BORROR ROAD OVER PLUM RUN
PID NO. 26616
FRANKLIN COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT

Prepared For:
Resource International, Inc.
6350 Presidential Gateway
Columbus, Ohio 43231

Prepared By:
Resource International, Inc.
6350 Presidential Gateway
Columbus, OH 43231

Rii Project No. W-17-137

June 2019

February 20, 2018 (Revised June 12, 2019)

Mr. Nikhil C. Khedekar, Ph.D., P.E.
Vice President – Engineering and Planning
Resource International, Inc.
6350 Presidential Gateway
Columbus, Ohio 43231

Re: Structure Foundation Exploration Report
Borror Road over Plum Run (SFN: 2532271)
Franklin County, Ohio
PID No. 26616
Rii Project No. W-17-137

Mr. Khedekar:

Resource International, Inc. (Rii) is pleased to submit this Structure Foundation Exploration final report for the above-referenced project. Engineering logs have been prepared and are attached to this report along with results of laboratory testing. This report includes recommendations for the replacement of the bridge structure carrying Borror Road over Plum Run in Jackson Township in Franklin County, 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.

Peyman P. Majidi, P.E.
Project Engineer

Peter S. Lee, Ph.D., P.E.
Cleveland Regional Manager

Enclosure: Final Structure Foundation Exploration Report

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APPENDICES

EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration for the replacement of the bridge structure carrying Borror Road over Plum Run in Jackson Township in Franklin County, Ohio. The existing structure consists of a19-foot single span concrete slab bridge with concrete abutments supported on spread footings. Based on final plans submitted, it is understood that the existing structure will be replaced with a 3-sided flat topped precast concrete. The proposed structure will be widened to meet current design standards.

Exploration and Findings

On November 13, 2017, a total of two (2) structure borings, designated as B-001-0-17 and B-002-0-17, were drilled at the locations illustrated on the boring plans presented in Appendix I of this report and summarized in table below.

Test Boring Summary

Reference Alignment	Boring Number	Station	Offset	Latitude	Longitude	Ground Elevation (feet msl)	Boring Depth (feet)
Ex. CL Borror Road	B-001-0-17	87+50.43	8.2' L	39.829597	-83.059635	770.9	40.0
	B-002-0-17	87+80.30	6.3' R	39.829678	-83.059580	771.2	40.0

Two pavement cores were performed at the boring locations B-001-0-17 and B-002-0-17 through the existing pavement of Borror Road and encountered 9.0 and 10.0 inches of asphalt, overlying 3.0 and 2.0 inches of aggregate base at the ground surface, respectively. Beneath the surface materials in borings B-001-0-17 and B-002-0-17, material identified as fill and possible fill were encountered to a depth of 15.0 feet below the ground surface. Fill material were consisted of medium stiff to very stiff, brown sandy silt, silt and clay (ODOT A-4a, A-6a), and medium dense to dense gravel and sand (ODOT A-1b). Limestone and concrete fragments were encountered in the fill samples. Underlying the surface material and fill material natural cohesive and granular soils were encountered. The cohesive soils were generally described as light brown, brown to gray, grayish brown silt and clay, sandy silt (ODOT A-6a, A-4a). The granular soils were described as brown, gray gravel and sand (ODOT A-1b).

The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soils encountered ranged from medium stiff ($0.5 < HP \leq 1.0$ tsf) to hard ($HP > 4.0$ tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 1.0 to 4.5 tsf (limit of instrument). The relative density of granular soils is primarily derived from SPT blow counts (N_{60}). Based on the SPT blow counts obtained, the granular material encountered ranged from loose ($5 \leq N_{60} \leq 10$ bpf) to very dense (50 <

N_{60} bpf). Overall blow counts recorded from the SPT sampling ranged from 7 bpf to 80 bpf.

Bedrock was not encountered in any of the borings performed for this exploration.

Conclusions and Recommendations

Design details of the proposed structure were provided by Rii. Based on the information provided, it is understood that the existing structure will be replaced with a 20-foot by 48-foot 3-sided flat topped culvert.

3-Sided Culvert

Based on the soil conditions encountered at borings and the proposed inlet and outlet bottom of footing elevation at 759.65 feet msl, Rii anticipates the proposed culvert structure may be supported on stiff to hard silty clay and sandy silt (ODOT A-6a, and A-4a). Box culvert bearing at or below this elevation may be proportioned to meet the following bearing capacity requirements:

- Nominal bearing resistance of q_n = 3.0 ksf at the service limit state.
- Nominal bearing resistance of q_n = 10.0 ksf at the strength limit state.
- LRFD Bearing Resistance Factor of φ = 1.0 at the service limit state.
- LRFD Bearing Resistance Factor of φ = 0.5 at the strength limit state.

The bearing resistance at service limit state is the bearing pressure that results in a maximum total settlement of 1 inch, and considers a net increase in applied pressure based on an initial overburden stress of 1.7 ksf at the service limit state.

Scour Data

7.0-foot continuous sampling was performed below the existing stream bed in both of the borings to determine the median grain size, D_{50}, of the streambed soils for use in scour analysis calculations. The streambed soils encountered at the site consisted of natural cohesive soils identified as stiff to hard silty clay and sandy silt (ODOT A-6a, and A-4a). Based on the results of the grain size analysis performed on the recovered samples, the D_{50} of the stream bed soils encountered at the structure ranged from 0.013 to 0.45 millimeters. The results of the grain size analysis are summarized in Table Below.

Scour Sampling Summary

Boring	Sample No.	Depth (feet)	Elevation (feet msl)	Soil Classification	D_{50} Value (mm)
B-001-0-17	SS-4A	10.0 - 10.5	760.9 - 760.4	A-4a	0.019
	SS-5	10.5 - 12.0	760.4 – 758.9	A-6a	0.013
	SS-7	13.5 - 15.0	757.4 – 755.9	A-6a	0.040
B-002-0-17	SS-5	10.0 - 11.5	761.2 – 759.7	A-4a	0.032
	SS-6	11.5 - 13.0	759.7 – 758.2	A-4a	0.045
	SS-7	13.0 - 14.5	758.2 – 756.7	A-4a	0.040
	SS-8	14.5 - 16.0	756.7 – 755.2	A-4a	0.036

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 replacement of the existing bridge structure carrying Borror Road over Plum Run in Jackson Township in Franklin County, Ohio. The existing structure consists of a 19-foot single span concrete slab bridge with concrete abutments supported on spread footings.

Based on final plans submitted, it is understood that the existing structure will be replaced with a 3-sided flat topped precast concrete. The proposed structure will be widened to meet current design standards. The project areas are shown on the vicinity maps presented in Appendix I of this report.

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Site Geology

Both the Illinoian and Wisconsinan glaciers advanced over two-thirds of the State of Ohio, leaving behind glacial features such as moraines, kame deposits, lacustrine deposits and outwash terraces. The glacial and non-glacial regions comprise five physiographic sections grouped by age, depositional process and geomorphic occurrence. The study area lies within the Columbus Lowland of the Central Lowland Till Plains. This area is characterized by flat to gently rolling ground moraines comprised of silty loam till (Darby, Bellefontaine, Centerburg, Grand Lake, Arcanum, Knightstown tills). Along the Scioto River and its tributaries, the soils are comprised of outwash and alluvium deposits. Outwash deposits consist of undifferentiated sand and gravel deposited by meltwater in front of glacial ice, and often occurs as valley terraces or low plains. Alluvium and alluvial terrace deposits range in composition from silty clay sized particles to cobbles, usually deposited in present and former floodplain areas.

Based on the Bedrock Geology and Bedrock Topography maps of the Columbus area, obtained from Ohio Department of Natural Resources (ODNR), the bedrock at the proposed project site consists of the Upper Devonian-aged Ohio Shale Formation overlying the Middle and Lower Devonian-aged Columbus Limestone Formation. The Ohio Shale Formation is further subdivided into three primary members, in descending order: the Cleveland, Chagrin, and Huron Members. The Cleveland Member consists of black shale and is thickest in the north-central portion of the state but thins out to the south and east. The Huron Member consists of gray to greenish gray interbedded shale, siltstone, and very fine-grained sandstone, and is thickest in the northeastern portion of the state, thinning out to the southwest. The Chagrin Member grades into the overlying and underlying members and consists of black, carbonaceous shale. The entire Ohio Shale formation ranges from 250 to over 500 feet thick, with generally laminated to thin bedding and fissile partings, and is characterized by such features as having a petroliferous odor and carbonate/siderite concretions. The Columbus Limestone Formation consists of interbedded limestone and dolomite and can also be subdivided into four members, with two of the members present in the central part of the state, the

Delhi and Bellepoint Members. The Delhi Member consists primarily of light gray, finely to coarsely crystalline, fossiliferous limestone in irregular beds with an occasional chert nodule. The Bellepoint Member consists of brown, finely crystalline and limy dolomite in massive beds. This member contains a conglomerate and sandstone layer at the base. The Columbus Limestone Formation can range from 0 to 105 feet thick.

