Resource International, Inc.

HAM-75-7.85
RETAINING WALL J
PID NO. 77889
HAMILTON COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT

Prepared For:
EMH&T
5500 New Albany Road
Columbus, Ohio 43054

Prepared By:
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4480 Lake Forest Drive, Suite 308
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Rii Project No. B-10-020

July, 2015

RESOURCE INTERNATIONAL, INC.
ISO | ISO 9001:2008 Certified QMS
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Planning

Engineering

Construction Management

Technology

January 20, 2012 (Revised July 21, 2015)

Mr. Edward D. Kagel, P.E.
Director of Transportation
EMH&T
5500 New Albany Road
Columbus, Ohio 43054

Re: Structure Foundation Exploration
HAM-75-7.85
Retaining Wall J
PID No. 77889
Rii Project No. B-10-020

Mr. Kagel:

Resource International, Inc. (Rii) is pleased to submit this structure foundation exploration report for the 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 proposed Retaining Wall J as part of the HAM-75-7.85 project in Hamilton 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.

Brian R. Trenner, P.E.
Project Manager

Jonathan P. Sterenberg, P.E.
Director – Geotechnical Services

Enclosure: Structure Foundation Exploration Report

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TABLE OF CONTENTS

Section **Page**

APPENDICIES

Appendix I	**State Geology**
Appendix II	**Vicinity Map and Boring Plan**
Appendix III	**Description of Soil Terms**
Appendix IV	**Boring Logs: B-031-1-13 through B-035-0-11 and B-037-0-11 through B-039-0-11**
Appendix V	**Laboratory Testing Results**
Appendix VI	**MSE Wall Calculations**

EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration for the design and construction of proposed Retaining Wall J as part of the HAM-75-7.85 project. The wall alignment traverses areas where the proposed grade change will require fill along the south end of the alignment and transition to a cut section along the north end of the alignment where the wall will connect to the HAM-75-0701 Seymour Avenue over I-75 bridge structure. It is understood that a mechanically stabilized earth (MSE) wall type will be utilized along the south end of the alignment where fill will be required to achieve the proposed profile grade, which will transition to a graded embankment with guardrail where the proposed grade change is minimal, and then will transition to a cast-in-place wall type which will connect to the southwest wingwall of the HAM-75-0701 bridge structure. The total length of the MSE wall portion, referred to as Retaining Wall J1, is approximately 1,050 lineal feet, and the total length of the cast-in-place wall, referred to as Retaining Wall J3, is approximately 30 lineal feet. The proposed Retaining Wall J1 begins at Sta. 475+87 and continues north to Sta. 486+00, and the proposed Retaining Wall J3 begins at Sta. 490+42 and continues north to Sta. 490+71 along the west side of I-75.

Exploration and Findings

Between September 27 and 29, 2011, seven (7) structure borings, designated as B-032-0-11 through B-035-0-11 and B-037-0-11 through B-039-0-11, were drilled to depths ranging from 25.0 to 50.0 feet below the ground surface at the locations illustrated on the boring plan presented in Appendix II of the full report. Between July 7 and 14, 2014, three (3) additional structure borings, designated as B-031-1-13 through B-031-3-13, were drilled to a depth of 70.0 feet each along the extended portion of Retaining Wall J1.

Borings B-031-1-13 through B-031-3-13 were performed within the existing shoulder of I-75 southbound and encountered 4.0 to 6.0 inches of asphalt overlying 9.0 to 12.0 inches of concrete, followed by 4.0 to 6.0 inches of aggregate base. The remaining borings were drilled along the embankment separating the I-75 mainline and the service road to the west and encountered 5.0 to 7.0 inches of topsoil at the existing ground surface.

Beneath the pavement materials in borings B-031-1-13 through B-031-3-13, existing embankment fill was encountered extending to a depths ranging from 23.0 to 25.0 feet below the existing grade of I-75, which corresponds to elevations ranging from 526.2 to 534.4 feet msl. The existing embankment fill consisted primarily of cohesive soils described as brown, dark brown and black sandy silt, silt and clay and silty clay (ODOT A-4a, A-6a, A-6b) and non-plastic sand silt (ODOT A-4a). In addition, material identified as existing fill consisting of brown gravel (ODOT A-1-a) was encountered in boring B-035-0-11extending to a depth of 3.0 feet below existing grade.

Underlying the surface materials and existing embankment fill or fill material, natural granular soils with intermittent seams of cohesive material were encountered. The granular soils were generally described as brown and gray gravel, gravel and sand, gravel with sand, silt and clay, fine sand, coarse and fine sand and sandy silt (ODOT A-1-a, A-1-b, A-2-6, A-3, A-3a, A-4a). The cohesive soils were generally described as brown, gray and dark brown sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6).

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

Analyses and Recommendations

Design details of the proposed retaining wall were provided by the Rii design team. It is understood that a mechanically stabilized earth (MSE) wall type will be utilized for Retaining Wall J1, where fill will be required to achieve the proposed profile grade, which will transition to a graded embankment with guardrail where the proposed grade change is minimal, and then will transition to Retaining Wall J3, which will consist of a cast-in-place wall type that will connect to the southwest wingwall of the HAM-75-0701 bridge structure.

It is understood that driven piles are being utilized to support Retaining Wall J3 due to the short length of the wall and the proposed wall height. Given the close proximity to the rear abutment of the proposed HAM-75-0701 bridge structure, and also given that the proposed southwest wingwall of the bridge structure will be supported on driven piles, the driven pile recommendations for this structure should be utilized in the design of the driven pile foundation for Retaining Wall J3.

MSE Wall Recommendations

It is understood that a MSE retaining wall is being considered for use in supporting the proposed Ramp C and I-75 roadway along the alignment of Retaining Wall J1. Based on the proposed plan and profile and cross section information, wall heights along the alignment of Retaining Wall J1 are anticipated to range between 9.6 feet and 25.8 feet. The wall will support a graded embankment with a 2:1 (H:V) backslope that extends up to the roadway elevation from the beginning of the wall alignment to Sta. 478+35, and the wall will directly support the roadway and/or short graded embankments between Sta. 478+35 and end of the wall alignment.

The anticipated bearing materials along the proposed alignment of Retaining Wall J1 consist of loose to medium dense gravel, gravel and sand, gravel with sand, silt and clay and fine sand (ODOT A-1-a, A-1-b, A-2-6, A-3), and medium stiff to hard silt and clay and clay (ODOT A-6a, A-7-6) was encountered at the proposed bearing elevation in borings B-031-2-13, B-031-3-13 and B-033-0-11, which extended to an elevation of 524.1, 526.2 and 526.0 feet msl, respectively. Given the shallow depth of these deposits, along with the reduced shear strength of these soil types, it is recommended that this material, where encountered, be completely over excavated to expose the underlying competent granular soils and replaced ODOT Item 203 granular embankment. MSE wall foundations bearing on these competent natural soils or granular embankment, placed and compacted in accordance with ODOT Item 203, may be proportioned for a nominal bearing resistance as indicated in the following table. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored nominal bearing resistance at the strength limit state.

Retaining Wall J1 MSE Wall Design Parameters

From Station [1]	To Station [1]	Wall Height Analyzed (feet)	Backslope Behind Wall in Analysis	Minimum Required Reinforcement Length [2] (feet)	Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing Pressure [4] (ksf)
					Nominal	Factored [3]	
475+87	478+35	20.0	2:1	20.0 (1.0H)	18.7	12.2	4.87
478+35	483+50	25.8	Level	18.1 (0.7H)	14.2	9.2	6.51
483+50	486+00	12.6	Level	8.8 (0.7H ≥ 8.0)	17.6	11.5	3.70

1. *Stationing listed is referenced to the mainline I-75 centerline.*
2. *The required foundation width is expressed as a percentage of the wall height, H.*
3. *A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.*
4. *The strength limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the strength limit state.*

Total settlements of up to 3.00 inches at the center of the reinforced soil mass and 2.35 inches at the facing of the wall are anticipated along the alignment of Retaining Wall J1. Based on the results of the analysis, 100 percent of the total settlement at the facing of the wall is anticipated to occur during construction of the wall or within fifteen (15) days following the completion of construction of the wall.

Based on the results of the external and global stability analysis performed for the MSE wall, the recommended controlling strap length is 0.7 times the height of the MSE wall (measured from the top of the leveling pad to the top of the coping) between Sta. 478+35 and Sta. 486+00, and the recommended controlling strap length is 1.0 times the height of the MSE wall between Sta. 475+87 and Sta. 478+35. Global stability was the controlling factor in the determination of the recommended strap length of 100 percent of the wall height between Sta. 475+87 and Sta. 478+35.

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

The overall purpose of this project is to provide detailed subsurface information and recommendations for the design and construction of the HAM-75-7.85 project in Hamilton County, Ohio. This project represents the northern portion of HAM-75-2.30 Mill Creek Expressway improvements. The overall project will consist of roadway improvements, and several retaining wall and bridge replacements along I-75 from Vine Street to State Route 126. The project site is located in the community limits of St. Bernard, Elmwood Place, Roselawn, and Cincinnati, in Hamilton County, Ohio.

This report is a presentation of the structure foundation exploration performed for the design and construction of proposed Retaining Wall J as part of the HAM-75-7.85 project, as shown on the vicinity map and boring plan presented in Appendix II. It is understood that this wall will be connected to the rear abutment of the proposed HAM-561-0701 Seymour Avenue over I-75 bridge structure at the north end of the wall alignment and will extend south along the west side of the proposed Ramp C as it merges with the I-75 southbound mainline. According to design details provided by EMH&T the rear abutment for the bridge structure is currently proposed to be a full height cast-in-place wall type abutment with associated wingwalls extending to the north and south of the structure.

The wall alignment traverses areas where the proposed grade change will require fill along the south end of the alignment and transition to a cut section along the north end of the alignment where the wall will connect to the HAM-75-0701 bridge structure. It is understood that a mechanically stabilized earth (MSE) wall type will be utilized along the south end of the alignment where fill will be required to achieve the proposed profile grade, which will transition to a graded embankment with guardrail where the proposed grade change is minimal, and then will transition to a cast-in-place wall type which will connect to the southwest wingwall of the HAM-75-0701 bridge structure. The total length of the MSE wall portion, referred to as Retaining Wall J1, is approximately 1,050 lineal feet, and the total length of the cast-in-place wall, referred to as Retaining Wall J3, is approximately 30 lineal feet. The proposed Retaining Wall J1 begins at Sta. 475+87 and continues north to Sta. 486+00, and the proposed Retaining Wall J3 begins at Sta. 490+42 and continues north to Sta. 490+71 along the west side of I-75.

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. Physiographically, the site lies within the Illinoian Till Plain of the Till Plains Section. This area is characterized by rolling ground moraine deposits with many buried valleys alternating between broad floodplains and bedrock gorges. The site area contains silty loam till deposited as ground moraine covered with loess and dissected by the modern day Mill Creek. Ground moraines are deposited during the retreat of a glacier which results in an undifferentiated mixture of clay, silt, sand and gravel. The valley area also contains outwash and alluvium which eroded from hills and valleys with moderate relief. 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 size particles to cobbles, usually deposited in present and former floodplain areas.

Based on Bedrock Geology and Topography Maps of the area, from the Ohio Department of Natural Resources (ODNR), the underlying bedrock consists of the Ordovician-aged Point Pleasant Formation. The Point Pleasant Formation is comprised of interbedded limestone and shale, averaging 60 percent limestone and 40 percent shale, and ranges from 0 to 80 feet thick. The bedrock surface forms a valley roughly beneath, and following, the alignment of Mill Creek which is aligned northeast-to-southwest. I-75 is aligned roughly parallel to this main bedrock valley from the approximate intersection with State Route 126 to the approximate intersection with Regina Graeter Way, and lies just east of the bottom of the bedrock valley. Along the project alignment, the bedrock surface directly beneath I-75 lies along the slope of the bedrock valley and the bedrock surface ranges between approximate elevations of 385 to 425 feet msl. A smaller bedrock valley branches off to the southeast of the bedrock valley that follows Mill Creek just south of the interchange with State Route 562, and runs roughly parallel with Ross Run and generally beneath the SR 562 alignment. Overall, the bedrock surface along the majority of the project alignment slopes downward to the northwest. According to bedrock topography mapping, the depth to top of bedrock in the vicinity of the project ranges from approximately 120 to 170 feet below the existing ground surface. An illustration of the general geology of Ohio is presented in Appendix I.

2.2 Existing Conditions

The site for the proposed Retaining Wall J is located along the west side of I-75, just south of the HAM-561-7.01 Seymour Avenue over I-75 bridge structure. Overall, the project is located approximately 1.37 miles south of the Lockland split. The wall will be located along the west side of I-75, separating the proposed entrance ramp from Paddock Road to I-75 southbound and a service road that services local businesses to the west. The existing I-75 roadway that runs adjacent to the proposed structure is a six-lane, asphalt paved road, and the existing service road is a 30-foot wide, asphalt-paved roadway that services local businesses that are located just west of I-75 and south of Seymour Avenue. The terrain west of I-75 is relatively flat lying and the I-75 mainline slopes downward gently from the south side of the proposed wall alignment to the north where I-75 crosses under Seymour Avenue.

3.0 EXPLORATION

Between September 27 and 29, 2011, seven (7) structure borings, designated as B-032-0-11 through B-035-0-11 and B-037-0-11 through B-039-0-11, were drilled to depths ranging from 25.0 to 50.0 feet below the ground surface. Between July 7 and 14, 2014, three (3) additional structure borings, designated as B-031-1-13 through B-031-3-13, were drilled to a depth of 70.0 feet each along the extended portion of Retaining Wall J1. The boring locations are illustrated on the boring plan presented in Appendix II and summarized in Table 1.

