154.4	23.2	25.898	0.230	7.58	17.6	D 19-42
19.0	205.2	42.1	163.1	25.3	26.227	0.624	7.72	17.6	D 19-42
20.0	218.9	47.1	171.8	27.5	26.531	0.540	7.85	17.5	D 19-42
21.0	232.8	52.4	180.4	29.8	26.867	0.629	7.97	17.5	D 19-42
22.0	247.0	57.9	189.1	32.3	27.212	0.446	8.10	17.5	D 19-42
23.0	261.4	63.6	197.8	34.9	27.532	0.523	8.23	17.6	D 19-42
24.0	276.1	69.7	206.4	37.6	27.588	0.673	8.31	17.4	D 19-42
25.0	290.9	75.6	215.3	39.8	27.982	0.736	8.41	17.5	D 19-42
26.0	305.7	81.1	224.6	42.1	28.358	0.938	8.50	17.6	D 19-42
27.0	320.6	86.7	233.9	45.0	28.767	1.186	8.61	17.7	D 19-42
28.0	335.9	92.6	243.2	47.8	29.213	1.330	8.70	17.8	D 19-42
29.0	351.3	98.8	252.5	50.8	29.513	1.426	8.79	18.0	D 19-42
30.0	367.0	105.1	261.8	54.3	30.036	1.199	8.90	18.1	D 19-42
31.0	382.9	111.7	271.1	57.9	30.441	1.632	9.02	18.2	D 19-42
32.0	399.0	118.6	280.4	61.6	30.821	1.844	9.12	18.5	D 19-42
33.0	415.4	125.6	289.7	65.5	31.307	2.277	9.20	18.6	D 19-42
34.0	432.0	132.9	299.1	70.5	31.461	2.622	9.21	18.6	D 19-42
35.0	846.7	140.9	705.7	257.0	48.347	4.846	11.16	23.2	D 19-42
36.0	868.8	150.4	718.4	284.2	48.192	4.513	11.17	23.1	D 19-42
37.0	884.9	160.1	724.7	309.4	47.853	4.285	11.14	23.1	D 19-42
38.0	894.9	170.1	724.7	331.9	47.340	3.935	11.10	23.0	D 19-42

39.0	905.1	180.4	724.7	359.2	46.821	3.824	11.07	22.9	D 19-42
40.0	915.7	190.9	724.7	390.3	46.313	4.171	11.03	22.7	D 19-42

Total driving time: 70 minutes; Total Number of Blows: 2631 (starting at penetration 1.0 ft)

GRLWEAP: Wave Equation Analysis of Pile Foundations

MOT-Johnson Station Rear Abutment B-002 7/30/2025
RESOURCE INTERNATIONAL INC 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.

SOIL PROFILE

Depth	Soil Type	Spec. Wt	Su	Phi	Unit Rs	Unit Rt
ft	-	lb/ft³	ksf	°	ksf	ksf
0.0	Sand	120.0	0.0	39.0	0.00	0.00
1.2	Sand	120.0	0.0	39.0	0.05	6.92
1.2	Sand	130.0	0.0	34.0	0.03	2.56
2.7	Sand	130.0	0.0	34.0	0.07	6.31
2.7	Sand	130.0	0.0	39.0	0.12	17.06
10.7	Sand	130.0	0.0	39.0	0.51	71.17
10.7	Sand	130.0	0.0	40.0	0.56	85.29
24.7	Sand	130.0	0.0	40.0	1.30	198.78
24.7	Sand	135.0	0.0	40.0	1.30	198.78
34.7	Sand	135.0	0.0	40.0	1.87	285.84
34.7	Sand	130.0	0.0	43.0	1.87	656.63
43.7	Sand	130.0	0.0	43.0	2.35	677.94

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	45.000	Pile Penetration: (ft)	40.000
Pile Size: (ft)	1.17	Toe Area: (in²)	153.94

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	26.3	30,000.0	492.0	3.7	0
45.0	26.3	30,000.0	492.0	3.7	0