According to bedrock topography mapping from ODNR, the site lies along the side of an irregularly shaped plateau which is generally higher to the northeast, east, and southwest of the site. This bedrock plateau crests at an approximate elevation of 650 feet and the bedrock surface slopes from this plateau downward toward the west-southwest. This plateau is capped with the Ohio Shale Formation and the slope to the west is comprised of the Columbus Limestone Formation. The top of bedrock lies at an approximate elevation of 640 to 650 feet mean sea level (msl) at the bridge location which is approximately 120 to 130 feet below the existing ground surface.

2.2 Existing Site Conditions

The existing structure is located on Borror Road, approximately 0.25 mile south of the intersection with SR 665. The existing structure was constructed in 1942, and the last major reconstruction on the structure was performed in 1982. The existing structure is a single span bridge with concrete abutment supported on spread footings. Borror Road is classified as a local road.

3.0 EXPLORATION

On November 13, 2017, a total of two (2) structure borings, designated as B-001-0-17 and B-002-0-17, were drilled at the locations illustrated on the boring plans presented in Appendix I of this report and summarized in Table 1. Both borings were extended to a depth of 40.0 feet, below the existing ground surface. The boring locations and depths are summarized in Table 1 below.

Table 1. Test Boring Summary

Reference Alignment	Boring Number	Station	Offset	Latitude	Longitude	Ground Elevation (feet msl)	Boring Depth (feet)
Ex. CL Borror Road	B-001-0-17	87+50.43	8.2' L	39.829597	-83.059635	770.9	40.0
	B-002-0-17	87+80.30	6.3' R	39.829678	-83.059580	771.2	40.0

The boring locations were determined and located in the field by Rii representatives. The boring locations were surveyed by Rii and the geographic latitude and longitude coordinates and ground surface elevations are provided on the boring logs in Appendix III.

The borings were drilled with CME-55 truck-mounted rotary drilling machine, utilizing a 3.25-inch inside diameter hollow stem auger. Standard penetration test (SPT) and split spoon sampling were performed at 2.5-foot intervals to 10 feet beneath the ground surface. Continuous sampling was performed at the bottom of the creek level to approximately 10 feet below. The sampling was followed by 5-foot intervals sampling to boring termination depths The SPT, per the American Society for Testing and Materials (ASTM) designation D1586, is conducted using a 140-pound hammer free falling 30.0 inches to drive a 2.0-inch outside diameter split spoon sampler 18.0 inches. Rii utilized a calibrated automatic drop hammer to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of blows per 6.0-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). SPT blow counts aid in determining soil properties applicable in foundation system design. Measured blow count (N_m) values are corrected to an equivalent (60 percent) energy ratio, N_{60}, by the following equation. Both values are represented on boring logs in Appendix III.

$$N_{60} = N_m*(ER/60)$$

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

The hammer for the CME-55 drill rig used for this project was calibrated on September 22, 2016, and has a drill rod energy ratio of 85.9 percent.

Upon completion of drilling, the borings with a mixture of bentonite chips and soil cuttings generated during the drilling process and sealed with cement-bentonite grout in accordance with ODOT standards. The pavement surface was repaired with an equivalent thickness of quick-set concrete.

During drilling, field personnel prepared field logs showing the encountered subsurface conditions. Soil samples obtained from the drilling operation were preserved in sealed 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	AASHTO T265	31
Plastic and Liquid Limits	AASHTO T89, T90	6
Sieve/Hydrometers	AASHTO T88	12

The tests performed are necessary to classify existing soil according to the Ohio Department of Transportation (ODOT) classification system and to estimate engineering properties of importance in determining foundation design and construction recommendations. Results of the laboratory testing are presented on the boring logs in Appendix III. A description of the soil terms used throughout this report is presented in Appendix II.

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.

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

4.0 FINDINGS

Interpreted engineering logs have been prepared from field logs, visual examination of samples and laboratory testing. Classification follows the current version of the ODOT Specifications of Geotechnical Exploration (SGE). The following is a generalization of what was found in the test borings and what is represented on the boring logs.

4.1 Surface Materials

Pavement cores were obtained at both boring locations B-001-0-17 and B-002-0-17. The pavement cores appeared in fair to good condition. Approximately 9.0 and 10.0 inches of asphalt, overlying 3.0 and 2.0 inches of aggregate base, were encountered at the ground surface in B-001-0-17 and B-002-0-17, respectively. For more details on pavement cores please see Appendix V.

4.2 Subsurface Soils

Beneath the surficial pavement materials in borings B-001-0-17 and B-002-0-17, material identified as fills were encountered to a depth of 10 feet below the ground surface. Fill materials consist of medium stiff to very stiff, brown sandy silt, and silt and clay (ODOT A-4a and A-6a), and medium dense to dense gravel and sand (ODOT A-1b). Limestone and concrete fragments were encountered in the fill samples.

Underlying the pavement materials and fills, natural cohesive and granular soils were encountered. The cohesive soils were generally described as light brown, brown to gray, grayish brown silt and clay, and sandy silt (ODOT A-6a and A-4a). The granular soils were described as brown, gray gravel and sand (ODOT A-1b).

The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soils encountered ranged from medium stiff ($0.5 < HP \leq 1.0$ tsf) to hard ($HP > 4.0$ tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 1.0 to 4.5 tsf (limit of instrument). The relative density of granular soils is primarily derived from SPT blow counts (N_{60}). Based on the SPT blow counts obtained, the granular material encountered ranged from loose ($5 \leq N_{60} \leq 10$ bpf) to very dense ($50 < N_{60}$ bpf). Overall blow counts recorded from the SPT sampling ranged from 7 bpf to 80 bpf.

Moisture contents of the soil samples tested ranged from 8 to 24 percent. The natural moisture contents of the cohesive soil samples tested for plasticity ranged from 2 percent below to 6 percent below their corresponding plastic limits. In general, the soil exhibited natural moisture contents ranging from slightly below to moderately below optimum moisture levels.

4.3 Bedrock

Bedrock was not encountered in any of the borings performed for this exploration.

4.4 Groundwater

Groundwater was encountered initially in both borings at depths of 10.0 feet and 14.5 feet beneath existing ground surface in borings B-001-0-17 and B-002-0-17, respectively. Upon completion of the drilling and pulling out the augers groundwater was encountered in both borings at depths of 7.1 feet and 6.4 feet below existing ground surface, respectively.

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

5.0 CONCLUSIONS AND RECOMMENDATIONS

Data obtained from the drilling and testing program have been used to determine the foundation support capabilities and the settlement potential for the soil/rock conditions encountered at the site. These parameters have been used to provide guidelines for the design of foundation system for the subject culvert, as well as the construction specifications related to the placement of foundation systems and general earthwork recommendations, all of which are discussed in the following paragraphs.

Design details of the proposed structure were provided by Rii. Based on the information provided, it is understood that the existing structure will be replaced with a 20-foot by 48-foot 3-sided flat topped culvert.

5.1 Foundation Recommendations

5.1.1 3-Sided Culvert

Based on the soil conditions encountered at borings and the proposed inlet and outlet bottom of footing elevation at 759.65 feet msl, Rii anticipates the proposed culvert structure may be supported on stiff to hard silty clay and sandy silt (ODOT A-6a, and A-4a). Box culvert bearing at or below this elevation may be proportioned to meet the following bearing capacity requirements:

- Nominal bearing resistance of q_n = 3.0 ksf at the service limit state.
- Nominal bearing resistance of q_n = 10.0 ksf at the strength limit state.
- LRFD Bearing Resistance Factor of φ = 1.0 at the service limit state.
- LRFD Bearing Resistance Factor of φ = 0.5 at the strength limit state.