Table 1. Test Boring Summary

Boring Number	Station [1]	Offset [1]	Latitude	Longitude	Ground Elevation (feet msl)	Boring Depth (feet)
B-031-1-13	439+47.81	328.2' Lt.	39.180159023	-84.484493474	559.9	70.0
B-031-2-13	476+33.38	44.1' Lt.	39.190083513	-84.480507003	554.6	70.0
B-031-3-13	477+95.88	42.6' Lt.	39.190446873	-84.480154307	549.2	70.0
B-032-0-11	480+99.46	90.5' Lt.	39.191055614	-84.479969446	532.7	50.0
B-033-0-11	483+15.31	101.2' Lt.	39.191518417	-84.479485137	533.8	50.0
B-034-0-11	484+36.55	91.3' Lt.	39.191744711	-84.479169544	535.2	50.0
B-035-0-11	485+91.35	105.8' Lt.	39.192084006	-84.478836739	533.6	50.0
B-037-0-11	487+14.20	121.3' Lt.	39.192360602	-84.478582797	534.3	25.0
B-038-0-11	488+43.87	109.0' Lt.	39.192599270	-84.478240581	538.3	25.0
B-039-0-11	489+88.69	114.9' Lt.	39.192902551	-84.477909539	545.2	50.0

1. *Station and offset referenced to the proposed centerline of I-75.*

The boring locations were determined and located in the field by Rii representatives. Geographic latitude and longitude coordinates as well as ground surface elevations at the boring locations are included on the boring logs provided in Appendix IV.

The borings were drilled using a truck or all-terrain vehicle (ATV) mounted rotary drilling machine, utilizing a 4.25-inch inside diameter, continuous hollow-stem auger to advance the holes. In general, standard penetration test (SPT) and split spoon sampling were performed in the borings at 2.5-foot increments of depth to 20 or 30 feet below the proposed bottom of wall elevation, and at 5.0-foot increments thereafter to the boring termination depth. The SPT, per the American Society for Testing and Materials (ASTM) designation D1586, is conducted using a 140-pound hammer falling 30.0 inches to drive a 2.0-inch outside diameter split spoon sampler 18.0 inches. Rii utilized a calibrated automatic drop hammer to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of blows per 6.0-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). Standard penetration blow counts aid in determining soil properties applicable in foundation system 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 IV.

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

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

The hammer for the CME 750X drill rig used to perform the 2011 borings was calibrated on May 6, 2011, and has a drill rod energy ratio of 77.1 percent. The hammer for the Mobile B-53 drill rig used to perform the 2014 borings was calibrated on April 26, 2013, and has a drill rod energy ratio of 77.7 percent.

During drilling, Rii personnel prepared a field log showing 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	160
Plastic and Liquid Limits	AASHTO T89, T90	39
Sieve/Hydrometers	AASHTO T88	39
Unconfined Compression Test	ASTM D2166	1

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

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

4.0 FINDINGS

Interpreted engineering logs have been prepared from the field logs, visual examination of samples, and laboratory testing. Classification follows the current version of the ODOT SGE at the time the borings were performed. The following is a summary of what was found in the test borings and what is represented on the boring logs.

4.1 Surficial Material

Borings B-031-1-13 through B-031-3-13 were performed within the existing shoulder of I-75 southbound and encountered 4.0 to 6.0 inches of asphalt overlying 9.0 to 12.0 inches of concrete, followed by 4.0 to 6.0 inches of aggregate base. The remaining borings were drilled along the embankment separating the I-75 mainline and the service road to the west and encountered 5.0 to 7.0 inches of topsoil at the existing ground surface, identified by the significant presence of organic matter and vegetation.

4.2 Subsurface Soils

Beneath the pavement materials in borings B-031-1-13 through B-031-3-13, existing embankment fill was encountered extending to a depths ranging from 23.0 to 25.0 feet below the existing grade of I-75, which corresponds to elevations ranging from 526.2 to 534.4 feet msl. The existing embankment fill consisted primarily of cohesive soils described as brown, dark brown and black sandy silt, silt and clay and silty clay (ODOT A-4a, A-6a, A-6b) and non-plastic sand silt (ODOT A-4a). In addition, material identified as existing fill consisting of brown gravel (ODOT A-1-a) was encountered in boring B-035-0-11extending to a depth of 3.0 feet below existing grade.

Underlying the surface materials and existing embankment fill or fill material, natural granular soils with intermittent seams of cohesive material were encountered. The granular soils were generally described as brown and gray gravel, gravel and sand, gravel with sand, silt and clay, fine sand, coarse and fine sand and sandy silt (ODOT A-1-a, A-1-b, A-2-6, A-3, A-3a, A-4a). The cohesive soils were generally described as brown, gray and dark brown sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6).

The relative density of granular soils is primarily derived from SPT blow counts (N_{60}). Based on the SPT blow counts obtained, the granular soil encountered ranged from very loose (N_{60} < 5 blows per foot [bpf]) to very dense (N_{60} > 50 bpf). Overall blow counts recorded from the SPT sampling ranged from 3 to 98 bpf, generally increasing with depth. The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soil encountered ranged from medium stiff (0.5 < HP ≤ 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.

Natural moisture contents of the inorganic soil samples tested ranged from 2 to 28 percent. The natural moisture contents of the cohesive soil samples tested for plasticity index ranged from 6 percent below to 7 percent above their corresponding plastic limits. The moisture contents of the native soils are generally considered to be moderately below to moderately above 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 in the borings as noted in Table 3.

Table 3. Groundwater

Boring Number	Ground Elevation (feet msl)	Initial Groundwater		At Completion		Cave-in Depth	
		Depth	Elevation	Depth	Elevation	Depth	Elevation
B-031-1-13	559.9	60.0	499.9	N/A [1]	N/A	N/A	N/A
B-031-2-13	554.6	48.0	506.6	N/A [1]	N/A	N/A	N/A
B-031-3-13	549.2	43.5	505.7	N/A [1]	N/A	N/A	N/A
B-032-0-11	533.1	29.5	503.6	N/A [1]	N/A	N/A	N/A
B-033-0-11	534.0	29.0	505.0	N/A [1]	N/A	N/A	N/A
B-034-0-11	535.3	34.3	501.0	N/A [1]	N/A	N/A	N/A
B-035-0-11	533.9	34.2	499.7	25.4 [2]	508.5	15.7	518.2
B-037-0-11	534.4	Dry	Dry	Dry	Dry	11.8	522.6
B-038-0-11	538.6	Dry	Dry	Dry	Dry	11.6	527.0
B-039-0-11	544.9	36.5	508.4	30.4 [2]	514.5	17.7	527.2

1. *Groundwater at completion was not measured due to the addition of mud as a drilling fluid.*
2. *Groundwater level at completion was measured inside the auger stems.*

Groundwater was encountered initially during the drilling process in borings B-031-1-13 through B-031-3-13, B-032 -0-11 through B-035-0-11 and B-039-0-11 at depths ranging from 29.5 to 60.0 feet below the ground surface, which corresponds to elevations ranging from 499.7 to 508.4 feet msl. At the completion of drilling and prior to removing the augers, groundwater accumulated in the auger stems in borings B-035-0-11 and B-039-0-11 to depths of 25.4 and 30.4 feet below the ground surface, respectively. The groundwater level at the completion of drilling could not be obtained in borings B-031-1-13 through B-031-3-13, B-032-0-11 and B-034-0-11 due to the addition of mud as a drilling fluid. Borings B-037-0-11 and B-038-0-11 were observed to be dry, meaning that no appreciable amount of groundwater accumulated in the auger stems during or at the completion of drilling. Please note that short-term water level readings, especially in cohesive soils, are not necessarily an accurate indication of the actual groundwater level. In addition, groundwater levels or the presence of groundwater are considered to be dependent on seasonal fluctuations in precipitation.

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

5.0 ANALYSES 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 encountered at the site. These parameters have been used to provide guidelines for the design of foundation systems for the subject retaining wall, 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 retaining wall were provided by the Rii design team. It is understood that a mechanically stabilized earth (MSE) wall type will be utilized for Retaining Wall J1, where fill will be required to achieve the proposed profile grade, which will transition to a graded embankment with guardrail where the proposed grade change is minimal, and then will transition to Retaining Wall J3, which will consist of a cast-in-place wall type that will connect to the southwest wingwall of the HAM-75-0701 bridge structure.

It is understood that driven piles are being utilized to support Retaining Wall J3 due to the short length of the wall and the proposed wall height. Given the close proximity to the rear abutment of the proposed HAM-75-0701 bridge structure, and also given that the proposed southwest wingwall of the bridge structure will be supported on driven piles, the driven pile recommendations for this structure should be utilized in the design of the driven pile foundation for Retaining Wall J3.

5.1 MSE Wall Recommendations

It is understood that a MSE retaining wall is being considered for use in supporting the proposed Ramp C and I-75 roadway along the alignment of Retaining Wall J1. MSE walls are constructed on earthen foundations at a minimum depth of 3.0 feet below grade, as defined by the top of the leveling pad to the ground surface located 4.0 feet from the face of the wall. Note that the reinforced soil mass extends from the foundation bearing elevation (top of leveling pad) to the top of coping elevation. The width of the

MSE wall foundation (B) is defined by the length of the reinforced soil mass. Per the 2007 ODOT Bridge Design Manual (BDM) and Supplemental Specification (SS) 840, the minimum length of the reinforced soil mass is equal to 70 percent the height of the MSE wall or 8.0 feet whichever is greater. A non-structural leveling pad consisting of a minimum of 6.0-inches of unreinforced concrete should be placed at the base of the wall facing panels for constructability purposes. Please note that the leveling pad is not a structural foundation.

Based on the proposed plan and profile and cross section information provided by the Rii design team, wall heights along the alignment of Retaining Wall J1 are anticipated to range between 9.6 feet and 25.8 feet. The wall will support a graded embankment with a 2:1 (H:V) backslope that extends up to the roadway elevation from the beginning of the wall alignment to Sta. 478+35, and the wall will directly support the roadway and/or short graded embankments between Sta. 478+35 and end of the wall alignment. For the analysis, the foundation width was set at 70 percent of the wall height (or 8.0 feet for wall heights less than 11.4 feet) and the foundation width was increased, if required, until external and global stability requirements were satisfied.

Per Section 840.06.D of ODOT SS 840, the foundation subgrade should be inspected to verify that the subsurface conditions are the same as those anticipated in this report. The anticipated soils at the proposed bearing elevation along the majority of the wall alignment consists of loose to medium dense gravel, gravel and sand, gravel with sand, silt and clay and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3). However, cohesive soil deposits consisting of medium stiff to hard silt and clay and clay (ODOT A-6a, A-7-6) were encountered at the proposed bearing elevation in borings B-031-2-13, B-031-3-13 and B-033-0-11, which extended to an elevation of 524.1, 526.2 and 526.0 feet msl, respectively. Given the shallow depth of these deposits, along with the reduced shear strength of these soil types, it is recommended that this material, where encountered, be completely over excavated to expose the underlying competent granular soils and replaced with ODOT Item 203 granular embankment. Over excavation depths on the order of 1.5 to 6.0 feet are anticipated based on the elevation of the bottom of the cohesive soil deposits encountered in the borings. The actual limits and depth of over excavation will need to be determined during the construction of the wall based on observation of the subgrade condition by a qualified soil technician or geotechnical engineer.

5.1.1 Strength Parameters Utilized in External and Global Stability Analyses

The shear strength parameters utilized in the external and global stability analysis of the retaining wall are provided in Table 4.

Table 4. Shear Strength Parameters Utilized in MSE Wall Stability Analyses

Material Type	γ (pcf)	φ' (1) (°)	c' (2) (psf)	S_u (3) (psf)
MSE Wall Backfill (Select granular backfill)	120	34	0	N/A
ODOT Item 203 Embankment Fill (Retained soil)	120	30	0	2,000
Ex. Embankment Fill: Stiff to Hard Sandy Silt, Silt and Clay, Silty Clay (ODOT A-4a, A-6a, A-7-6)	120	28	50	1,500
Loose to Very Dense Granular Soils (ODOT A-1-a, A-1-b, A-2-4, A-3, A-3a, A-4a)	120 to 135	28 to 35	0	N/A

1. *Per Figure 74, Section 5.6.2.4 of FHWA GEC 5.*
2. *Estimated based on overconsolidated nature of soil.*
3. *Per Table 33 of Section 5.6.5 of FHWA GEC 5.*

Shear strength parameters for the reinforced soil backfill and retained embankment are provided in ODOT SS 840. Per SS 840, the select granular backfill in the reinforced zone and the retained embankment must meet the shear strength requirements provided in Table 4. The shear strength parameters for the natural soils were assigned using correlations provided in FHWA Geotechnical Engineering Circular (GEC) No. 5 (FHWA-IF-02-034) Evaluation of Soil and Rock Properties and based on past experience in the vicinity of the site with projects performed in similar subsurface profiles.

5.1.2 Bearing Stability

The anticipated bearing materials along the proposed alignment of Retaining Wall J1 consist of loose to medium dense gravel, gravel and sand, gravel with sand, silt and clay and fine sand (ODOT A-1-a, A-1-b, A-2-6, A-3), and medium stiff to hard silt and clay and clay (ODOT A-6a, A-7-6) was encountered at the proposed bearing elevation in borings B-031-2-13, B-031-3-13 and B-033-0-11, which extended to an elevation of 524.1, 526.2 and 526.0 feet msl, respectively. Given the shallow depth of these deposits, along with the reduced shear strength of these soil types, it is recommended that this material, where encountered, be completely over excavated to expose the underlying competent granular soils and replaced ODOT Item 203 granular embankment. MSE wall foundations bearing on these competent natural soils or granular embankment, placed and compacted in accordance with ODOT Item 203, may be proportioned for a nominal bearing resistance as indicated in Table 5. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored nominal bearing resistance at the strength limit state. The reinforcement length presented in the following table represents the minimum foundation width required to satisfy external and global stability requirements, expressed as a percentage of the wall height.

Table 5. Retaining Wall J1 MSE Wall Design Parameters

From Station [1]	To Station [1]	Wall Height Analyzed (feet)	Backslope Behind Wall in Analysis	Minimum Required Reinforcement Length [2] (feet)	Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing Pressure [4] (ksf)
					Nominal	Factored [3]	
475+87	478+35	20.0	2:1	20.0 (1.0H)	18.7	12.2	4.87
478+35	483+50	25.8	Level	18.1 (0.7H)	14.2	9.2	6.51
483+50	486+00	12.6	Level	8.8 (0.7H ≥ 8.0)	17.6	11.5	3.70

1. *Stationing listed is referenced to the mainline I-75 centerline.*
2. *The required foundation width is expressed as a percentage of the wall height, H.*
3. *A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.*
4. *The strength limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the strength limit state.*

Rii performed a verification of the bearing pressure exerted on the subgrade material for the maximum specified wall heights indicated in Table 5. Based on the minimum length of reinforced soil mass presented, the factored equivalent bearing pressure exerted below the wall **will not exceed** the factored bearing resistance at the strength limit state.