HAMMER INPUT

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

Hammer Data

ID	Ram Wt	Ram L.	Ram Ar.	Rtd. Stk	Effic.	Rtd. Energy
-	kips	in	in²	ft	-	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	E-Modulus	Thickness	COR	Round-out	Stiffness
-	in²	ksi	in	-	in	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	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	0.0	0.0	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
1.2	0.1	6.9	0.10	0.04	0.05	0.15	1.0	6.0	1.0	153.9
1.2	0.0	2.6	0.10	0.05	0.05	0.15	1.0	6.0	1.0	153.9
2.7	0.1	6.3	0.10	0.05	0.05	0.15	1.0	6.0	1.0	153.9
2.7	0.2	17.1	0.10	0.04	0.01	0.15	24.0	6.0	1.2	153.9
4.7	0.3	30.6	0.10	0.04	0.01	0.15	24.0	6.0	1.2	153.9
6.7	0.4	44.1	0.10	0.04	0.01	0.15	24.0	6.0	1.2	153.9
8.7	0.5	57.6	0.10	0.04	0.01	0.15	24.0	6.0	1.2	153.9
10.7	0.7	71.2	0.10	0.04	0.01	0.15	24.0	6.0	1.2	153.9
10.7	0.7	85.3	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
12.5	0.9	99.5	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
14.2	1.0	113.7	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
16.0	1.1	127.9	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
17.7	1.2	142.0	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
19.5	1.4	156.2	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
21.2	1.5	170.4	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
23.0	1.6	184.6	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
24.7	1.7	198.8	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
24.7	1.7	198.8	0.10	0.03	0.10	0.15	24.0	6.0	1.2	153.9
26.4	1.9	213.3	0.10	0.03	0.10	0.15	24.0	6.0	1.2	153.9
28.0	2.0	227.8	0.10	0.03	0.10	0.15	24.0	6.0	1.2	153.9
29.7	2.1	242.3	0.10	0.03	0.10	0.15	24.0	6.0	1.2	153.9
31.4	2.2	256.8	0.10	0.03	0.10	0.15	24.0	6.0	1.2	153.9
33.0	2.4	271.3	0.10	0.03	0.10	0.15	24.0	6.0	1.2	153.9
34.7	2.5	285.8	0.10	0.03	0.10	0.15	24.0	6.0	1.2	153.9
34.7	2.5	656.6	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
36.5	2.7	677.9	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
38.3	2.8	677.9	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9
40.0	2.9	677.9	0.10	0.03	0.05	0.15	1.0	6.0	1.0	153.9

APPENDIX VI

LATERAL DESIGN PARAMETERS

Lateral Design - Soil Parameters
MOT-Johnson Station Road Bridge Replacement
PID 120484
Rii Project No.WB-24-093

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-001-0-24	685.6 to 682.6	A-1-a	G	4	33	130	67.6	φ = 35°	115 pci	-	-
	682.6 to 678.1	A-1-b	G	4	33	130	67.6	φ = 34°	115 pci	-	-
	678.1 to 676.1	A-1-b	G	4	71	135	72.6	φ = 37°	225 pci	-	-
	676.1 to 673.6	A-1-b	G	4	120	135	72.6	φ = 37°	225 pci	-	-
	673.6 to 663.6	A-1-a	G	4	42	130	67.6	φ = 36°	150 pci	-	-
	663.6 to 661.1	A-1-a	G	4	68	135	72.6	φ = 38°	125 pci	-	-
	663.6 to 651.1	A-1-b	G	4	141	135	72.6	φ = 37°	225 pci	-	-
B-002-0-24	687.1 to 686.1	A-3a	G	4	6	120	57.6	φ = 27°	15 pci	-	-
	686.1 to 684.6	A-1-b	G	4	26	130	67.6	φ = 32°	50 pci	-	-
	684.6 to 676.6	A-2-4	G	4	50	135	72.6	φ = 37°	125 pci	-	-
	676.6 to 662.6	A-1-a	G	4	40	130	67.6	φ = 36°	90 pci	-	-
	662.6 to 652.6	A-2-4	G	4	119	135	72.6	φ = 37°	125 pci	-	-
	676.6 to 644.1	A-1-b	G	4	66	135	72.6	φ = 37°	125 pci	-	-

APPENDIX VII

SUBGRADE ANALYSIS

OHIO DEPARTMENT OF TRANSPORTATION

OFFICE OF GEOTECHNICAL ENGINEERING

PLAN SUBGRADES
Geotechnical Design Manual Section 600

Instructions: Enter data in the shaded cells only.
(Enter state route number, project description,county, consultant's name, prepared by name, and date prepared. This information will be transferred to all other sheets. The date prepared must be entered in the appropriate cell on this sheet to remove these instructions prior to printing.)