The bearing resistance at service limit state is the bearing pressure that results in a maximum total settlement of 1 inch, and considers a net increase in applied pressure based on an initial overburden stress of 1.7 ksf at the service limit state.

5.1.2 Wingwalls

It is understood the proposed structure will have wingwall structure with bearing elevation similar to the culvert (759.65 ft. msl at the inlet and outlet structure). Based on the soil conditions at the bearing depth, the shallow foundation for the wingwall should follow the recommendations provided for the culvert in section 5.1.1.

5.2 Lateral Earth Pressure Parameters

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 3 and Table 4.

Table 3. Estimated Undrained Soil Parameters for Design

Soil Type	γ (pcf) [1]	c (psf)	φ	k_a	k_o	k_p
Medium Stiff to Stiff Cohesive Soils	115	1,000	0°	N/A	N/A	N/A
Very Stiff to Hard Cohesive Soil	130	3,000	0°	N/A	N/A	N/A
Medium Dense to Dense Granular Soil	130	0	32°	0.31	0.47	3.25
Very Dense Granular Soil	135	0	35°	0.27	0.43	3.69
Compacted Cohesive Engineered Fill	125	2,000	0°	N/A	N/A	N/A
Compacted Granular Engineered Fill	130	0	33°	0.30	0.46	3.39

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

Table 4. Estimated Drained 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	26°	0.39	0.56	2.56
Very Stiff to Hard Cohesive Soil	130	0	27°	0.38	0.55	2.66
Medium Dense to Dense Granular Soil	130	0	32°	0.31	0.47	3.25
Very Dense Granular Soil	130	0	35°	0.27	0.43	3.69
Compacted Cohesive Engineered Fill	125	0	28°	0.36	0.53	2.77
Compacted Granular Engineered Fill	130	0	33°	0.29	0.46	3.39

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

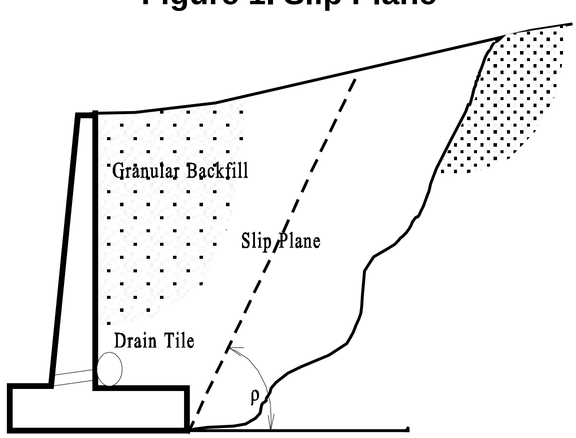
These parameters are considered appropriate for the design of subsurface walls, wing walls and excavation support systems. Subsurface structures (where the top of the structure is restrained from movement) should be designed based on at-rest conditions. For proposed wing walls or temporary retaining structures (where the top of the structure is allowed to move), earth pressure distributions should be based on active conditions (k_a) and passive pressure (k_p). The values in this table have been estimated from correlation charts based on minimum standards specified for compacted engineered fill materials. 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.

In order to alleviate the build-up of hydrostatic pressure above the flow line of the stream behind the walls a minimum of 2.0 feet of clean free-draining granular fill (i.e., No. 57 gravel) should be placed full depth behind the walls. If granular fill other than No. 57 gravel is used, it should not have more than 8 percent (by weight) passing the No. 200 screen, and should be compacted to 95 percent of the maximum dry density as determined by the Standard Proctor Test (ASTM D698). A perforated, corrugated drain tile, wrapped with filter fabric, should be placed along the perimeter at the base of the walls or at the design flow line/flood line for drainage purposes. A clay cap (minimum 1.0-foot thick) should be placed overtop the granular backfill to deter inflow of the surface water. The drainage system should properly outlet to a sewer or to a properly sized sump pump system.

Temporary retaining structures should be designed using the undrained soil parameters provided in Table 3, and the design should follow all applicable guidelines for the type of retaining structure utilized. Permanent retaining structures should be designed using the drained soil parameters provided in Table 4. Regardless of whether the retaining structure is temporary or permanent, the effective unit weight ($\gamma' = \gamma$ - 62.4 pcf) plus the hydrostatic water pressure ($\gamma_w * h_w$, where h_w is the height of water behind the wall above the base of the wall) should be utilized below the design groundwater level. The lateral earth pressure coefficients should only be applied to the horizontal pressure resulting from the effective overburden pressure, and should not be applied to the hydrostatic water pressure.

The 2.0 feet of free draining material placed behind the wall prevents the formation of hydrostatic pressures as noted above. However, unless the free draining granular backfill is placed beyond the slip plane (see Figure 1), it has no influence on the equivalent fluid weight of the soil. If free draining granular fill (meeting the requirements listed above) is to be placed beyond the slip plane (ρ=45° for at-rest conditions; ρ=45°+φ/2 for active conditions), the values presented for the compacted granular engineered fill can be employed, consequently lowering the pressures on the wall.

Figure 1. Slip Plane



Backfill Rankine Zone with Select Backfill

5.3 Scour Data

7.0-foot continuous sampling was performed below the existing stream bed in both of the borings to determine the median grain size, D_{50}, of the streambed soils for use in scour analysis calculations. The streambed soils encountered at the site consisted of natural cohesive soils identified as stiff to hard silty clay and sandy silt (ODOT A-6a, A-4a). Based on the results of the grain size analysis performed on the recovered samples, the D_{50} of the stream bed soils encountered at the structure ranged from 0.013 to 0.45 millimeters. The results of the grain size analysis are summarized in Table 5.

Table 5. Scour Sampling Summary

Boring	Sample No.	Depth (feet)	Elevation (feet msl)	Soil Classification	D_{50} Value (mm)
B-001-0-17	SS-4A	10.0 - 10.5	760.9 - 760.4	A-4a	0.019
	SS-5	10.5 - 12.0	760.4 – 758.9	A-6a	0.013
	SS-7	13.5 - 15.0	757.4 – 755.9	A-6a	0.040
B-002-0-17	SS-5	10.0 - 11.5	761.2 – 759.7	A-4a	0.032
	SS-6	11.5 - 13.0	759.7 – 758.2	A-4a	0.045
	SS-7	13.0 - 14.5	758.2 – 756.7	A-4a	0.040
	SS-8	14.5 - 16.0	756.7 – 755.2	A-4a	0.036

5.4 Construction Considerations

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

5.4.1 Excavation Considerations

All excavations should be shored / braced or laid back at a safe angle in accordance to Occupational Safety and Health Administration (OSHA) guidelines. During excavation, if slopes cannot be laid back to OSHA Standards due to adjacent structures or other obstructions, temporary shoring may be required. The following Table 6 should be utilized as a general guide for implementing OSHA guidelines when estimating excavation back slopes at the various boring locations. Actual excavation back slopes must be field verified by qualified personnel at the time of excavation in strict accordance with OSHA guidelines.

Table 6. Excavation Back Slopes

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

6.0 LIMITATIONS OF STUDY

The recommendations presented in this report 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 our 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. 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.