5.1.3 Settlement Evaluation

The compressibility parameters utilized in the settlement analyses of the proposed MSE wall are provided in Table 6.

Table 6. Compressibility Parameters Utilized in Settlement Analysis

Material Type	γ (pcf)	N_{60}	C' (1)
Loose to Very Dense Granular Soils (ODOT A-1-a, A-1-b, A-2-4, A-3, A-3a, A-4a)	120 to 135	6 to 50	40 to 155

1. *Per Figure 10.6.2.4.2-1 of 2012 AASHTO LRFD BDS.*

Results of the settlement analysis are tabulated in Table 7. Total settlements of up to 3.00 inches at the center of the reinforced soil mass and 2.35 inches at the facing of the wall are anticipated along the alignment of Retaining Wall J1. Based on the results of the analysis, 100 percent of the total settlement at the facing of the wall is anticipated to occur during construction of the wall or within fifteen (15) days following the completion of construction of the wall. Please note that the settlement and time rate of settlement are based on estimates using the correlated material properties provided in Table 6 for the underlying soils. Actual settlement and time rate of settlement should be determined by monitoring the settlement of the wall using settlement platforms.

Table 7. Retaining Wall J1 MSE Wall Settlement Values

From Station [1]	To Station [1]	Wall Height Analyzed (feet)	Backslope Behind Wall in Analysis	Service Limit Equivalent Bearing Pressure [2] (ksf)	Total Settlement Values (inches)		Time for 100% Consolidation (Days)
					Center of Wall Mass	Facing of Wall	
475+87	478+35	20.0	2:1	3.49	3.00	2.35	0
478+35	483+50	25.8	Level	4.52	2.63	2.17	0
483+50	486+00	12.6	Level	2.49	1.01	0.86	0

1. *Stationing listed is referenced to the mainline I-75 centerline.*
2. *The service limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the service limit state.*

Per Section 204.6.2.1 of the ODOT BDM, “the maximum allowable differential settlement in the longitudinal direction (regardless of the size of panels) is one (1) percent.” Based on the total anticipated settlement at the facing of the walls, maximum differential settlements in the longitudinal directions are anticipated to be less than 1/500, which is within the tolerable limit of 1/100. If the total or differential settlement values predicted for the proposed walls present an issue with respect to the deformation tolerances that the walls can withstand, then measures should be taken to minimize the amount of settlement that will occur. This can be achieved by preloading the site and consolidating the underlying soils prior to constructing the walls. If preloading the site is not a desired option, then consideration could be given to ground improvement through the use of stone columns. Settlement calculations are provided in Appendix VI.

5.1.4 Eccentricity (Overturning Stability)

The resistance of the MSE wall to overturning will be dependent on the on the location of the resultant force at the bottom of the wall due to the overturning and resisting moments acting on the wall. For MSE walls, overturning stability is determined by calculating the eccentricity of the resultant force from the midpoint of the base of the wall and comparing this value to a limiting eccentricity value. Per Section 11.10.5.5 of the 2014 AASHTO LRFD BDS, for foundations bearing on soil or bedrock, the location of the resultant of the reaction forces shall be within the middle two-thirds ($^2/_3$) of the base width. Therefore, the limiting eccentricity is one-third ($^1/_3$) of the base width of the wall. Rii performed a verification of the eccentricity of the resultant force for the specified wall heights indicated in Table 5. Based on the minimum length of reinforced soil mass presented in Table 5 and utilizing the soil parameters listed in Section 5.1.1 for the retained embankment material, the calculated eccentricity of the resultant force **will not exceed** the limiting eccentricity at the strength limit state.

5.1.5 Sliding Stability

The resistance of the MSE wall to sliding was evaluated per Section 11.10.5.3 of the 2014 AASHTO LRFD BDS. Given that the bearing soils consist of granular material, the sliding resistance was only evaluated under drained conditions. For drained conditions, the sliding resistance is determined by multiplying a coefficient of sliding friction “f” times the total vertical force at the base of the wall. The coefficient of sliding friction is determined based on the limiting friction angle between the foundation soil and the reinforced soil backfill. Based on the soil parameters listed in Section 5.1.1 for the foundation and reinforced soil backfill material, a coefficient of sliding friction of 0.53 and 0.58 was utilized for design. A geotechnical resistance factor of φ_τ=1.0 was considered in calculating the factored shear resistance. Based on the minimum length of reinforced soil mass presented in Table 5 and utilizing the soil parameters listed in Section 5.1.1 for the retained embankment material, the resultant horizontal forces on the back of the MSE wall **will not exceed** the factored shear resistance at the strength limit state.

5.1.6 Global (Overall) Stability

A slope stability analysis was performed to check the global stability of the wall along the alignment. As per AASHTO LRFD BDS, safety against soil failure shall be evaluated at the service limit state by assuming the reinforced soil mass to be a rigid body. Soil parameters utilized in the global stability analyses are presented Section 5.1.1. For the global stability condition, it was considered that the failure plane will not cross through the reinforced soil mass. The computer software program Slide 6.0 manufactured by Rocscience Inc. was utilized to perform the analyses.

Per Section 11.6.2.3 of the 2014 AASHTO LRFD BDS, overall (global) stability for MSE walls that are not integrated with or supporting structural foundations or elements is satisfied if the product of the factor of safety from the slope stability output multiplied by the resistance factor φ=0.75 is greater than 1.0. Therefore, global stability is satisfied when a minimum factor of safety of 1.3 is obtained. For an MSE walls designed with minimum strap lengths listed in Table 5, the resulting factor of safety under drained conditions (long-term stability) along the alignment was greater than 1.3. Given the granular nature of the subsurface profile below the bottom of wall elevation, an undrained analysis was not performed.

5.1.7 Final MSE Wall Considerations

Based on the results of the external and global stability analysis performed for the MSE wall, the recommended controlling strap length is 0.7 times the height of the MSE wall (measured from the top of the leveling pad to the top of the coping) between Sta. 478+35 and Sta. 486+00, and the recommended controlling strap length is 1.0 times the height of the MSE wall between Sta. 475+87 and Sta. 478+35. Global stability was the controlling factor in the determination of the recommended strap length of 100 percent of the wall height between Sta. 475+87 and Sta. 478+35.

Calculations for external (bearing and sliding resistance and limiting eccentricity) and overall (global) stability of the MSE walls are provided in Appendix VI.

5.2 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 8 and Table 9.

Table 8. 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	1,500	0°	1.0	1.0	1.0
Very Stiff to Hard Cohesive Soil	120	2,500	0°	1.0	1.0	1.0
Very Loose to Loose Granular Soil	120	0	28°	0.36	0.53	2.77
Medium Dense Granular Soil	125	0	30°	0.33	0.50	3.00
Dense to Very Dense Granular Soil	135	0	34°	0.28	0.44	3.54
Compacted Cohesive Engineered Fill	120	1,500	0°	1.0	1.0	1.0
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 9. Estimated Drained (Long-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	C (psf)	φ	k_a	k_o	k_p
Natural Cohesive Soil	115	0	26°	0.39	0..56	2.56
Very Loose to Loose Granular Soil	120	0	28°	0.36	0.53	2.77
Medium Dense Granular Soil	125	0	30°	0.33	0.50	3.00
Dense to Very Dense Granular Soil	135	0	34°	0.28	0.44	3.54
Compacted Cohesive Engineered Fill	120	0	28°	0.36	0.53	2.77
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.*

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. 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 considered). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage.

5.3 Construction Considerations

All site work shall conform to local codes and to the latest ODOT Construction and Materials Specifications (CMS), including that all excavation and embankment preparation and construction should follow ODOT Item 200 (Earthwork) and MSE Wall Construction and foundation preparation follows Supplemental Specification 840.

5.3.1 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 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 10. 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
Rock to 3.0' +/- below Auger Refusal	0.75 : 1.0	Above Ground Water Table and No Seepage
Stable Rock	Vertical	Above Ground Water Table and No Seepage

5.3.2 Groundwater Considerations

Based on the groundwater observations made during drilling, little to no groundwater seepage is anticipated during construction. However, where/if groundwater is encountered, proper groundwater control should be employed and maintained to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or "boiling" condition where soft silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36 inches below the deepest excavation. Any seepage or groundwater encountered at this site should be able to be controlled by pumping from temporary sumps. Additional measures may be required depending on seasonal fluctuations of the groundwater level. 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

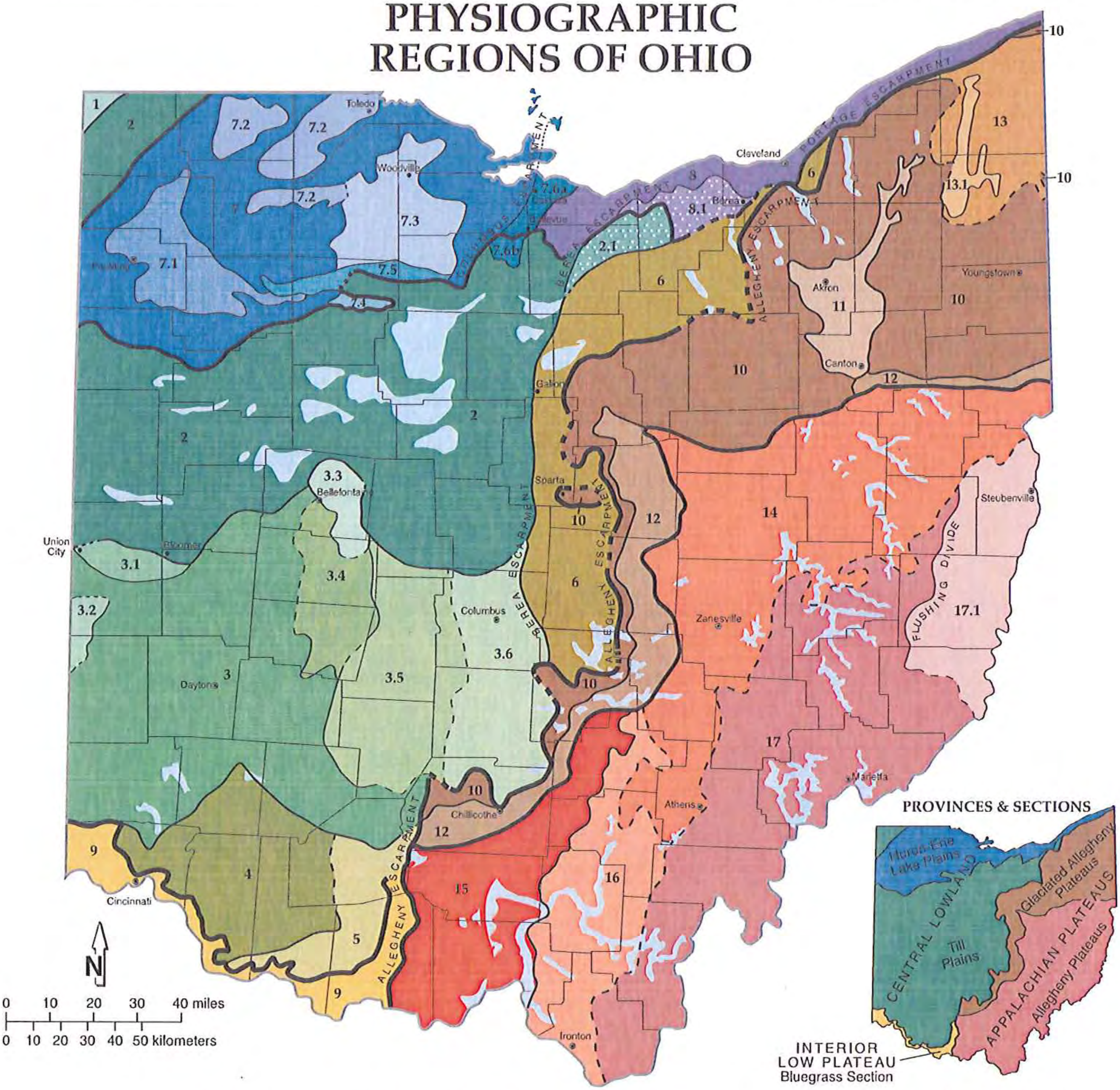
STATE GEOLOGY

STATE OF OHIO
Ted Strickland, Governor

DEPARTMENT OF NATURAL RESOURCES
Sean D. Logan, Director

DIVISION OF GEOLOGICAL SURVEY
Lawrence H. Wickstrom, Chief

PHYSIOGRAPHIC REGIONS OF OHIO



Till Plains

1. Steuben Till Plain
2. Central Ohio Clayey Till Plain
   - 2.1. Berea Headlands of the Till Plain
3. Southern Ohio Loamy Till Plain
   - 3.1. Union City-Bloomer Transitional Terrain
   - 3.2. Whitewater Interlobate Plain
   - 3.3. Bellefontaine Upland
   - 3.4. Mad River Interlobate Plain
   - 3.5. Darby Plain
   - 3.6. Columbus Lowland
4. Illinoian Till Plain
5. Dissected Illinoian Till Plain
6. Galion Glaciated Low Plateau

Transitional boundary

Lake basin/deposits outside Huron-Erie Lake Plains

Huron-Erie Lake Plains

7. Maumee Lake Plains
   - 7.1. Paulding Clay Basin
   - 7.2. Maumee Sand Plains
   - 7.3. Woodville Lake-Plain Reefs
   - 7.4. Findlay Embayment
   - 7.5. Fostoria Lake-Plain Shoals
   - 7.6a and 7.6b. Bellevue-Castalia Karst Plain
8. Erie Lake Plain
   - 8.1. Berea Headlands of the Erie Lake Plain

Bluegrass Section

9. Outer Bluegrass Region

Glaciated Allegheny Plateaus

10. Killbuck-Glaciated Pittsburgh Plateau
11. Akron-Canton Interlobate Plateau
12. Illinoian Glaciated Allegheny Plateau
13. Grand River Low Plateau
   - 13.1 Grand River Finger-Lake Plain

Allegheny Plateaus

14. Muskingum-Pittsburgh Plateau
15. Shawnee-Mississippian Plateau
16. Ironton Plateau
17. Marietta Plateau
   - 17.1. Little Switzerland Plateau