Johnson Station Road
120484

MOT-Johnson Station Road Bridge Replacement

Resource International, Inc.

Prepared By: Dan Hayes
Date prepared: Monday, January 13, 2025

Daniel K. Hayes
6350 Presidential Gateway
Columbus, Ohio 43212

614.823.4949
danh@resourceinternatinl.com

NO. OF BORINGS: 3

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.7 4/4/2024

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-001-0-24	Johnson Station	7+96	4	RT	Diedrich D-50	90	778.2	778.2	0.0
2	B-002-0-24	Johnson Station	7+40	6	RT	Diedrich D-50	90	778.2	778.2	0.0
3	B-003-0-24	Johnson Station	6+11	4	RT	Diedrich D-50	90	777.8	777.8	0.0

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.7 4/4/2024

#	Boring	Sample	Sample Depth		Subgrade Depth		Standard Penetration		HP (tsf)	Physical Characteristics						Moisture		Ohio DOT		Sulfate Content (ppm)	Problem		Excavate and Replace (Item 204)		Recommendation (Enter depth in inches)
			From	To	From	To	N_{60}	N_{60L}		LL	PL	PI	% Silt	% Clay	P200	M_C	M_{OPT}	Class	GI		Unsuitable	Unstable	Unsuitable	Unstable	
1	B	1	1.0	2.5	1.0	2.5	30									3	6	A-1-b	0	120					
	001-0	2	2.5	4.0	2.5	4.0	21									8	10	A-2-6	4						
	24	3	4.0	5.5	4.0	5.5	18		4.5	16	12	4	26	29	55	11	10	A-4a	4						
		4	5.5	7.0	5.5	7.0	30	18								6	10	A-4a							
2	B	1	1.5	3.0	1.5	3.0	17			16	12	4	15	9	24	8	6	A-1-b	0	100					
	002-0	2	3.0	4.5	3.0	4.5	12		2							10	14	A-6a	10						
	24	3	4.5	6.0	4.5	6.0	12		0.5							11	14	A-6a	10						
		4	6.0	7.5	6.0	7.5	6	6	1.5	25	14	11	22	16	38	15	14	A-6a							
3	B	1	1.0	2.5	1.0	2.5	30			NP	NP	NP	9	5	14	6	6	A-1-b	0	160					
	003-0	2	2.5	4.0	2.5	4.0	17			18	12	6	20	13	33	6	10	A-2-4	0						
	24	3	4.0	5.5	4.0	5.5	15									7	10	A-2-4	0						
		4	5.5	7.0	5.5	7.0	9	9	1.75							20	16	A-6b							

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.7 4/4/2024

PID: 120484

County-Route-Section: Johnson Station Road
No. of Borings: 3

Geotechnical Consultant: Resource International, Inc.
Prepared By: Dan Hayes
Date prepared: 1/13/2025

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

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

Design CBR	9

% Samples within 3 feet of subgrade			
$N_{60} \leq 5$	0%	HP ≤ 0.5	0%
$N_{60} < 12$	0%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	8%	1 < HP ≤ 2	8%
$N_{60} \geq 20$	25%	HP > 2	0%
M+	0%		
Rock	0%		
Unsuitable Soil	0%		