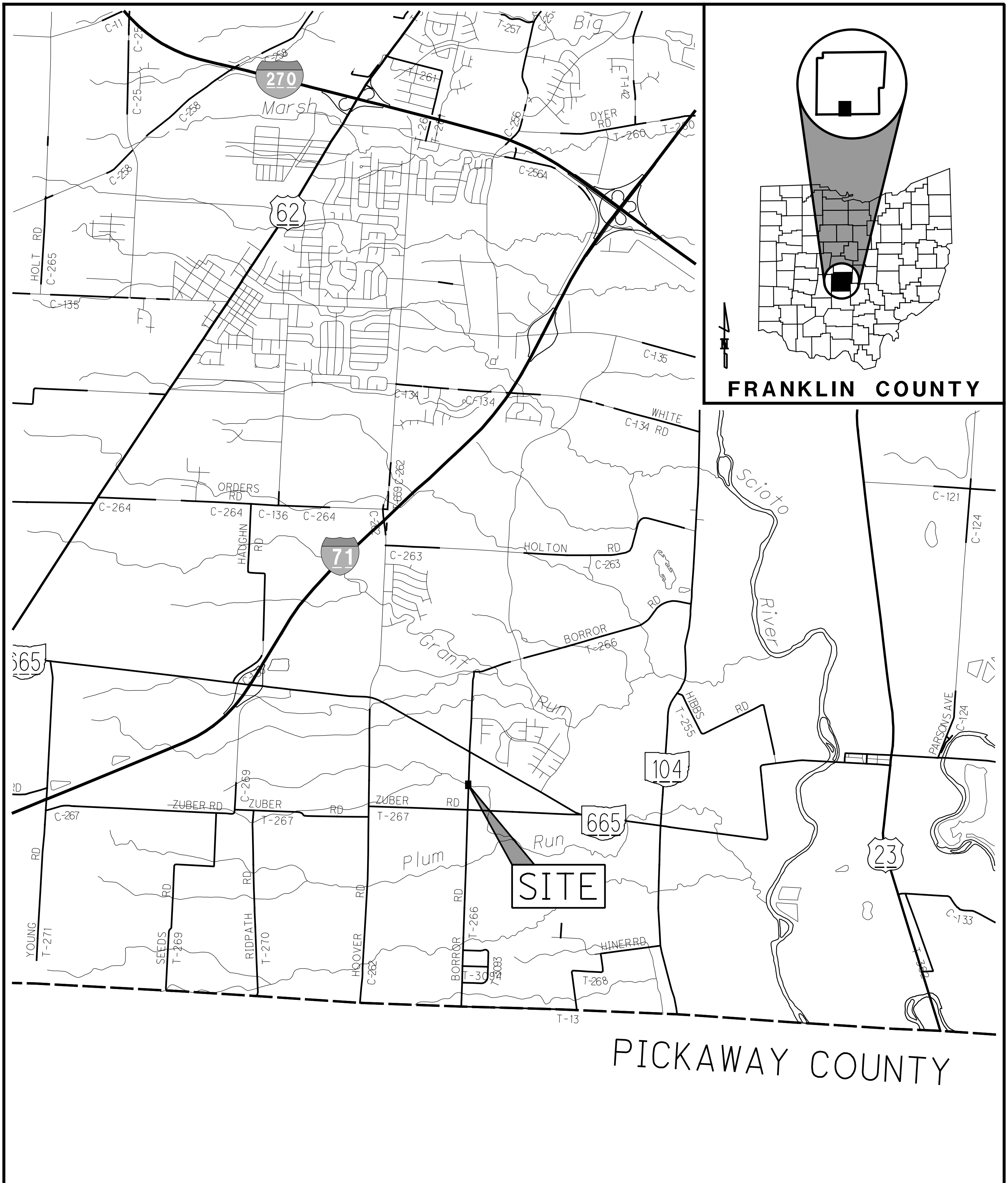
The conclusions and recommendations herein have been based upon the available soil information and the preliminary design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be 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 or 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

BORROR ROAD 1.66 OVER PLUM RUN

FRANKLIN COUNTY, OHIO

RII PROJECT NO. W-17-137	DRAWN RRM
	REVIEWED JPS
SCALE: 1"=5000' (0 2500 5000)	DATE 2-7-18

RESOURCE INTERNATIONAL Rii

BORING PLAN

BORROR ROAD 1.66 OVER PLUM RUN
FRANKLIN COUNTY, OHIO

RII PROJECT NO. W-17-137		DRAWN RRM
SCALE: 1"=20' 0 10 20	N	REVIEWED JPS
		DATE 2-7-18

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

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

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

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

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

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

Modifiers of Components - Modifiers of components are as follows:

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

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

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

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

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

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

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

DESCRIPTION OF ROCK TERMS

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

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

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

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

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

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

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

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

Degree of Fracturing

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

Aperture Width

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

Surface Roughness

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

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

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

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 AASHTO	Classifcation OHIO	LL_O/LL × 100*	% Pass #40	% Pass #200	Liquid Limit (LL)	Plastic Index (PI)	Group Index Max.	REMARKS
	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	
F S	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 A-2-5				35 Max.	40 Max. 41 Min.	10 Max.	0	
	Gravel and/or Stone Fragments with Sand, Silt and Clay	A-2-6 A-2-7				35 Max.	40 Max. 41 Min.	11 Min.	4	
	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.	≦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
- P 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-001-0-17 through B-002-0-17

BORING LOGS

Definitions of Abbreviations

AS	=	Auger sample
HP	=	Unconfined compressive strength as determined by a hand penetrometer (tons per square foot)
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).
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: BORROR ROAD OVER PLUM RUN	DRILLING FIRM / OPERATOR: RII / M.W.	DRILL RIG: CME 55 (SN 386345)	STATION / OFFSET: 87+50.43 / 8.2' LT	EXPLORATION ID B-001-0-17
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: RII / C.H.	HAMMER: AUTOMATIC	ALIGNMENT: CL BORROR RD	
PID: 26616 BR ID: FRA-T0266-01660	DRILLING METHOD: 3.25" - HSA	CALIBRATION DATE: 9/22/16	ELEVATION: 770.9 (MSL) EOB: 40.0 ft.	PAGE 1 OF 2
START: 11/13/17 END: 11/13/17	SAMPLING METHOD: SPT	ENERGY RATIO (%): 85.9	LAT / LONG: 39.829597000, -83.059635000	

MATERIAL DESCRIPTION AND NOTES	ELEV. 770.9
0.8' - ASPHALT (9.0")	770.1
0.2' - AGGREGATE BASE (3.0")	769.9
FILL: MEDIUM DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, WET.	767.9
FILL: MEDIUM STIFF TO STIFF, BROWN **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, MOIST. -LIMESTONE FRAGMENTS PRESENT THROUGHOUT -CONCRETE FRAGMENTS PRESENT IN SS-4A	760.4
VERY STIFF TO HARD, LIGHT BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP TO MOIST.	755.9
HARD, BROWNISH GRAY TO GRAY **SANDY SILT**, LITTLE TO SOME CLAY, LITTLE FINE GRAVEL, MOIST TO WET. -SHALE AND LIMESTONE FRAGMENTS PRESENT THROUGHOUT	743.9
VERY STIFF, GRAY **SILT AND CLAY**, LITTLE FINE SAND, MOIST.	

DEPTHS: 1 – 29 (water level symbols ▼ at approx. 7 ft and W at approx. 10 ft)

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
10 9 5	20	44	SS-1	-	67	15	7	- 11 -		-	-	-	12	A-1-b (V)
2 2 2	6	61	SS-2	1.50	-	-	-	-	-	-	-	-	24	A-4a (V)
2 2 4	9	50	SS-3	1.00	35	14	8	25	18	29	20	9	17	A-4a (2)
2 3 3	9	0	SS-4	-	-	-	-	-	-	-	-	-	-	
4	-	100	SS-4A	3.75	7	10	15	34	34	-	-	-	15	A-4a (V)
3 5 6	16	94	SS-5	4.50	4	10	10	39	37	30	19	11	13	A-6a (8)
5 6 9	21	100	SS-6	4.50	-	-	-	-	-	-	-	-	12	A-6a (V)
5 6 11	24	100	SS-7	4.50	15	11	16	32	26	-	-	-	13	A-6a (V)
11 16 17	47	100	SS-8	4.00	-	-	-	-	-	-	-	-	11	A-4a (V)
6 8 11	27	100	SS-9	4.50	12	18	14	37	19	22	15	7	12	A-4a (4)
3 7 11	26	100	SS-10	4.50	-	-	-	-	-	-	-	-	13	A-4a (V)
9 8 8	23	100	SS-11	4.00	-	-	-	-	-	-	-	-	17	A-6a (V)

PID: 26616	BR ID: FRA-T0266-01660	PROJECT: HORROR ROAD OVER PLUM RUN	STATION / OFFSET: 87+50.43 / 8.2 LT	START: 11/13/17	END: 11/13/17	PG 2 OF 2	B-001-0-17

MATERIAL DESCRIPTION AND NOTES	ELEV. 740.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
VERY STIFF, GRAY **SILT AND CLAY**, LITTLE FINE SAND, MOIST. *(same as above)*	738.9	31–32																
VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST.		32–34	14 19 37	80	72	SS-12	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
-LIMESTONE FRAGMENTS PRESENT THROUGHOUT		35–38																
	730.9	39–40 EOB	11 27 29	80	89	SS-13	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 10.0' AND AT COMPLETION @ 7.1'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 75 LBS BENTONITE CHIPS AND SOIL CUTTINGS; PLACED ASPHALT PATCH

RESOURCE INTERNATIONAL, INC.