4/98

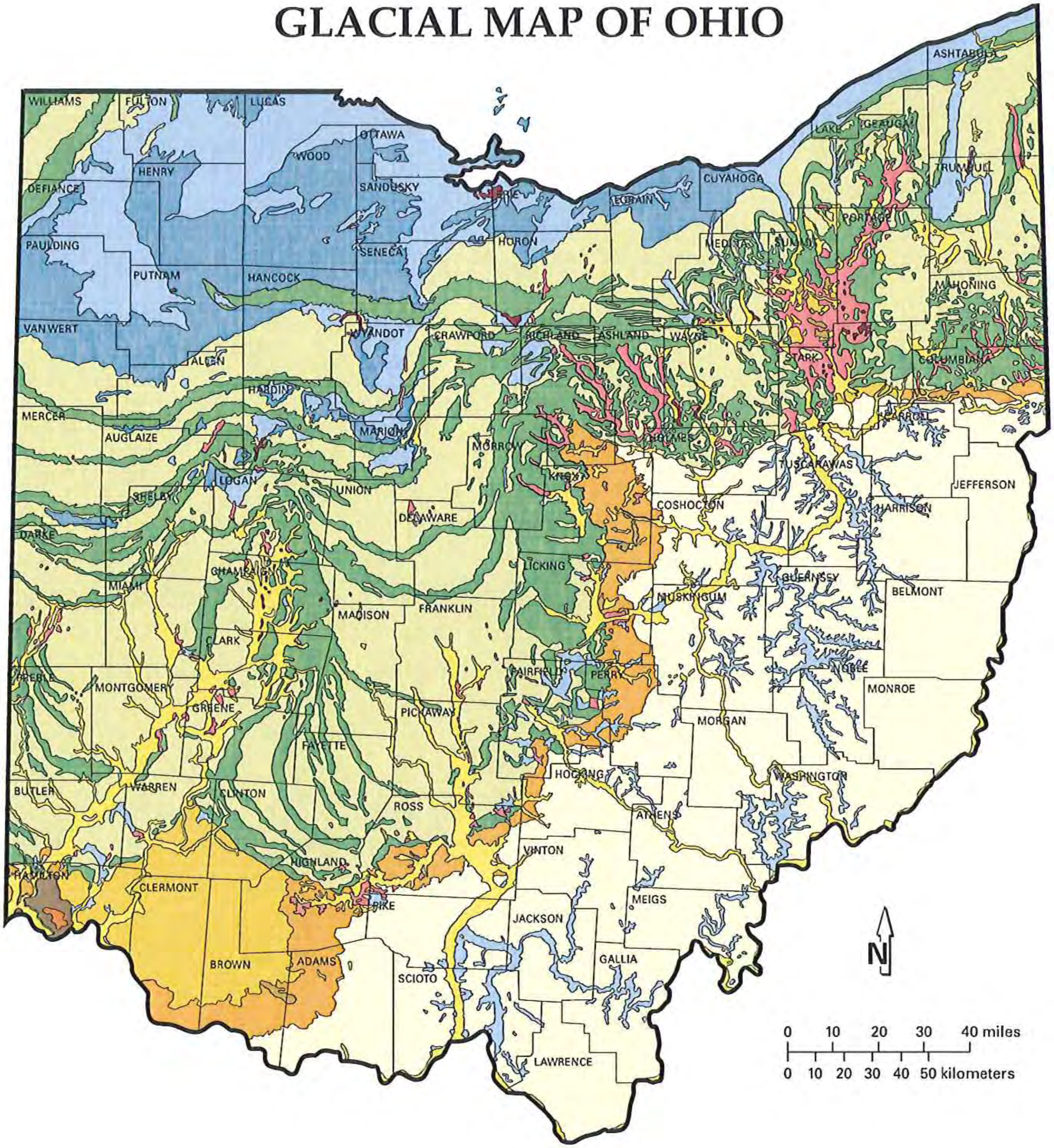
Recommended citation: Ohio Division of Geological Survey, 1998, Physiographic regions of Ohio: Ohio Department of Natural Resources, Division of Geological Survey, page-size map with text, 2 p., scale 1:2,100,00.

STATE OF OHIO
Bob Taft, Governor

DEPARTMENT OF NATURAL RESOURCES
Samuel W. Speck, Director

DIVISION OF GEOLOGICAL SURVEY
Thomas M. Berg, Chief

GLACIAL MAP OF OHIO



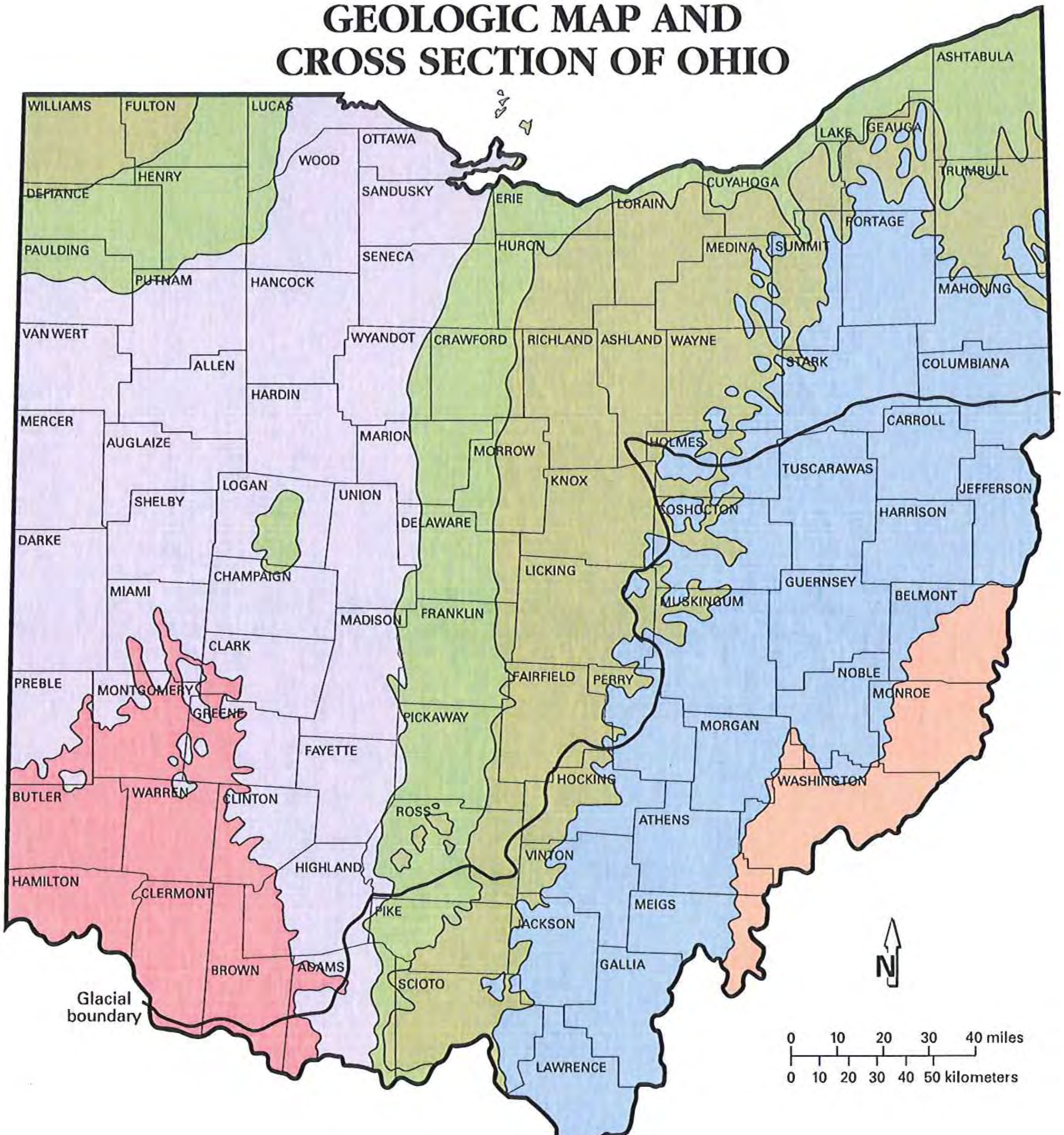
WISCONSINAN (14,000 to 24,000 years old)	ILLINOIAN (130,000 to 300,000 years old)	PRE-ILLINOIAN (older than 300,000 years)	
			Kames and eskers
Ground moraine	Ground moraine	Ground moraine	Outwash
Wave-planed ground moraine	Dissected ground moraine	Dissected ground moraine	Lake deposits
End moraine	Hummocky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

STATE OF OHIO
Bob Taft, Governor

DEPARTMENT OF NATURAL RESOURCES
Samuel W. Speck, Director

DIVISION OF GEOLOGICAL SURVEY
Thomas M. Berg, Chief

GEOLOGIC MAP AND CROSS SECTION OF OHIO



GEOLOGIC SYSTEM (million years before present)

Permian (286-245)

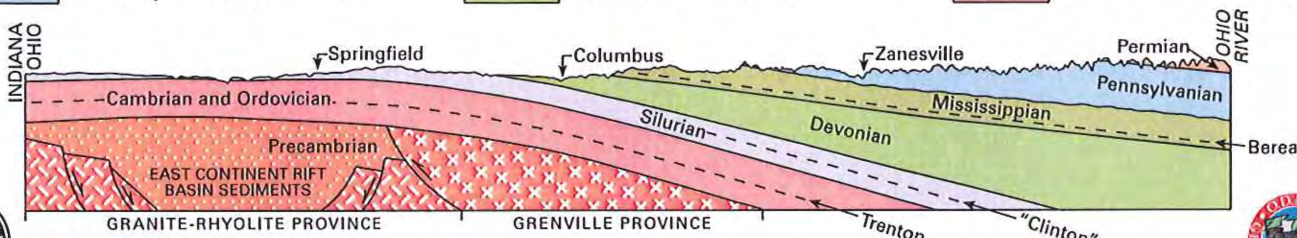
Pennsylvanian (320-286)

Mississippian (360-320)

Devonian (408-360)

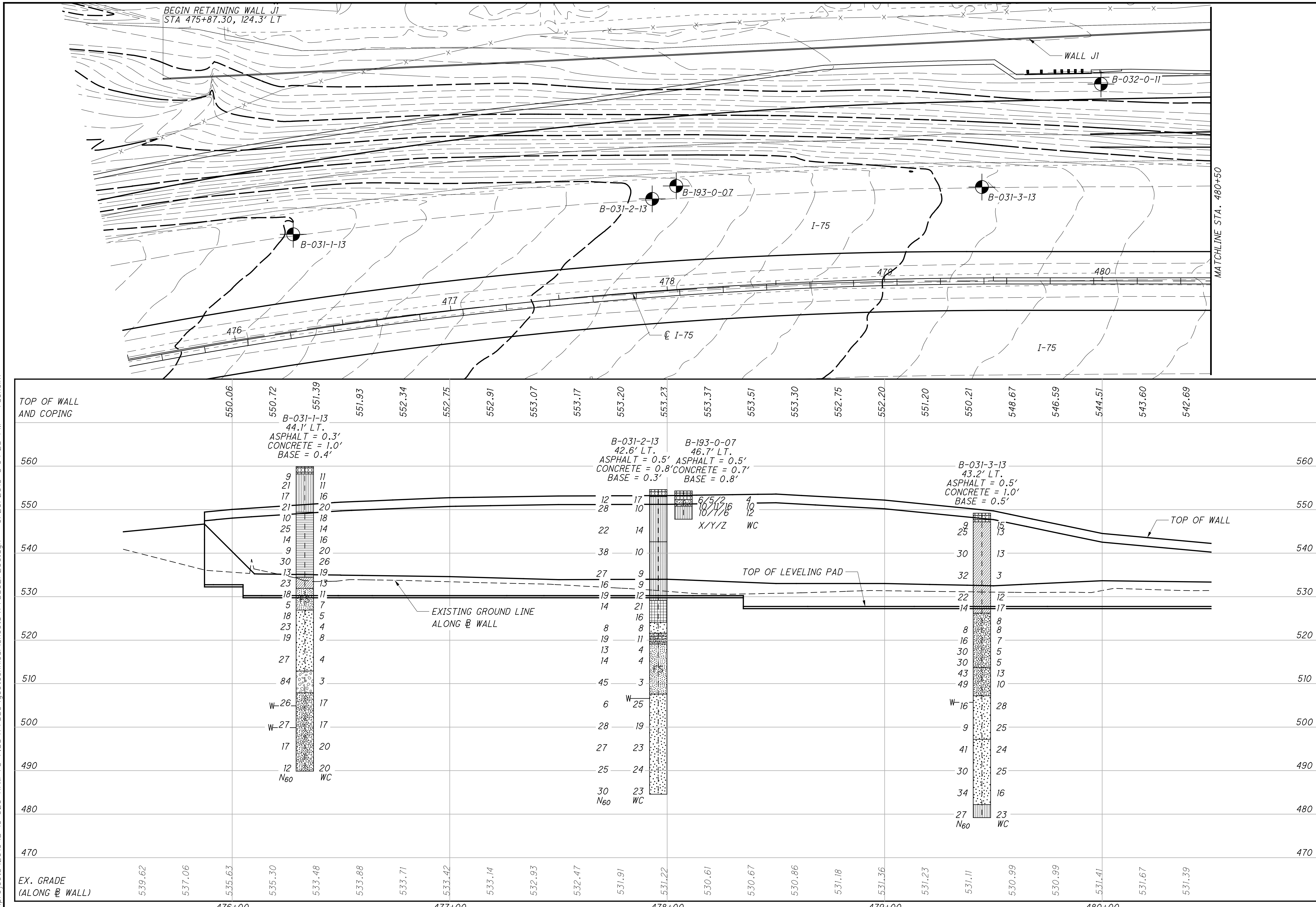
Silurian (438-408)

Ordovician (505-438)