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

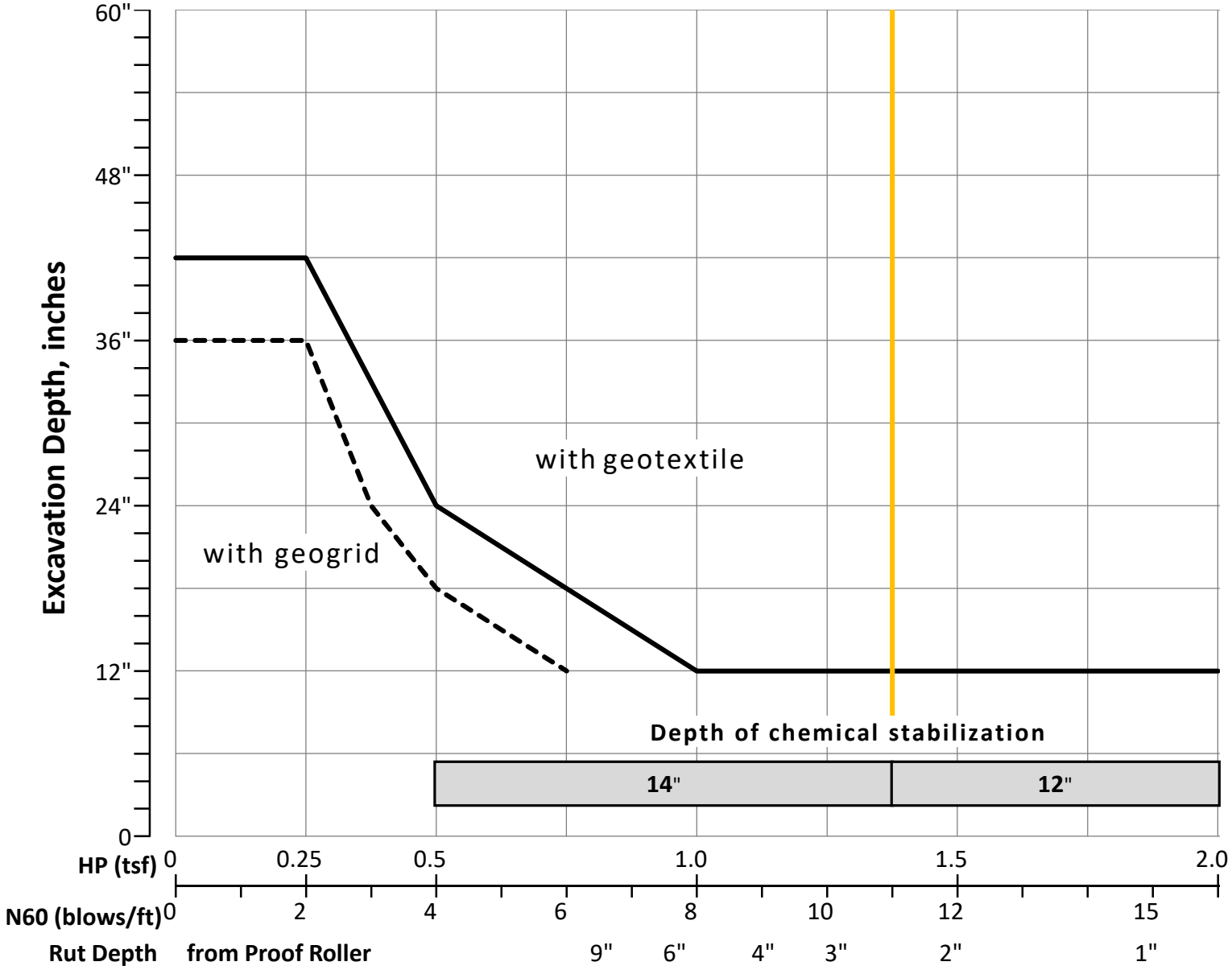
% Proposed Subgrade Surface	
Unstable & Unsuitable	0%
Unstable	0%
Unsuitable (Soil & Rock)	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	18	11	2.05	19	13	6	18	14	33	9	11	3
Maximum	30	18	4.50	25	14	11	26	29	55	20	16	10
Minimum	6	6	0.50	16	12	4	9	5	14	3	6	0

Classification Counts by Sample

ODOT Class	UCF	Rock	A-1-a	A-1-b	A-2-4	A-2-5	A-2-6	A-2-7	A-3	A-3a	A-4a	A-4b	A-5	A-6a	A-6b	A-7-5	A-7-6	A-8a	A-8b	Totals
Count	0	0	0	3	2	0	1	0	0	0	2	0	0	3	1	0	0	0	0	12
Percent	0%	0%	0%	25%	17%	0%	8%	0%	0%	0%	17%	0%	0%	25%	8%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	0%	67%									33%								100%
Surface Class Count	0	0	0	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5
Surface Class Percent	0%	0%	0%	60%	20%	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%

Fig. 600-1 – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
2.05	0.50	☐ HP
11.00	6.00	☐ N60L

Average HP
Average N_{60L}