PROJECT: BORROR ROAD OVER PLUM RUN	DRILLING FIRM / OPERATOR: RII / M.W.	DRILL RIG: CME 55 (SN 386345)	STATION / OFFSET: 87+80.30 / 6.3' RT
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: RII / C.H.	HAMMER: AUTOMATIC	ALIGNMENT: CL BORROR RD
PID: 26616 BR ID: FRA-T0266-01660	DRILLING METHOD: 3.25" - HSA	CALIBRATION DATE: 9/22/16	ELEVATION: 771.2 (MSL) EOB: 40.0 ft.
START: 11/13/17 END: 11/13/17	SAMPLING METHOD: SPT	ENERGY RATIO (%): 85.9	LAT / LONG: 39.829678000, -83.059580000

EXPLORATION ID B-002-0-17

MATERIAL DESCRIPTION AND NOTES	ELEV. 771.2
0.8' - ASPHALT (10.0")	770.4
0.2' - AGGREGATE BASE (2.0")	770.2
FILL: MEDIUM DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, WET.	768.2
FILL: STIFF, BROWN **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP.	767.2
FILL: LOOSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DAMP.	765.7
FILL: STIFF, BROWN **SANDY SILT**, SOME FINE GRAVEL, TRACE SILT, TRACE CLAY, MOIST.	764.9
FILL: LOOSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, WET.	763.2
FILL: SOFT, BROWN **SANDY SILT**, LITTLE CLAY, LITTLE FINE GRAVEL, MOIST. -LIMESTONE FRAGMENTS PRESENT IN SS-4B	761.2
STIFF TO HARD, LIGHT BROWN TO GRAY **SANDY SILT**, SOME CLAY, LITTLE FINE GRAVEL, DAMP TO MOIST. -LIMESTONE FRAGMENTS PRESENT @ 23.5'-28.5'	744.2
MEDIUM STIFF, GRAY **SANDY SILT**, LITTLE CLAY, TRACE FINE GRAVEL, MOIST.	742.7
DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST.	

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
12-9-6	21	61	SS-1	-	-	-	-	-	-	-	-	-	10	A-1-b (V)
2-3-3	9	61	SS-2A	2.00	24	18	14	26	18	25	17	8	15	A-4a (2)
			SS-2B	-	-	-	-	-	-	-	-	-	7	A-1-b (V)
2-2-3	7	39	SS-3A	1.50	-	-	-	-	-	-	-	-	15	A-4a (V)
			SS-3B	-	-	-	-	-	-	-	-	-	11	A-1-b (V)
1-2-4	9	72	SS-4A	0.50	-	-	-	-	-	-	-	-	17	A-4a (V)
			SS-4B	4.50	-	-	-	-	-	-	-	-	15	A-4a (V)
2-4-6	14	78	SS-5	4.50	13	14	13	31	29	26	16	10	13	A-4a (5)
6-7-15	31	33	SS-6	1.50	19	10	14	31	26	-	-	-	18	A-4a (V)
9-11-37	69	100	SS-7	4.50	20	8	13	34	25	-	-	-	14	A-4a (V)
7-8-18	37	100	SS-8	4.50	14	9	15	35	27	-	-	-	12	A-4a (V)
9-11-14	36	61	SS-9	4.50	-	-	-	-	-	-	-	-	13	A-4a (V)
7-8-11	27	100	SS-10	4.50	29	16	12	27	16	22	15	7	12	A-4a (2)
11-11-17	40	83	SS-11A	1.00	-	-	-	-	-	-	-	-	14	A-4a (V)
			SS-11B	-	-	-	-	-	-	-	-	-	15	A-2-4 (V)

PID: 26616 | BR ID: FRA-T0266-01660 | PROJECT: BORROR ROAD OVER PLUM RUN | STATION / OFFSET: 87+80.30 / 6.3 RT | START: 11/13/17 | END: 11/13/17 | | B-002-0-17

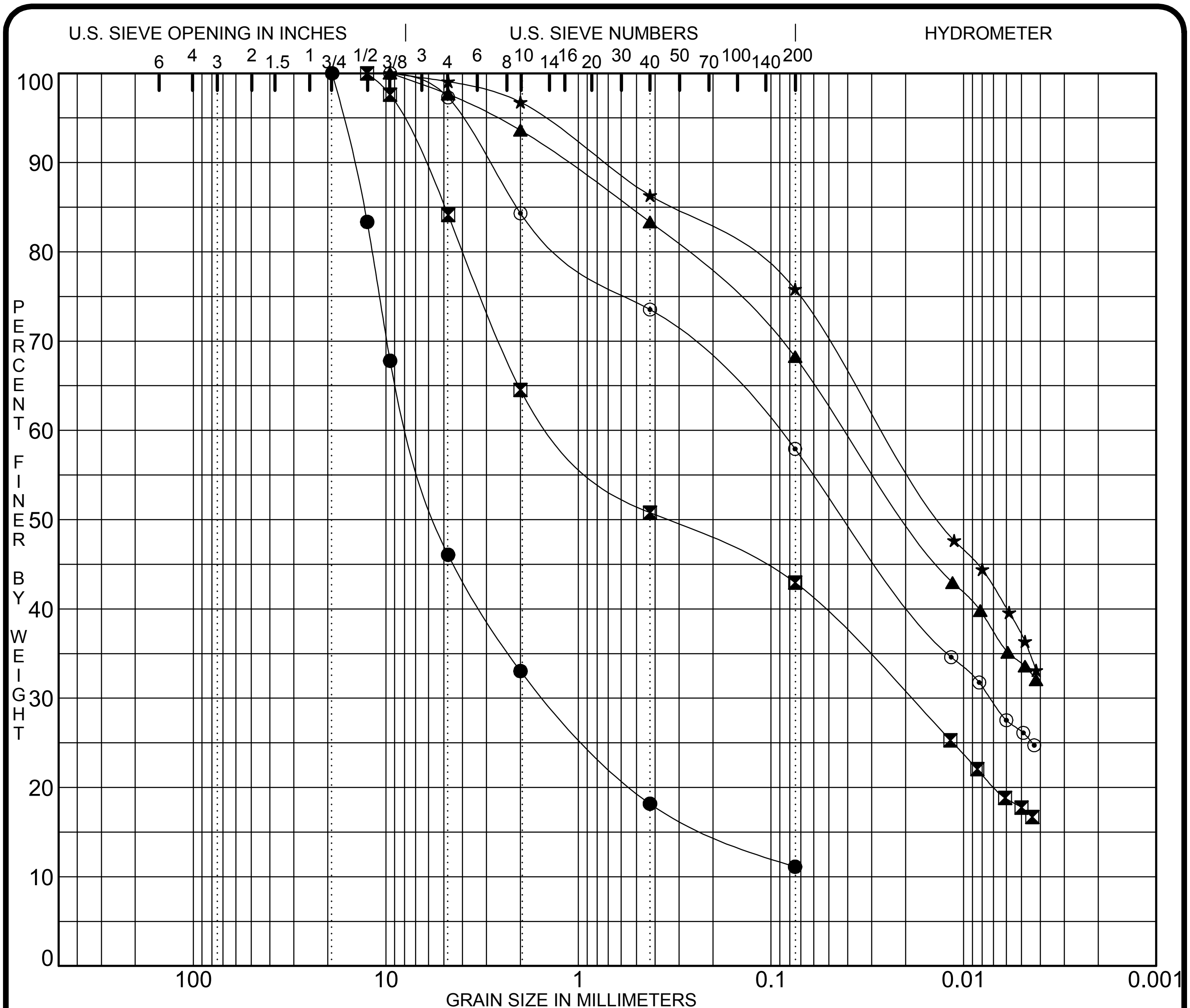
MATERIAL DESCRIPTION AND NOTES	ELEV. 741.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST. *(same as above)*	739.2	31, 32																
VERY STIFF, GRAY **SANDY SILT**, LITTLE CLAY, TRACE FINE GRAVEL, MOIST. -LIMESTONE FRAGMENTS PRESENT IN SS-12A	737.2	33, 34	11 17 22	56	89	SS-12A	4.00	-	-	-	-	-	-	-	-	15	A-4a (V)	
VERY DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST.	734.2	35, 36, 37				SS-12B	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	
VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST.	731.2	38, 39, EOB 40	7 21 24	64	67	SS-13	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 14.5' AND AT COMPLETION @ 6.4'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 75 LBS BENTONITE CHIPS AND SOIL CUTTINGS; PLACED ASPHALT PATCH