APPENDIX II

VICINITY MAP AND BORING PLAN

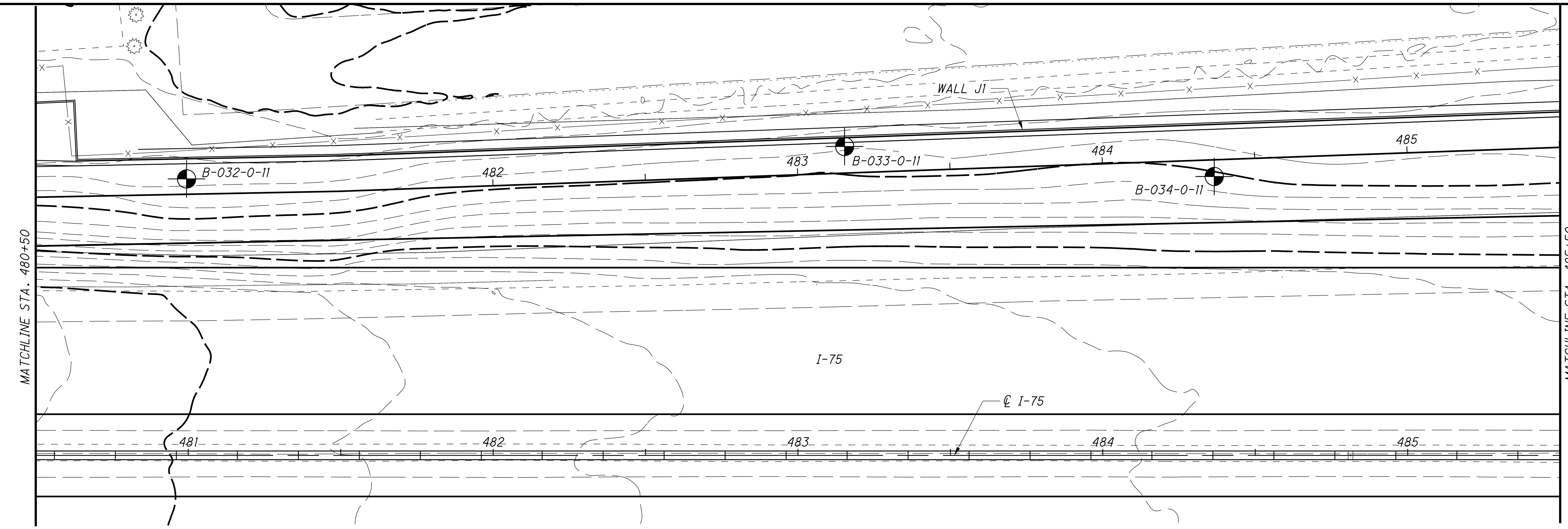


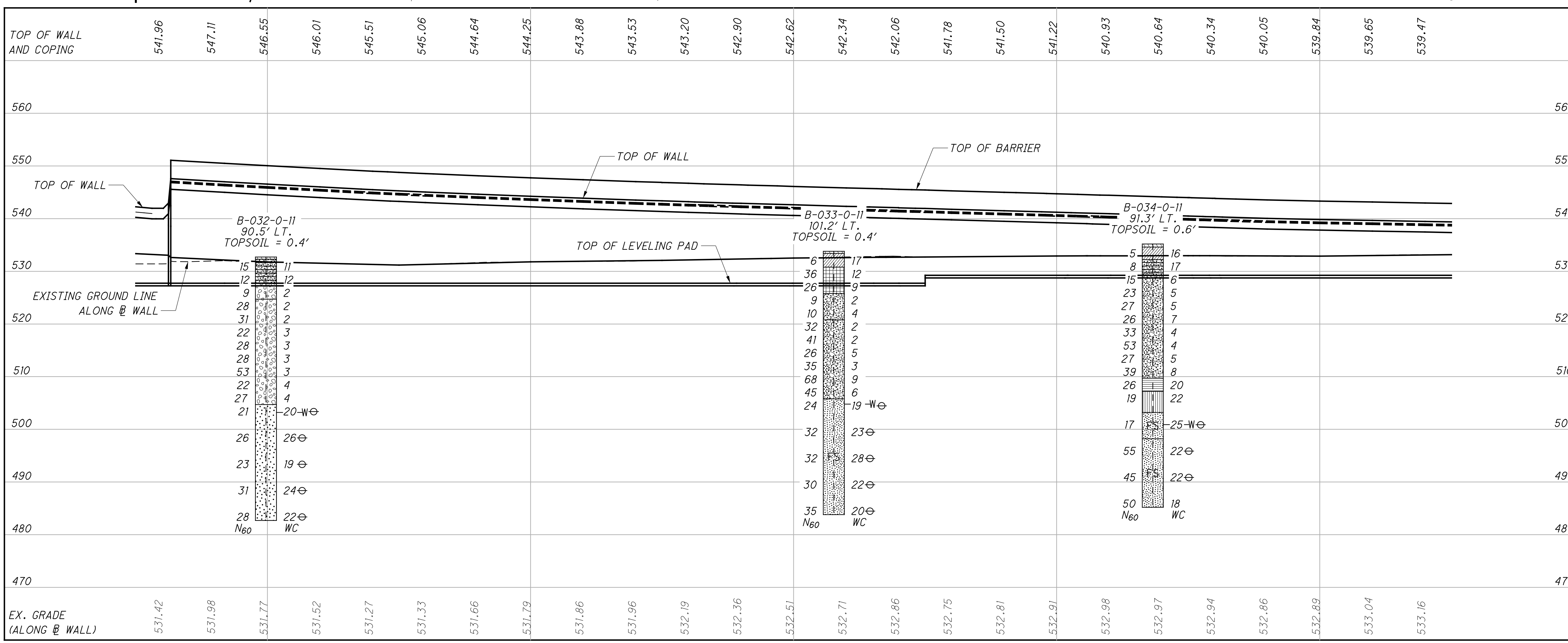
HORIZONTAL SCALE IN FEET
0 10 20 40

DRAWN RRM
CHECKED BRT

STRUCTURE FOUNDATION EXPLORATION
WALL J1
STA. 475+50 TO STA. 480+50

HAM-75-7.85





HORIZONTAL SCALE IN FEET

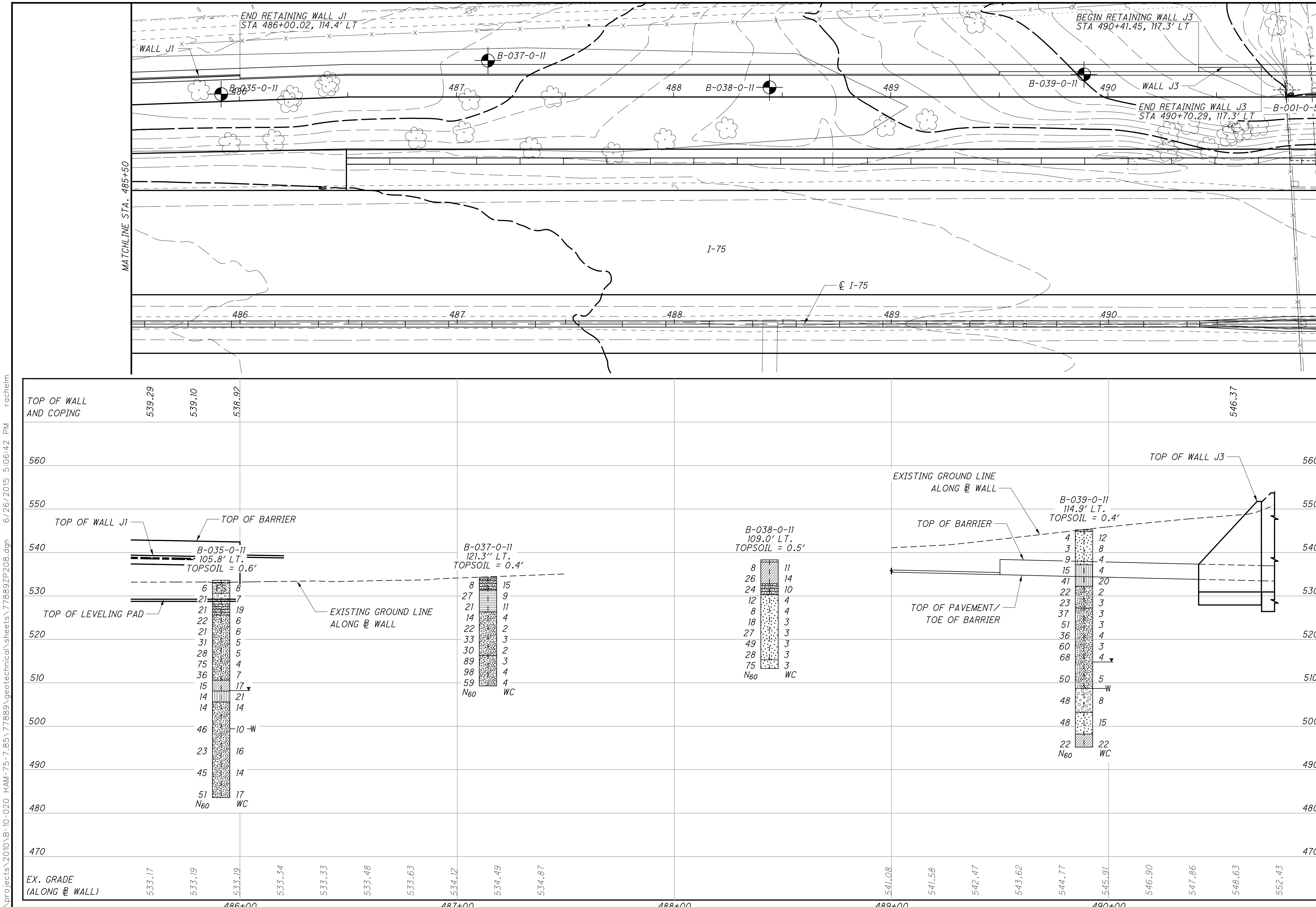
0 10 20 40

DRAWN RRM

CHECKED BRT

STRUCTURE FOUNDATION EXPLORATION
WALL J1
STA. 480+50 TO STA. 485+50

HAM-75-7.85



DRAWN RRM
CHECKED BRT

STRUCTURE FOUNDATION EXPLORATION
WALL J1 AND WALL J3
STA. 485+50 TO STA. 491+00

HAM-75-7.85

10/105

71/189

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APPENDIX III

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	Blows per foot – SPT (N_{60})			Unconfined Compression (tsf)
Very Soft	Below		2	UCS ≤ 0.25
Soft	2	-	4	0.25 < UCS ≤ 0.5
Medium Stiff	5	-	8	0.5 < UCS ≤ 1.0
Stiff	9	-	15	1.0 < UCS ≤ 2.0
Very Stiff	16	-	30	2.0 < UCS ≤ 4.0
Hard	Over		30	UCS > 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	^{3} 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 bedrock hardness:

Term	Blows per foot – SPT (N)		
Very Soft	Below		50
Soft	50/5”	–	50/6”
Medium Hard	50/3”	–	50/4”
Hard	50/1”	–	50/2”
Very Hard 50/0”			

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 x 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				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.	≤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, S-Sedimentary W-Woody F-Fibrous L-Loamy & etc

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

APPENDIX IV

BORING LOGS:

B-031-1-13 through B-035-0-11 and
B-037-0-11 through B-039-0-11

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 (%)

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 476+33.38 / 44.1' LT	EXPLORATION ID B-031-1-13
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: RII / T.F.	HAMMER: AUTOMATIC	ALIGNMENT: PR CL I-75	
PID: 77889 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 559.9 (MSL) EOB: 70.0 ft.	PAGE 1 OF 3
START: 7/7/14 END: 7/8/14	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.190083513, 84.480507003	

MATERIAL DESCRIPTION AND NOTES

Material Description and Notes	Elev. (559.9)
0.3' - ASPHALT (4.0")	559.6
1.0' - CONCRETE (12.0")	558.6
0.4' - AGGREGATE BASE (4.0")	558.2
FILL: VERY STIFF, BROWN AND BLACK **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP TO MOIST. -ROOT FIBERS AND PLASTIC FRAGMENTS PRESENT IN SS-1 -CINDERS AND BRICK FRAGMENTS PRESENT THROUGHOUT -PETROLEUM ODOR PRESENT IN SS-4	549.4
FILL: STIFF TO VERY STIFF, BROWN **SILTY CLAY**, AND COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST. -BRICK AND ROCK FRAGMENTS PRESENT IN SS-6 -ORGANICS PRESENT IN SS-8 -ATTEMPTED SHELBY TUBE @ 20.0'. TUBE CRUSHED @ 21.0'.	534.4
VERY STIFF, BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.	531.9
LOOSE TO MEDIUM DENSE, BROWN **FINE SAND**, LITTLE COARSE SAND, TRACE SILT, TRACE CLAY, DAMP TO MOIST.	

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
4 4 3	9	44	SS-1	2.50	-	-	-	-	-	-	-	-	11	A-4a (V)
7 8 8	21	56	SS-2	3.00	23	19	21	20	17	24	14	10	11	A-4a (0)
8 6 7	17	67	SS-3	-	-	-	-	-	-	-	-	-	16	A-4a (V)
10 8 8	21	61	SS-4	-	-	-	-	-	-	-	-	-	20	A-4a (V)
2 3 5	10	83	SS-5	2.00	-	-	-	-	-	-	-	-	18	A-6b (V)
10 10 9	25	94	SS-6	3.00	-	-	-	-	-	-	-	-	14	A-6b (V)
3 5 6	14	100	SS-7	2.50	2	4	32	28	34	32	14	18	16	A-6b (9)
3 3 4	9	100	SS-8	1.75	-	-	-	-	-	-	-	-	20	A-6b (V)
		0	ST-9	-	-	-	-	-	-	-	-	-	-	
15 15 8	30	44	SS-10	2.00	-	-	-	-	-	-	-	-	26	A-6b (V)
4 5 5	13	67	SS-11	1.75	0	7	47	18	28	28	12	16	19	A-6b (4)
6 9 9	23	78	SS-12	3.00	-	-	-	-	-	-	-	-	13	A-6a (V)
6 7 7	18	50	SS-13	-	-	-	-	-	-	-	-	-	11	A-3 (V)

PID: 77889	BR ID: N/A	PROJECT: HAM-75-7.85	STATION / OFFSET: 476+33.38 / 44.1 LT	START: 7/7/14	END: 7/8/14	PG 2 OF 3	B-031-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
LOOSE TO MEDIUM DENSE, BROWN **FINE SAND**, LITTLE COARSE SAND, TRACE SILT, TRACE CLAY, DAMP TO MOIST. *(same as above)*		31–32	2 2 2	5	78	SS-14	-	0	14	76	6	4	NP	NP	NP	7	A-3 (0)	
	526.9	33																
MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE FINE GRAVEL, DAMP TO MOIST.		34–35	3 5 9	18	100	SS-15	-	-	-	-	-	-	-	-	-	5	A-3a (V)	
		36–37	6 9 9	23	94	SS-16	-	-	-	-	-	-	-	-	-	4	A-3a (V)	
		39–40	6 8 7	19	100	SS-17	-	1	19	56	17	7	NP	NP	NP	8	A-3a (0)	
		44–45	9 10 11	27	100	SS-18	-	-	-	-	-	-	-	-	-	4	A-3a (V)	
	512.9	47																
VERY DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.		49–50	33 29 36	84	83	SS-19	-	60	21	13	4	2	NP	NP	NP	3	A-1-a (0)	
	507.9	52																
MEDIUM DENSE, BROWN **GRAVEL AND SAND**, TRACE CLAY, TRACE SILT, MOIST TO WET.		54–55 (W at 55)	7 8 12	26	94	SS-20	-	-	-	-	-	-	-	-	-	17	A-1-b (V)	
		59–60 (W at 60)	5 8 13	27	61	SS-21	-	-	-	-	-	-	NP	-	-	17	A-1-b (V)	

ELEV. at top: 529.9. Depth scale 31–61.

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/20/15 22:14 - U:\GI8\PROJECTS\2010\B-10-020\B-10-020-14.GPJ

PID: 77889	BR ID: N/A	PROJECT: HAM-75-7.85	STATION / OFFSET: 476+33.38 / 44.1 LT	START: 7/7/14	END: 7/8/14	PG 3 OF 3	B-031-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 497.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM DENSE, BROWN **GRAVEL AND SAND**, TRACE CLAY, TRACE SILT, MOIST TO WET. *(same as above)*		63																
-HEAVING SANDS ENCOUNTERED @ 65.0'		64–65	2 4 9	17	89	SS-22	-	6	62	26	2	4	NP	NP	NP	20	A-1-b (0)	
-INTRODUCED MUD @ 65.0'		66–68																
	489.9	69 – EOB 70	4 5 4	12	83	SS-23	-	-	-	-	-	-	-	-	-	20	A-1-b (V)	

NOTES: SEEPAGE ENCOUNTERED @ 55.0'; GROUNDWATER INITIALLY ENCOUNTERED @ 60.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 100 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 477+95.88 / 42.6' LT	EXPLORATION ID **B-031-2-13**
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: RII / T.F.	HAMMER: AUTOMATIC	ALIGNMENT: PR CL I-75	PAGE 1 OF 3
PID: 77889 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 554.6 (MSL) EOB: 70.0 ft.	
START: 7/9/14 END: 7/9/14	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.190446873, 84.480154307	

MATERIAL DESCRIPTION AND NOTES	ELEV. 554.6	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
0.5' - ASPHALT (6.0")	554.1															
0.8'- CONCRETE (9.0")	553.3															
0.3' - AGGREGATE BASE (4.0")	553.0															
FILL: STIFF TO VERY STIFF, DARK BROWN TO BROWN AND GRAY **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, DAMP TO MOIST.		6 5 4	12	50	SS-1	2.00	-	-	-	-	-	-	-	-	17	A-4a (V)
		3 7 15	28	61	SS-2	3.75	10	15	26	27	22	22	14	8	10	A-4a (3)
-CINDERS, BRICK AND ROCK FRAGMENTS PRESENT THROUGHOUT		5 7 10	22	83	SS-3	3.00	-	-	-	-	-	-	-	-	14	A-4a (V)
FILL: MEDIUM DENSE TO DENSE, BROWN **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, DAMP TO MOIST.	542.6	8 16 13	38	33	SS-4	-	-	-	-	-	-	-	-	-	10	A-4a (V)
		6 10 11	27	44	SS-5	-	-	-	-	-	-	-	-	-	9	A-4a (V)
		4 8 4	16	39	SS-6	-	2	22	37	18	21	21	13	8	9	A-4a (1)
		6 7 8	19	83	SS-7	-	-	-	-	-	-	-	-	-	12	A-4a (V)
STIFF, BROWN **CLAY**, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, LITTLE SILT, DAMP TO MOIST.	529.1	2 4 7	14	94	SS-8	2.00	-	-	-	-	-	-	-	-	21	A-7-6 (V)
-QU @ 28.8' = 0.89 tsf (1,787 psf)				100	ST-9	2.00	29	24	11	11	25	48	17	31	16	A-7-6 (4)

DEPTHS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

BACK FILL

PID: 77889	BR ID: N/A	PROJECT: HAM-75-7.85	STATION / OFFSET: 477+95.88 / 42.6 LT	START: 7/9/14	END: 7/9/14	PG 2 OF 3	B-031-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 524.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
	524.1																	
LOOSE, BROWN **COARSE AND FINE SAND**, TRACE SILT, TRACE FINE GRAVEL, DAMP.		31–32	8 3 3	8	44	SS-10	-	-	-	-	-	-	-	-	-	8	A-3a (V)	
	521.6																	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST. -LIMESTONE FRAGMENTS PRESENT IN SS-11		33.5–35	6 9 6	19	72	SS-11	-	-	-	-	-	-	-	-	-	11	A-2-6 (V)	
	519.1																	
MEDIUM DENSE TO DENSE, BROWN **FINE SAND**, SOME COARSE SAND, TRACE FINE GRAVEL, TRACE SILT, TRACE CLAY, DAMP.		36–37.5	3 4 6	13	78	SS-12	-	-	-	-	-	-	-	-	-	4	A-3 (V)	
		38.5–40	4 5 6	14	89	SS-13	-	1	22	69	5	3	NP	NP	NP	4	A-3 (0)	
		43.5–45	6 16 19	45	89	SS-14	-	-	-	-	-	-	-	-	-	3	A-3 (V)	
	507.6																	
LOOSE TO MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, TRACE FINE GRAVEL, TRACE SILT, TRACE CLAY, WET. -INTRODUCED MUD @ 48.0'		W (48)																
		48.5–50	2 2 3	6	83	SS-15	-	-	-	-	-	-	-	-	-	25	A-3a (V)	
		53.5–55	4 8 14	28	67	SS-16	-	-	-	-	-	-	-	-	-	19	A-3a (V)	
		58.5–60	7 9 12	27	33	SS-17	-	-	-	-	-	-	-	-	-	23	A-3a (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/20/15 22:14 - U:\GI8\PROJECTS\2010\B-10-020\B-10-020-14.GPJ

PID: 77889	BR ID: N/A	PROJECT: HAM-75-7.85	STATION / OFFSET: 477+95.88 / 42.6 LT	START: 7/9/14	END: 7/9/14	PG 3 OF 3	B-031-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 492.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
LOOSE TO MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, TRACE FINE GRAVEL, TRACE SILT, TRACE CLAY, WET. *(same as above)*		63																
		64–65	8 9 10	25	56	SS-18	-	1	46	42	5	6	NP	NP	NP	24	A-3a (0)	
		66																
		67																
		68																
	484.6	69–70 EOB	8 12 11	30	78	SS-19	-	-	-	-	-	-	-	-	-	23	A-3a (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/20/15 22:14 - U:\GI8\PROJECTS\2010\B-10-020\B-10-020-14.GPJ

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 48.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 100 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 479+44.71 / 43.2' LT
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: RII / E.S.	HAMMER: AUTOMATIC	ALIGNMENT: PR CL I-75
PID: 77889 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 549.2 (MSL) EOB: 70.0 ft.
START: 7/14/14 END: 7/14/14	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.190762982, 84.479805706

EXPLORATION ID **B-031-3-13**

MATERIAL DESCRIPTION AND NOTES	ELEV. 549.2
0.5' - ASPHALT (6.0")	548.7
1.0' - CONCRETE (12.0")	547.7
0.5' - AGGREGATE BASE (6.0")	547.2
FILL: STIFF TO HARD, BROWN TO GRAY **SILT AND CLAY**, SOME TO AND COARSE TO FINE SAND, TRACE TO LITTLE FINE GRAVEL, DAMP TO MOIST. -CINDERS AND BRICK FRAGMENTS PRESENT THROUGHOUT -ROCK FRAGMENTS PRESENT IN SS-4	526.2
LOOSE TO MEDIUM DENSE, BROWN **GRAVEL AND SAND**, TRACE TO LITTLE SILT, TRACE CLAY, DAMP.	

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
6 3 4	9	56	SS-1	1.50	-	-	-	-	-	-	-	-	15	A-6a (V)
2 8 11	25	78	SS-2	3.50	13	10	21	29	27	28	16	12	13	A-6a (5)
7 11 12	30	100	SS-3	3.00	-	-	-	-	-	-	-	-	13	A-6a (V)
45 15 10	32	56	SS-4	4.50	-	-	-	-	-	-	-	-	3	A-6a (V)
7 7 10	22	106	SS-5	2.75	6	17	35	18	24	25	14	11	12	A-6a (2)
4 5 6	14	100	SS-6	3.75	-	-	-	-	-	-	-	-	17	A-6a (V)
		88	ST-7	-	56	21	7	11	5	21	18	3	8	A-1-b (0)
2 3 3	8	78	SS-8	-	-	-	-	-	-	-	-	-	8	A-1-b (V)
7 7 5	16	89	SS-9	-	-	-	-	-	-	-	-	-	7	A-1-b (V)

PID: 77889	BR ID: N/A	PROJECT: HAM-75-7.85	STATION / OFFSET: 479+44.71 / 43.2 LT	START: 7/14/14	END: 7/14/14	PG 2 OF 3	B-031-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 519.2	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
LOOSE TO MEDIUM DENSE, BROWN **GRAVEL AND SAND**, TRACE TO LITTLE SILT, TRACE CLAY, DAMP. *(same as above)*		31 - 32.5	3-9-14	30	89	SS-10	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	
	513.7	33.5 - 35	6-10-13	30	78	SS-11	-	25	40	21	9	5	NP	NP	NP	5	A-1-b (0)	
DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST.		36 - 37.5	10-15-18	43	89	SS-12	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
-ROCK FRAGMENTS PRESENT IN SS-13	507.2	38.5 - 40	11-19-19	49	89	SS-13	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
LOOSE TO MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, TRACE FINE GRAVEL, TRACE SILT, TRACE CLAY, WET.		W (43.5); 43.5 - 45	4-5-7	16	56	SS-14	-	-	-	-	-	-	-	-	-	28	A-3a (V)	
	497.2	48.5 - 50	3-3-4	9	44	SS-15	-	6	11	66	9	8	NP	NP	NP	25	A-3a (0)	
MEDIUM DENSE TO DENSE, BROWN **COARSE AND FINE SAND**, TRACE FINE GRAVEL, TRACE SILT, TRACE CLAY, MOIST TO WET.		53.5 - 55	11-15-17	41	89	SS-16	-	-	-	-	-	-	-	-	-	24	A-3a (V)	
		58.5 - 60	10-11-12	30	83	SS-17	-	10	24	51	7	8	NP	NP	NP	25	A-3a (0)	

PID: 77889	BR ID: N/A	PROJECT: HAM-75-7.85	STATION / OFFSET: 479+44.71 / 43.2 LT	START: 7/14/14	END: 7/14/14	PG 3 OF 3	B-031-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 487.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM DENSE TO DENSE, BROWN **COARSE AND FINE SAND**, TRACE FINE GRAVEL, TRACE SILT, TRACE CLAY, MOIST TO WET. *(same as above)*	482.2	63–64	10 11 15	34	72	SS-18	-	-	-	-	-	-	-	-	-	16	A-3a (V)	
MEDIUM DENSE, BROWN **SANDY SILT**, TRACE FINE GRAVEL, TRACE CLAY, WET.	479.2	67–70 EOB	7 7 14	27	83	SS-19	-	-	-	-	-	-	-	-	-	23	A-4a (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/20/15 22:14 - U:\GI8\PROJECTS\2010\B-10-020\B-10-020-14.GPJ

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 43.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 100 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 480+99.46 / 90.5' Lt		EXPLORATION ID B-032-0-11
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: RII / S.M.	HAMMER: CME AUTOMATIC	ALIGNMENT: PROPOSED CL I-75		
PID: 77889 BR ID: NA	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 5/6/11	ELEVATION: 532.7 (MSL)	EOB: 50.0 ft.	PAGE 1 OF 2
START: 9/29/11 END: 9/29/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG: 39.191055614 ° N / 84.479969446 ° W		

MATERIAL DESCRIPTION AND NOTES	ELEV. 532.7
0.4' - TOPSOIL (5.0")	532.3
MEDIUM DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP. -TRACE ORGANICS PRESENT IN SS-2	527.7
LOOSE, BROWN **GRAVEL**, AND COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DRY.	524.7
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL**, AND COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DRY. -COBBLES PRESENT THROUGHOUT	504.7

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
3 7 5	15	78	SS-1	2.25	-	-	-	-	-	-	-	-	11	A-2-6 (V)
3 4 5	12	67	SS-2	2.00	8	28	33	14	17	33	17	16	12	A-2-6 (1)
4 4 3	9	44	SS-3	-	-	-	-	-	-	-	-	-	2	A-1-a (V)
5 9 13	28	61	SS-4	-	-	-	-	-	-	-	-	-	2	A-1-a (V)
11 11 13	31	78	SS-5	-	-	-	-	-	-	-	-	-	2	A-1-a (V)
5 8 9	22	83	SS-6	-	-	-	-	-	-	-	-	-	3	A-1-a (V)
8 12 10	28	78	SS-7	-	-	-	-	-	-	-	-	-	3	A-1-a (V)
6 10 12	28	78	SS-8	-	54	30	10	5	1	NP	NP	NP	3	A-1-a (0)
16 21 20	53	89	SS-9	-	-	-	-	-	-	-	-	-	3	A-1-a (V)
8 9 8	22	83	SS-10	-	-	-	-	-	-	-	-	-	4	A-1-a (V)
9 9 12	27	89	SS-11	-	-	-	-	-	-	-	-	-	4	A-1-a (V)

DEPTHS: 1 – 27

PID: 77889	BR ID: NA	PROJECT: HAM-75-7.85	STATION / OFFSET: 480+99.46 / 90.5' Lt	START: 9/29/11	END: 9/29/11	PG 2 OF 2	B-032-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV. 504.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM DENSE TO DENSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE FINE GRAVEL, WET.		W (29.5)	6 8 8	21	89	SS-12	-	-	-	-	-	-	-	-	-	20	A-3a (V)	
-INTRODUCED MUD @ 30.0'		30 – 33																
		34	2 8 12	26	100	SS-13	-	-	-	-	-	-	-	-	-	26	A-3a (V)	
		35 – 38																
		39	4 6 12	23	89	SS-14	-	1	4	80	12	3	NP	NP	NP	19	A-3a (0)	
-COBBLES PRESENT THROUGHOUT		40 – 43																
		44	4 11 13	31	100	SS-15	-	-	-	-	-	-	-	-	-	24	A-3a (V)	
		45 – 48																
	482.7	49 – EOB 50	6 8 14	28	100	SS-16	-	-	-	-	-	-	-	-	-	22	A-3a (V)	

NOTES: GROUNDWATER INITIALY ENCOUNTERED @ 29.5'

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

RESOURCE INTERNATIONAL, INC.