APPENDIX IV

LABORATORY TEST RESULTS



COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

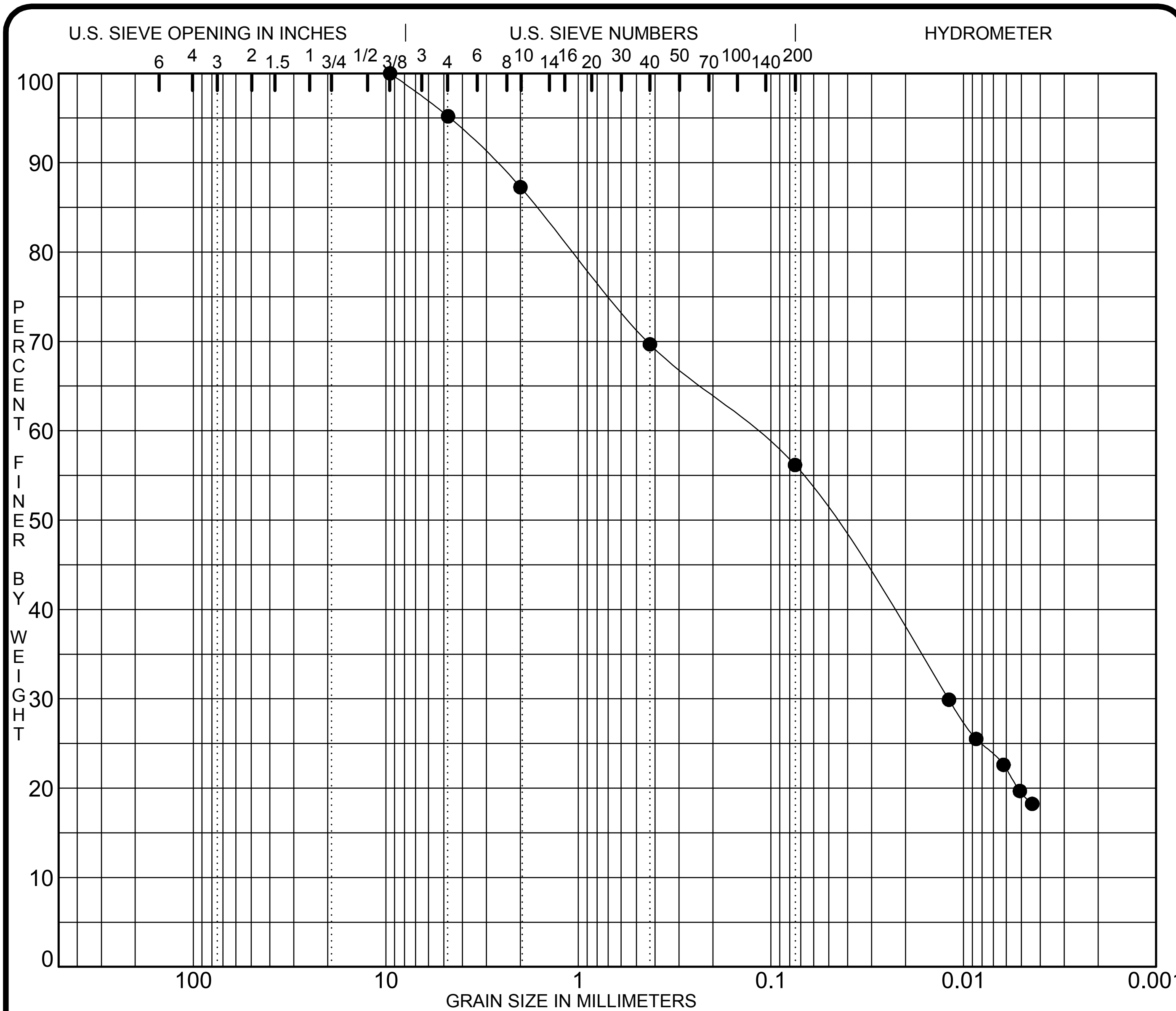
	Specimen Identification	Depth	Classification	MC%	LL	PL	PI	Cz	Cu
●	**B-1**	**1.0**		**12**				**5.03**	**129.9**
⧗	**B-1**	**6.0**	**A-4a**	**17**	**29**	**20**	**9**		
▲	**B-1**	**10.0**		**15**					
★	**B-1**	**10.5**	**A-6a**	**13**	**30**	**19**	**11**		
⊙	**B-1**	**13.5**		**13**					

	Specimen Identification	D60	D50	D30	D10	%Gravel coarse	%Gravel fine	%Sand coarse	%Sand fine	%Silt	%Clay
●	**B-1**	**7.409**	**5.386**	**1.458**		**0.0**	**67.0**	**14.9**	**7.1**	**11.1**	
⧗	**B-1**	**1.201**	**0.357**	**0.019**		**0.0**	**35.5**	**13.7**	**7.8**	**25.2**	**17.7**
▲	**B-1**	**0.041**	**0.019**			**0.0**	**6.4**	**10.3**	**15.1**	**34.4**	**33.9**
★	**B-1**	**0.026**	**0.013**			**0.0**	**3.2**	**10.5**	**10.5**	**38.8**	**37.1**
⊙	**B-1**	**0.094**	**0.040**	**0.007**		**0.0**	**15.7**	**10.8**	**15.6**	**31.7**	**26.3**

PROJECT **Borror Road Bridge 1.66 over Plum Run** PROJECT NO. **W-17-137**

GRADATION CURVES

RII



COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

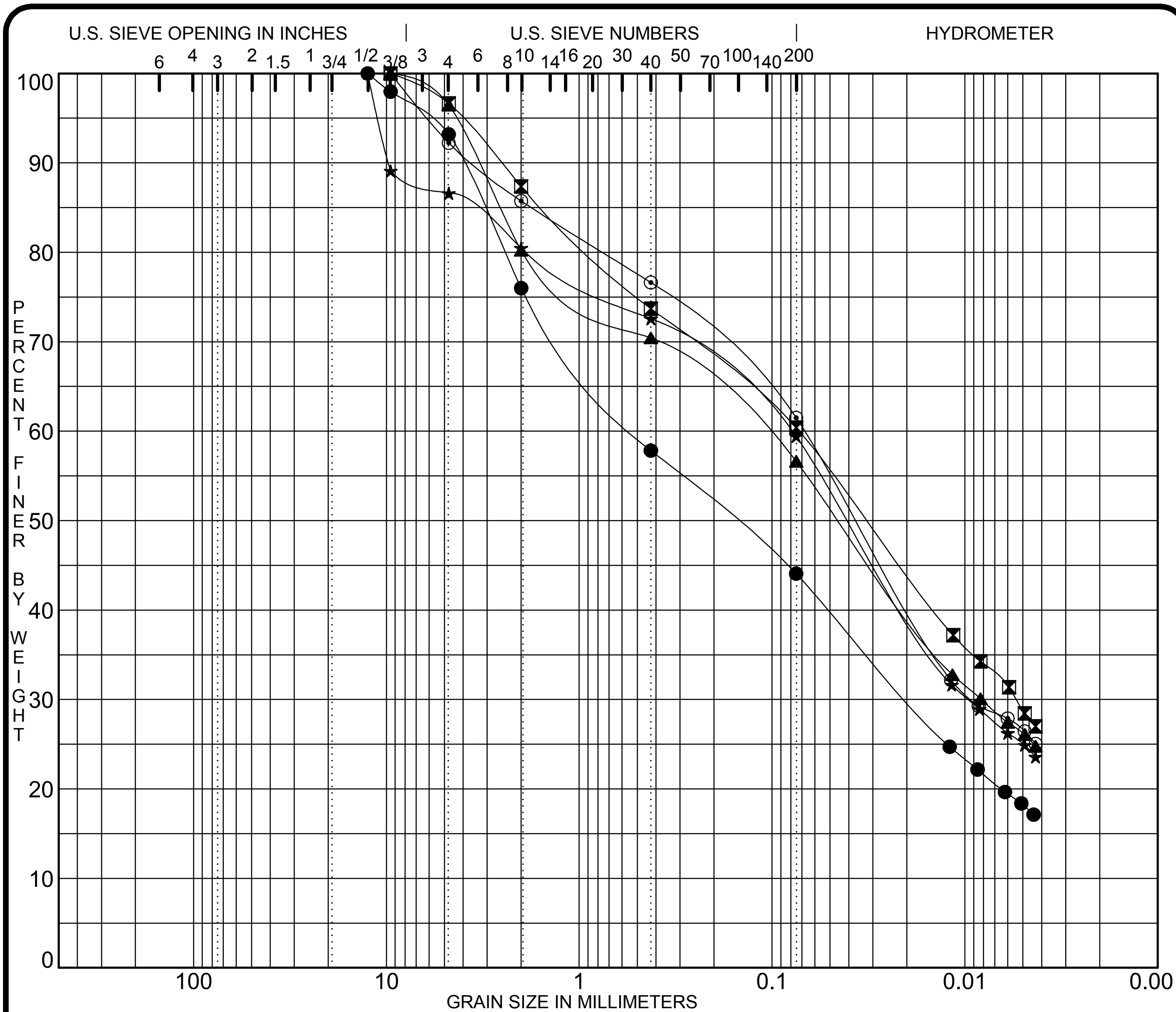
	Specimen Identification	Depth	Classification	MC%	LL	PL	PI	Cz	Cu
●	**B-1**	**18.5**	**A-4a**	**12**	**22**	**15**	**7**		