PROJECT: HAM-75-7.85 TYPE: RETAINING WALL PID: 77889 BR ID: NA START: 9/28/11 END: 9/28/11	DRILLING FIRM / OPERATOR: RII / T.F. SAMPLING FIRM / LOGGER: RII / S.M. DRILLING METHOD: 4.25" HSA SAMPLING METHOD: SPT	DRILL RIG: CME-750X (SN 310218) HAMMER: CME AUTOMATIC CALIBRATION DATE: 5/6/11 ENERGY RATIO (%): 77.1	STATION / OFFSET: 483+15.31 / 101.2' Lt ALIGNMENT: PROPOSED CL I-75 ELEVATION: 533.8 (MSL) EOB: 50.0 ft. LAT / LONG : 39.191518417 ° N / 84.479485137 ° W	EXPLORATION ID **B-033-0-11** PAGE 1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 533.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.4' - TOPSOIL (5.0")	533.4																	
MEDIUM STIFF, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DRY TO DAMP.	530.8	1–2	1 2 3	6	50	SS-1	1.00	-	-	-	-	-	-	-	-	17	A-6a (V)	
HARD, BROWN **CLAY**, AND COARSE TO FINE SAND, SOME SILT, TRACE FINE GRAVEL, DAMP.		4–5	7 13 15	36	78	SS-2	4.50	1	28	30	13	28	41	16	25	12	A-7-6 (5)	
-COBBLES PRESENT THROUGHOUT	525.8	6–7	17 13 7	26	67	SS-3	4.50	-	-	-	-	-	-	-	-	9	A-7-6 (V)	
LOOSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY.		9	3 3 4	9	22	SS-4	-	-	-	-	-	-	-	-	-	2	A-1-b (V)	
	520.8	11–12	4 3 5	10	56	SS-5	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY TO MOIST.		14–15	7 12 13	32	78	SS-6	-	-	-	-	-	-	-	-	-	2	A-1-b (V)	
		16–17	16 16 16	41	78	SS-7	-	-	-	-	-	-	-	-	-	2	A-1-b (V)	
		19–20	5 9 11	26	67	SS-8	-	28	43	21	7	1	NP	NP	NP	5	A-1-b (0)	
-COBBLES PRESENT THROUGHOUT		21–22	7 12 15	35	89	SS-9	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	
		24–25	12 28 25	68	50	SS-10	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
	505.8	26–27	16 16 19	45	78	SS-11	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	

PID: 77889	BR ID: NA	PROJECT: HAM-75-7.85	STATION / OFFSET: 483+15.31 / 101.2' Lt	START: 9/28/11	END: 9/28/11	PG 2 OF 2	B-033-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV. 505.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM DENSE TO DENSE, BROWN **FINE SAND**, TRACE SILT, TRACE COARSE SAND, TRACE FINE GRAVEL, TRACE CLAY, WET.		W 29	11 9 10	24	61	SS-12	-	-	-	-	-	-	-	-	-	19	A-3 (V)	
-INTRODUCED MUD @ 30.0'		30 – 33																
		34	9 11 14	32	100	SS-13	-	1	2	87	9	1	NP	NP	NP	23	A-3 (0)	
		35 – 38																
FS		39	8 11 14	32	100	SS-14	-	-	-	-	-	-	-	-	-	28	A-3 (V)	
-COBBLES PRESENT THROUGHOUT		40 – 43																
		44	11 12 11	30	100	SS-15	-	-	-	-	-	-	-	-	-	22	A-3 (V)	
		45 – 48																
	483.8	49 – EOB 50	10 12 15	35	100	SS-16	-	-	-	-	-	-	-	-	-	20	A-3 (V)	

NOTES: GROUNDWATER INITIALY ENCOUNTERED @ 29.0'

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

RESOURCE INTERNATIONAL, INC.

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 484+36.55 / 91.3' Lt
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: RII / S.M.	HAMMER: CME AUTOMATIC	ALIGNMENT: PROPOSED CL I-75
PID: 77889 BR ID: NA	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 5/6/11	ELEVATION: 535.2 (MSL) EOB: 50.0 ft.
START: 9/28/11 END: 9/28/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG : 39.191744711 ° N / 84.479169544 ° W

EXPLORATION ID B-034-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV. 535.2
0.6' - TOPSOIL (7.0")	534.6
MEDIUM STIFF, DARK BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, MOIST. -TRACE ORGANICS PRESENT IN SS-1	532.2
LOOSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP.	529.7
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY TO DAMP.	509.7
VERY STIFF, BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, MOIST.	507.2

DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
1 - 2.5	1, 2, 2	5	33	SS-1	1.00	-	-	-	-	-	-	-	-	16	A-6a (V)
3.5 - 5	1, 2, 4	8	33	SS-2	3.00	7	35	24	9	25	50	20	30	17	A-2-7 (4)
6 - 7.5	3, 5, 7	15	67	SS-3	-	-	-	-	-	-	-	-	-	6	A-1-b (V)
8.5 - 10	6, 9, 9	23	67	SS-4	-	-	-	-	-	-	-	-	-	5	A-1-b (V)
11 - 12.5	12, 9, 12	27	78	SS-5	-	-	-	-	-	-	-	-	-	5	A-1-b (V)
13.5 - 15	14, 8, 12	26	78	SS-6	-	-	-	-	-	-	-	-	-	7	A-1-b (V)
16 - 17.5	14, 12, 14	33	83	SS-7	-	20	46	23	10	1	NP	NP	NP	4	A-1-b (0)
18.5 - 20	12, 20, 21	53	67	SS-8	-	-	-	-	-	-	-	-	-	4	A-1-b (V)
21 - 22.5	20, 13, 8	27	78	SS-9	-	-	-	-	-	-	-	-	-	5	A-1-b (V)
23.5 - 25	9, 16, 14	39	72	SS-10	-	-	-	-	-	-	-	-	-	8	A-1-b (V)
26 - 27.5	9, 9, 11	26	44	SS-11	3.50	0	2	14	42	42	32	16	16	20	A-6b (10)

PID: 77889	BR ID: NA	PROJECT: HAM-75-7.85	STATION / OFFSET: 484+36.55 / 91.3' Lt	START: 9/28/11	END: 9/28/11	PG 2 OF 2	B-034-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV. 507.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM DENSE, GRAY **SANDY SILT**, LITTLE CLAY, TRACE FINE GRAVEL, MOIST.		29 – 30	3 3 12	19	50	SS-12	-	-	-	-	-	-	-	-	-	22	A-4a (V)	
	503.2	31 – 32																
MEDIUM DENSE, BROWN **FINE SAND**, LITTLE COARSE SAND, TRACE SILT, TRACE CLAY, WET.		33																
(W)		34 – 35	4 7 6	17	67	SS-13	-	-	-	-	-	-	-	-	-	25	A-3 (V)	
-INTRODUCED MUD @ 35.0'	498.2	36 – 37																
DENSE TO VERY DENSE, BROWN **FINE SAND**, LITTLE COARSE SAND, TRACE SILT, TRACE CLAY, WET.		38																
		39 – 40	9 19 24	55	89	SS-14	-	-	-	-	-	-	-	-	-	22	A-3 (V)	
		41 – 43																
		44 – 45	12 16 19	45	67	SS-15	-	-	-	-	-	-	-	-	-	22	A-3 (V)	
		46 – 48																
	485.2	49 – 50 (EOB)	9 21 18	50	56	SS-16	-	-	-	-	-	-	-	-	-	18	A-3 (V)	

NOTES: GROUNDWATER INITIALY ENCOUNTERED @ 34.3'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 188 LBS CEMENT / 25 LBS BENTONITE POWDER / 40 GAL WATER

2010 ODOT BORING LOG-RII-WITH LAT/LONG - OH DOT.GDT - 6/13/12 13:32 - G:\GINT8\PROJECTS\2010\B-10-020\B-10-020 B-32 TO B-39.GPJ

RESOURCE INTERNATIONAL, INC.

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 485+91.35 / 105.8' Lt	EXPLORATION ID **B-035-0-11**
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: RII / S.M.	HAMMER: CME AUTOMATIC	ALIGNMENT: PROPOSED CL I-75	
PID: 77889 BR ID: NA	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 5/6/11	ELEVATION: 533.6 (MSL) EOB: 50.0 ft.	PAGE 1 OF 2
START: 9/28/11 END: 9/28/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG : 39.192084006 ° N / 84.478836739 ° W	

MATERIAL DESCRIPTION AND NOTES	ELEV. 533.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.6' - TOPSOIL (7.0")	533.0																	
FILL: LOOSE, BROWN **GRAVEL**, AND COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DRY. -TRACE ASPHALT FRAGMENTS PRESENT IN SS-1	530.6	1–3	2 2 3	6	33	SS-1	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
MEDIUM DENSE, BROWN **GRAVEL**, AND FINE TO COARSE SAND, TRACE SILT, TRACE CLAY, DRY. -COBBLE PRESENT IN SS-2	528.1	4–5	6 12 4	21	44	SS-2	-	51	26	12	8	3	NP	NP	NP	7	A-1-a (0)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST. -COBBLE PRESENT IN SS-3	525.6	6–8	7 9 7	21	33	SS-3	2.75	-	-	-	-	-	-	-	-	19	A-2-6 (2)	
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY.		9–10	10 8 9	22	39	SS-4	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
		11–12	10 8 8	21	67	SS-5	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
		13–15	4 10 14	31	50	SS-6	-	39	33	15	10	3	NP	NP	NP	5	A-1-b (0)	
		16–17	10 10 12	28	78	SS-7	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	
		18–20	18 27 31	75	22	SS-8	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	
	510.6	21–23	15 15 13	36	83	SS-9	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
VERY STIFF, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.	508.1	24–25 ▼	6 6 6	15	33	SS-10	2.25	2	2	12	46	38	26	14	12	17	A-6a (9)	
MEDIUM DENSE, GRAY **SANDY SILT**, LITTLE CLAY, MOIST.	505.6	26–27	8 6 5	14	39	SS-11	-	-	-	-	-	-	-	-	-	21	A-4a (V)	

MATERIAL DESCRIPTION AND NOTES	ELEV. 505.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MMEDIUM DENSE TO VERY DENSE, BROWN CHANGING TO GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST TO WET.		29 – 30	5 6 5	14	44	SS-12	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
		34 – 35 (W)	15 17 19	46	67	SS-13	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
-COBBLES PRESENT THROUGHOUT		39 – 40	12 10 8	23	33	SS-14	-	-	-	-	-	-	-	-	-	16	A-1-b (V)	
		44 – 45	11 17 18	45	44	SS-15	-	36	36	17	7	4	NP	NP	NP	14	A-1-b (0)	
	483.6	49 – 50 (EOB)	15 21 19	51	44	SS-16	-	-	-	-	-	-	-	-	-	17	A-1-b (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALY @ 34.2' AND AT COMPLETION @ 25.4'; CAVE-IN DEPTH @ 16.7'

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

RESOURCE INTERNATIONAL, INC.

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 487+14.20 / 121.3' Lt	EXPLORATION ID B-037-0-11
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: RII / S.M.	HAMMER: CME AUTOMATIC	ALIGNMENT: PROPOSED CL I-75	
PID: 77889 BR ID: NA	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 5/6/11	ELEVATION: 534.3 (MSL) EOB: 25.0 ft.	PAGE
START: 9/27/11 END: 9/27/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG : 39.192360602 ° N / 84.478582797 ° W	1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 534.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.4' - TOPSOIL (5.0")	533.9																	
LOOSE, DARK BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP.	531.3	1–2	3 3 3	8	67	SS-1	2.25	-	-	-	-	-	-	-	-	15	A-2-6 (V)	
HARD, BROWN **SILTY CLAY**, AND COARSE TO FINE SAND, LITTLE FINE GRAVEL, DRY TO DAMP.		4–5	4 9 12	27	56	SS-2	4.50	-	-	-	-	-	-	-	-	9	A-6b (V)	
-COBBLES PRESENT THROUGHOUT	526.3	6–7	8 9 7	21	39	SS-3	4.50	12	25	26	13	24	37	17	20	11	A-6b (3)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DRY.		9–10	2 5 6	14	22	SS-4	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	
		11–12	8 8 9	22	39	SS-5	-	-	-	-	-	-	-	-	-	2	A-1-b (V)	
-COBBLES PRESENT THROUGHOUT		14–15	5 11 15	33	56	SS-6	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	
	516.3	16–17	17 16 7	30	78	SS-7	-	25	41	20	13	1	NP	NP	NP	2	A-1-b (0)	
VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DRY.		19–20	9 33 36	89	67	SS-8	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	
-COBBLES PRESENT THROUGHOUT		21–22	25 33 43	98	83	SS-9	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	
	509.3	24–25 EOB	11 21 25	59	67	SS-10	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING; CAVE-IN DEPTH @ 11.8'

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

RESOURCE INTERNATIONAL, INC.