	Specimen Identification	D60	D50	D30	D10	%Gravel coarse	%Gravel fine	%Sand coarse	%Sand fine	%Silt	%Clay
●	**B-1**	**0.123**	**0.049**	**0.012**		**0.0**	**12.7**	**17.6**	**13.5**	**36.7**	**19.5**

PROJECT **Borror Road Bridge 1.66 over Plum Run** PROJECT NO. **W-17-137**

GRADATION CURVES

RII



COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

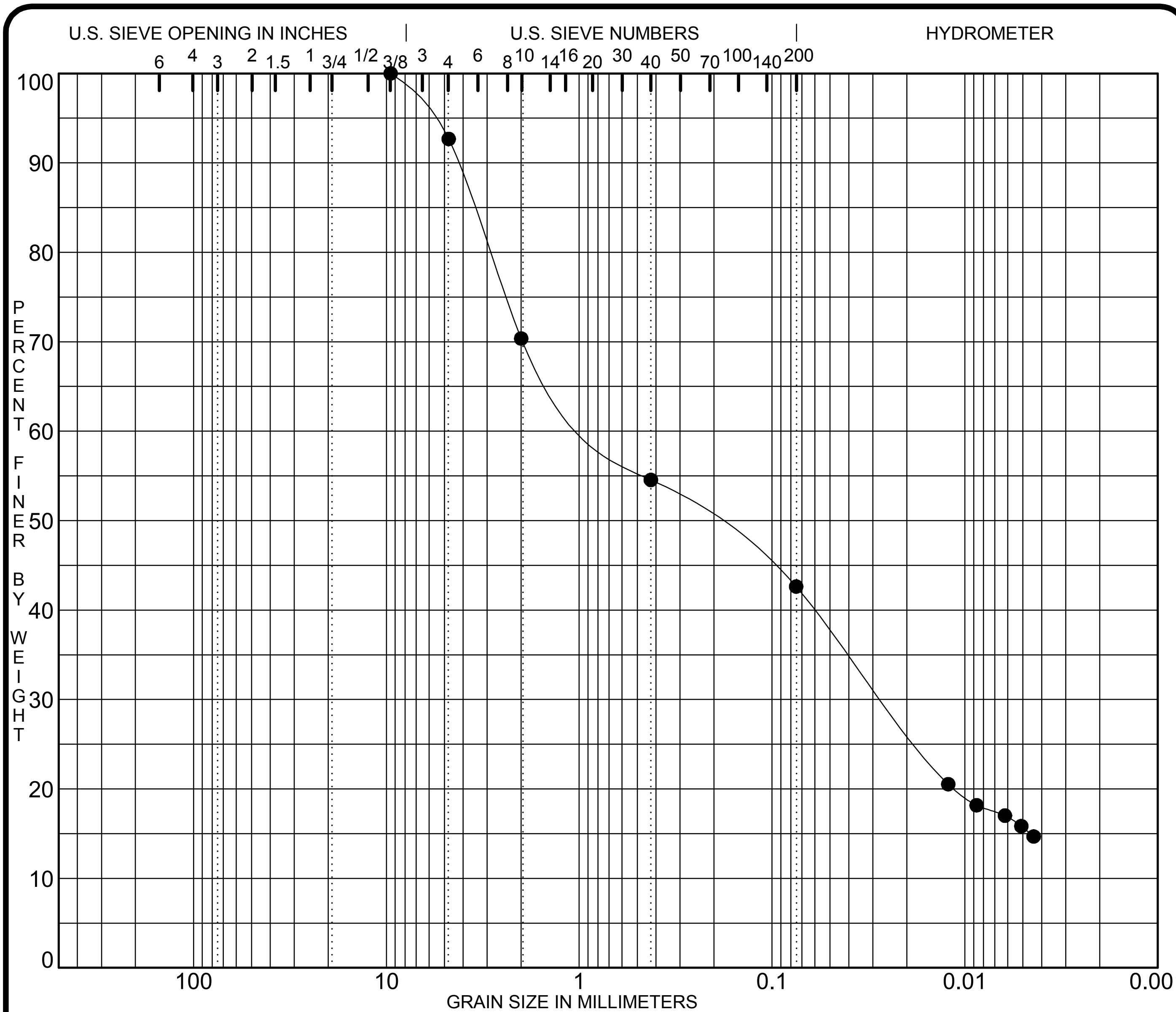
	Specimen Identification	Depth	Classification	MC%	LL	PL	PI	Cz	Cu
●	**B-2**	**3.5**	**A-4a**	**15**	**25**	**17**	**8**		
⧗	**B-2**	**10.0**	**A-4a**	**13**	**26**	**16**	**10**		
▲	**B-2**	**11.5**		**18**					
★	**B-2**	**13.0**		**14**					
⊙	**B-2**	**14.5**		**12**					

	Specimen Identification	D60	D50	D30	D10	%Gravel coarse	%Gravel fine	%Sand coarse	%Sand fine	%Silt	%Clay
●	**B-2**	**0.511**	**0.158**	**0.020**		**0.0**	**24.0**	**18.2**	**13.8**	**25.9**	**18.2**
⧗	**B-2**	**0.073**	**0.032**	**0.005**		**0.0**	**12.6**	**13.7**	**13.3**	**31.6**	**28.8**
▲	**B-2**	**0.115**	**0.045**	**0.008**		**0.0**	**19.8**	**9.8**	**13.8**	**30.4**	**26.2**
★	**B-2**	**0.081**	**0.040**	**0.010**		**0.0**	**19.5**	**7.9**	**13.2**	**34.4**	**25.0**
⊙	**B-2**	**0.068**	**0.036**	**0.009**		**0.0**	**14.3**	**9.1**	**15.1**	**34.9**	**26.6**

PROJECT **Borror Road Bridge 1.66 over Plum Run** PROJECT NO. **W-17-137**

GRADATION CURVES

RII



COBBLES	GRAVEL		SAND		SILT OR CLAY
	coarse	fine	coarse	fine	

	Specimen Identification	Depth	Classification	MC%	LL	PL	PI	Cz	Cu
●	**B-2**	**23.5**	**A-4a**	**12**	**22**	**15**	**7**		

	Specimen Identification	D60	D50	D30	D10	%Gravel coarse	%Gravel fine	%Sand coarse	%Sand fine	%Silt	%Clay
●	**B-2**	**0.725**	**0.219**	**0.027**		**0.0**	**29.6**	**15.8**	**11.9**	**26.9**	**15.7**

PROJECT **Borror Road Bridge 1.66 over Plum Run** PROJECT NO. **W-17-137**

GRADATION CURVES

RII

APPENDIX V

PAVEMENT DATA SHEET

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

Pavement Core Data Summary

PROJECT	Borror Road Bridge 1.66 over Plum Run
LOCATION	Sta. 87+50.43 / 8.2' Lt.
JOB No.	W-17-137
BORING/CORE No.	B-001-0-17
DATE CORE OBTAINED	11/13/2017
CORE OBTAINED BY	M.Wolf/C.Hoskins

Core Composition

Core Number	Lift Thickness (in.)	Asphalt 404	Asphalt 402	Asphalt 301	Concrete	Aggregate/Granular Base	Other			
B-001-0-17	1.75	✓								
	1.50	✓								
	3.25			✓						
	2.50		✓							
	3.00					✓				

Comments/Remarks

- Core is separated @ 6.5 inches.
- Overall condition is good down to thickness of 6.5 inches, below 6.5 inches the core is irregularly separated and contains voids and cracked aggregate throughout.

Total Pavement Thickness =	9.00	in.	Total Asphalt Thickness =	9.00	in.	Total Concrete Thickness =	0.00	in.	Total Base Thickness =	3.00	in.

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

Pavement Core Data Summary

PROJECT: Borror Road Bridge 1.66 over Plum Run
LOCATION: 87+80.30 / 6.3' Rt.
JOB No.: W-17-137

BORING/CORE No.: B-002-0-17
DATE CORE OBTAINED: 11/13/2017
CORE OBTAINED BY: M.Wolf/C.Hoskins

Core Composition

Core Number	Lift Thickness (in.)	Asphalt 404	Asphalt 402	Asphalt 301	Concrete	Aggregate/Granular Base	Other			
B-002-0-17	1.75	✓								
	0.75	✓								
	3.25			✓						
	4.25		✓							
	2.00					✓				

Comments/Remarks

- Core is intact.
- Overall condition of core is good.
- Core seems to be bitumen rich at 5.75 inches and more bitumen rich below 5.75 inches.

Total Pavement Thickness = 10.00 in.
Total Asphalt Thickness = 10.00 in.
Total Concrete Thickness = 0.00 in.
Total Base Thickness = 2.00 in.

APPENDIX VI

ANALYSIS CALCULATION

W-17-137 - Borror road over plum Creek

3-sided Culvert Shallow Foundation Bearing Resistance _ inlet

Boring B-001-0-17

B =	4.0	ft	
L =	48	ft	
c =	4,000	psf	
γ =	130	pcf	
D_f =	4.7	ft	
φ =	0	deg	
D_w =	0.0	ft	Below ground surface

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$ = 21.20 ksf

$$N_{cm} = N_c s_c i_c$$ = 5.22

$$N_{qm} = N_q s_q d_q i_q$$ = 1.00

$$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$$ = 0.00

N_c =	5.14	s_c =	1.016	i_c =	1.000	d_q =	1.000
N_q =	1.00	s_q =	1.000	i_q =	1.000	C_{wq} =	0.500
N_γ =	0.00	s_γ =	0.967	i_γ =	1.000	$C_{w\gamma}$ =	0.500

$$q_R = q_n \cdot \phi_b$$ = 10.60 ksf

φ_b = 0.5

W-17-137 - Borror Road over Plum Creek
Shallow Foundation Settlement - 3-sided culvert

Calculated By: PM Date: 2/12/2018
Checked By: PSL Date: 2/20/2018

Boring B-001-0-17

B =	4.0	ft	
D_w =	0.0	ft	
q =	4,700	psf	(11.8 ft. x 125 pcf = 1475 psf)
q_{net} =	3,000	psf	Net loading from structure (considers initial overburden stress of 1,475 psf)
σ_m =	4,000	psf	(for moderately overconsolidated soil deposit)

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' [1] (psf)	LL	C_c [2]	C_r [3]	e_o [4]	N_{60}	$(N1)_{60}$ [5]	C' [6]	Z_f/B	I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)
1	A-6a	C	0.0	1.7	1.7	0.9	138	235	117	64	4,064	30	0.180	0.014	0.507				0.21	0.973	2,920	2,984	0.025	0.305
	A-6a	C	1.7	3.2	1.5	2.5	138	442	338	185	4,185	30	0.180	0.014	0.507				0.61	0.748	2,243	2,428	0.015	0.180
2	A-4a	C	3.2	6.2	3.0	4.7	138	856	649	355	4,355	22	0.108	0.008	0.444				1.18	0.485	1,456	1,812	0.012	0.143
	A-4a	C	6.2	9.2	3.0	7.7	138	1,270	1,063	582	4,582	22	0.108	0.008	0.444				1.93	0.317	950	1,532	0.007	0.085
	A-4a	C	9.2	12.2	3.0	10.7	138	1,684	1,477	809	4,809	22	0.108	0.008	0.444				2.68	0.233	698	1,507	0.005	0.055
	A-4a	C	12.2	15.2	3.0	13.7	138	2,098	1,891	1,036	5,036	22	0.108	0.008	0.444				3.43	0.183	550	1,586	0.003	0.037
3	A-6a	C	15.2	17.7	2.5	16.5	135	2,435	2,266	1,240	5,240	30	0.180	0.014	0.507				4.11	0.153	460	1,700	0.003	0.037
	A-6a	C	17.7	20.2	2.5	19.0	135	2,773	2,604	1,421	5,421	30	0.180	0.014	0.507				4.74	0.133	400	1,822	0.002	0.029
																						Total:		0.870 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 4,000 psf for moderately overconsolidated soil deposit; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 26, FHWA GEC 5
3. $C_r = 0.15(C_c)$ for medium stiff to stiff natural soil deposits and existing fill material, 0.075 to $0.10(C_c)$ for very stiff to hard natural soil deposits, and 0.05(Cc) for new embankment fill; Ref. Section 5.4.2.5 of FHWA GEC 5
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-17-137 - Borror Road over Plum Creek

Shallow Foundation Settlement - 3-sided culvert

Calculated By: PM Date: 2/12/2018

Checked By: PSL Date: 2/20/2018

Boring B-002-0-17

B =	4.0	ft	
D_w =	0.0	ft	
q =	4,700	psf	
q_{net} =	3,000	psf	Net loading from structure (considers initial overburden stress of 1,700 psf)
σ_m =	4,000	psf	(for moderately overconsolidated soil deposit)

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)
1	A-4a	C	0.0	2.0	2.0	1.0	138	276	138	76	4,076	26	0.144	0.011	0.475				0.25	0.959	2,878	2,954	0.023	0.280
	A-4a	C	2.0	4.0	2.0	3.0	138	552	414	227	4,227	26	0.144	0.011	0.475				0.75	0.668	2,004	2,231	0.015	0.174
	A-4a	C	4.0	6.0	2.0	5.0	138	828	690	378	4,378	26	0.144	0.011	0.475				1.25	0.462	1,385	1,763	0.010	0.118
	A-4a	C	6.0	8.0	2.0	7.0	138	1,104	966	529	4,529	26	0.144	0.011	0.475				1.75	0.345	1,036	1,565	0.007	0.083
	A-4a	C	8.0	10.0	2.0	9.0	138	1,380	1,242	680	4,680	26	0.144	0.011	0.475				2.25	0.274	822	1,502	0.005	0.060
	A-4a	C	10.0	12.0	2.0	11.0	138	1,656	1,518	832	4,832	26	0.144	0.011	0.475				2.75	0.227	680	1,511	0.004	0.046
	A-4a	C	12.0	14.0	2.0	13.0	138	1,932	1,794	983	4,983	22	0.108	0.008	0.444				3.25	0.193	579	1,561	0.002	0.027
	A-4a	C	14.0	16.0	2.0	15.0	138	2,208	2,070	1,134	5,134	22	0.108	0.008	0.444				3.75	0.168	503	1,637	0.002	0.021
2	A-2-4	G	16.0	19.5	3.5	17.8	138	2,691	2,450	1,342	5,342					40	45	151	4.44	0.142	427	1,769	0.003	0.033
3	A-4a	C	19.5	21.5	2.0	20.5	138	2,967	2,829	1,550	5,550	22	0.108	0.011	0.444	80	87	140	5.13	0.123	370	1,920	0.001	0.017
																						Total:		0.859 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 4,000 psf for moderately overconsolidated soil deposit; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 26, FHWA GEC 5
3. $C_r = 0.15(C_c)$ for medium stiff to stiff natural soil deposits and existing fill material, 0.075 to $0.10(C_c)$ for very stiff to hard natural soil deposits, and 0.05(Cc) for new embankment fill; Ref. Section 5.4.2.5 of FHWA GEC 5
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)