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 488+43.87 / 109.0' Lt
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: RII / S.M.	HAMMER: CME AUTOMATIC	ALIGNMENT: PROPOSED CL I-75
PID: 77889 BR ID: NA	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 5/6/11	ELEVATION: 538.3 (MSL) EOB: 25.0 ft.
START: 9/27/11 END: 9/27/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG : 39.19259927 ° N / 84.478240581 ° W

EXPLORATION ID **B-038-0-11**

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 538.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.5' - TOPSOIL (6.0")	537.8																	
STIFF TO VERY STIFF, DARK BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP. -TRACE ORGANICS PRESENT IN SS-1 -COBBLES PRESENT THROUGHOUT		1–3	2 3 3	8	50	SS-1	2.00	-	-	-	-	-	-	-	-	11	A-6a (V)	
	532.8	3–5	6 14 6	26	44	SS-2	3.00	12	17	18	34	19	28	15	13	14	A-6a (5)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP.	530.3	6–8	8 10 9	24	78	SS-3	4.5+	-	-	-	-	-	-	-	-	10	A-2-6 (V)	
LOOSE TO DENSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, TRACE FINE GRAVEL, TRACE CLAY, DRY.		8.5–10	5 5 4	12	50	SS-4	-	-	-	-	-	-	-	-	-	4	A-3a (V)	
		11–12.5	3 3 3	8	78	SS-5	-	4	30	49	15	2	NP	NP	NP	4	A-3a (0)	
		13.5–15	4 6 8	18	67	SS-6	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
		16–17.5	10 11 10	27	78	SS-7	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
		18.5–20	6 18 20	49	33	SS-8	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
	515.3	21–22.5	16 12 10	28	56	SS-9	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
VERY DENSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, TRACE FINE GRAVEL, TRACE CLAY, DRY.	513.3	23.5–25 EOB	7 23 35	75	72	SS-10	-	-	-	-	-	-	-	-	-	3	A-3a (V)	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING; CAVE-IN DEPTH @ 11.6'

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

RESOURCE INTERNATIONAL, INC.

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 489+88.69 / 114.9' Lt	EXPLORATION ID **B-039-0-11**
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: RII / S.M.	HAMMER: CME AUTOMATIC	ALIGNMENT: PROPOSED CL I-75	PAGE
PID: 77889 BR ID: NA	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 5/6/11	ELEVATION: 545.2 (MSL) EOB: 50.0 ft.	1 OF 2
START: 9/27/11 END: 9/27/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG : 39.192902551 ° N / 84.477909539 ° W	

MATERIAL DESCRIPTION AND NOTES	ELEV. 545.2	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
0.4' - TOPSOIL (5.0")	544.8																	
VERY LOOSE TO LOOSE, DARK BROWN TO BROWN **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE FINE GRAVEL, DRY TO DAMP.		1 – 2	2 1 2	4	44	SS-1	-	7	17	52	16	8	NP	NP	NP	12	A-3a (0)	
-COBBLES PRESENT THROUGHOUT		3 – 5	2 1 1	3	44	SS-2	-	-	-	-	-	-	-	-	-	8	A-3a (V)	
	537.2	6 – 7	3 4 3	9	50	SS-3	-	-	-	-	-	-	-	-	-	4	A-3a (V)	
MEDIUM DENSE TO DENSE, BROWN **SANDY SILT**, TRACE FINE GRAVEL, TRACE CLAY, DRY TO MOIST.		8 – 10	3 4 8	15	67	SS-4	-	10	12	34	41	3	NP	NP	NP	4	A-4a (2)	
	532.2	11 – 12	11 16 16	41	78	SS-5	-	-	-	-	-	-	-	-	-	20	A-4a (V)	
MEDIUM DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY.		13 – 15	5 8 9	22	67	SS-6	-	-	-	-	-	-	-	-	-	2	A-1-b (V)	
	527.2	16 – 17	7 7 11	23	67	SS-7	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	
DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY.		18 – 20	7 13 16	37	67	SS-8	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	
		21 – 22	20 19 21	51	78	SS-9	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	
-COBBLES PRESENT THROUGHOUT		23 – 25	6 10 18	36	78	SS-10	-	26	54	13	6	1	NP	NP	NP	4	A-1-b (0)	
		26 – 27	20 22 25	60	78	SS-11	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	

PID: 77889	BR ID: NA	PROJECT: HAM-75-7.85	STATION / OFFSET: 489+88.69 / 114.9' Lt	START: 9/27/11	END: 9/27/11	PG 2 OF 2	B-039-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV. 517.2	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 TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY. *(same as above)* -COBBLES PRESENT THROUGHOUT	508.7	29–30	11 21 32	68	83	SS-12	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	
		34–35	19 21 18	50	78	SS-13	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	
DENSE, BROWN **GRAVEL**, AND FINE TO COARSE SAND, TRACE SILT, TRACE CLAY, DRY. -COBBLES PRESENT THROUGHOUT	503.2	39–40	12 19 18	48	89	SS-14	-	57	30	7	5	1	NP	NP	NP	8	A-1-a (0)	
DENSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, MOIST.	498.2	44–45	9 17 20	48	50	SS-15	-	-	-	-	-	-	-	-	-	15	A-3a (V)	
VERY STIFF, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, MOIST.	495.2	49–50 EOB	7 9 8	22	44	SS-16	3.50	-	-	-	-	-	-	-	-	22	A-6a (V)	

Water level symbols: ▼ at 30.4 (completion); W at 36.5 (initial).

NOTES: GROUNDWATER ENCOUNTERED INITIALY @ 36.5' AND AT COMPLETION @ 30.4' ; CAVE-IN DEPTH @ 17.7'

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

APPENDIX V

LABORATORY TESTING RESULTS

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

UNCONFINED COMPRESSION

ASTM D -2166

PROJECT	HAM-75-7.85
JOB No.	B-10-020
BORING / SAMPLE No.	B-031-2-11 / ST-9
SAMPLE DEPTH	28.8 ft
DATE OF TESTING	7/16/2014
TESTED BY	KR

Soil Description: Brown CLAY, some coarse to fine sand, some fine gravel, little silt.
Soil Classification: ODOT A-7-6

PHYSICAL CHARACTERISTICS	Gravel %	C. Sand %	F. Sand %	Silt %	Clay %	LL	PL	PI
	29	24	11	11	25	48	17	31

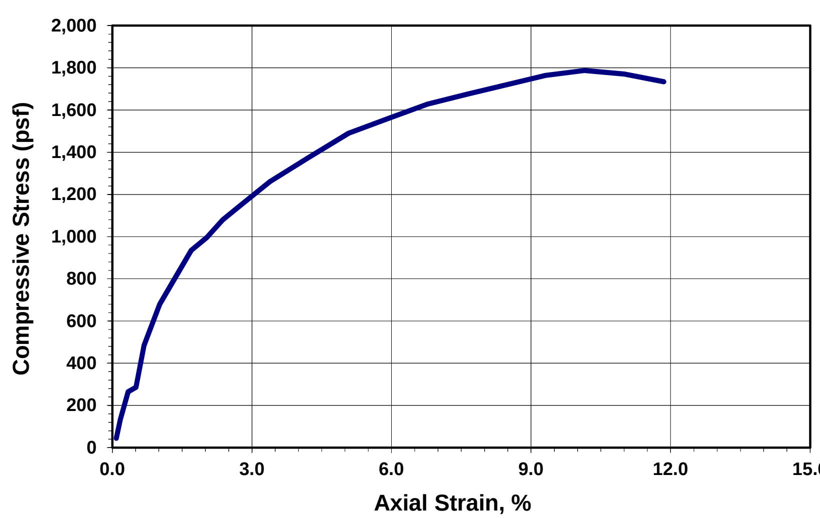
DIAMETER, D_0	2.880	in	73.2	mm	STRAIN RATE	1.00	%/min
AREA, A_0	6.514	in^2	42.0	cm^2	WET SOIL + PAN MASS	1425.0	g
HEIGHT, L_0	5.906	in	150.0	mm	PAN MASS	126.9	g
VOLUME, V_0	38.474	in^3	630.5	cm^3	DRY SOIL + PAN MASS	1237.0	g
MACH. RATE	0.591	in/min			WET DENSITY	128.53	lb/ft^3
WATER CONT.	16.94	%			DRY DENSITY	109.92	lb/ft^3

UNCONFINED COMPRESSION STRESS, q_u **1,787** **psf** 0.89 tsf

HAND PENETROMETER 2.00 tsf

Failure Sketch

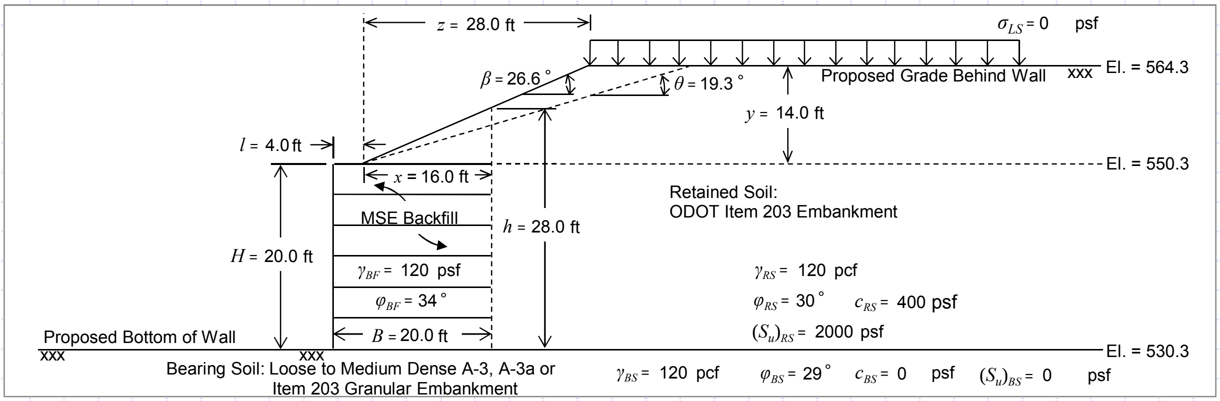
Unconfined Compression Test



APPENDIX VI

MSE WALL CALCULATIONS

Retaining Wall J1 - Sta. 475+87 to Sta. 478+35 - 2:1 Backslope - 20.0 ft. Wall Height - B-031-1-13 and B-031-2-13



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	20.0	ft
MSE Wall Width (Reinforcement Length), (B) =	20.0	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1050	ft
MSE Wall Effective Height, (h) =	28.0	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	19.3	°
Distance from Toe to Top of Backslope, (z) =	28.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	400	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.407	
Live Surcharge Load, (σ_{LS}) =	0	psf

MSE Backfill and Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(S_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	23.7	ft

LRFD Load Factors

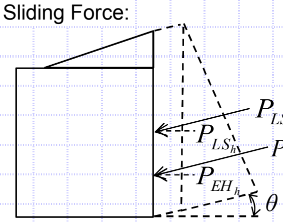
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Sections 11.6.3.6 and 11.10.5.3

Sliding Force:



$$P_H = (P_{EH} + P_{LS})\cos\theta$$

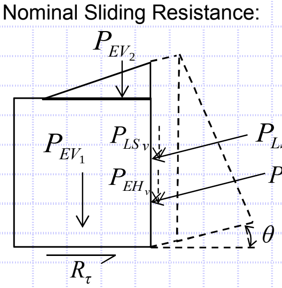
$P_{EH} = ½\gamma_{RS}h^2K_a\gamma_{EH}$ = ½(120 pcf)(28.0 ft)²(0.407)(1.50) = 28.73 kip/ft

$P_{LS} = \sigma_{LS}hK_a\gamma_{LS}$ = (0 psf)(28.0 ft)(0.407)(1.75) = 0.00 kip/ft

P_H = (28.73 + 0.00)cos(19.3°) = 27.12 kip/ft

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance: $R_\tau = (P_{EV_1} + P_{EV_2} + P_{EH}\sin\theta)\tan\delta$ (Neglect P_{LS_v} for conservatism)



$P_{EV_1} = \gamma_{BF}\cdot H\cdot B\cdot\gamma_{EV}$ = (120 pcf)(20.0 ft)(20.0 ft)(1.00) = 48 kip/ft

$P_{EV_2} = ½\gamma_{RS}(h-H)(B-l)\gamma_{EV}$ = ½(120 pcf)(28.0 ft - 20.0 ft)(20.0 ft - 4.0 ft)(1.00) = 7.69 kip/ft

$P_{EH} = ½\gamma_{RS}h^2K_a\gamma_{EH}$ = ½(120 pcf)(28.0 ft)²(0.407)(1.50) = 28.73 kip/ft

$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$ ⟶ tan(29) ≤ tan(34) ⟶ 0.55 ≤ 0.67 = 0.55

R_τ = [48.00 kip/ft + 7.69 kip/ft + (28.73 kip/ft)sin(19.3°)](0.55) = 35.85 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$P_H \le R_\tau\cdot\phi_\tau$ ⟶ 27.12 kip/ft ≤ (35.85 kip/ft)(1.0) = 35.85 kip/ft ⟶ 27.12 kip/ft ≤ 35.85 kip/ft **OK**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	20.0	ft
MSE Wall Width (Reinforcement Length), (B) =	20.0	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1050	ft
MSE Wall Effective Height, (h) =	28.0	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	19.3	°
Distance from Toe to Top of Backslope, (z) =	28.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	400	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.407	
Live Surcharge Load, (σ_{LS}) =	0	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	23.7	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

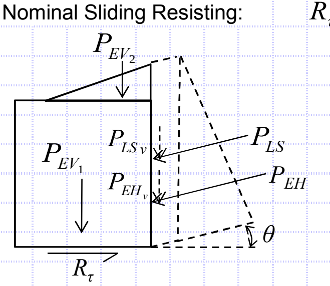
(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 ***(Continued)***

Check Sliding Resistance - Undrained Condition

Nominal Sliding Resisting: $R_\tau = \left((S_u)_{BS} \le \frac{q_s}{2} \right) \cdot B$



$(S_u)_{BS}$ = N/A ksf

$q_s = P_V / B$

$P_V = P_{EV_1} + P_{EV_2} + P_{EH} \sin\theta$

$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(20.0 ft)(20.0 ft)(1.00) = 48 kip/ft

(Neglect P_{LSv} for conservatism) $P_{EV_2} = \frac{1}{2}\gamma_{RS}(h-H)(B-l)\gamma_{EV}$ = ½(120 pcf)(28.0 ft - 20.0 ft)(20.0 ft - 4.0 ft)(1.00) = 7.69 kip/ft

$P_{EH} = \frac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH}$ = ½(120 pcf)(28.0 ft)²(0.407)(1.50) = 28.73 kip/ft

P_V = 48 kip/ft + 7.69 kip/ft + (28.73 kip/ft)sin(19.3°) = 65.19 kip/ft

q_s = (65.19 kip/ft) / (20 ft) = 3.26 ksf

R_τ = [N/A ksf ≤ (3.26 ksf)/2](20.0 ft) = [N/A ksf ≤ 1.63 ksf](20.0 ft)

R_τ = (1.63 ksf)(20.0 ft) = 32.60 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ N/A ⟶ N/A

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	20.0	ft
MSE Wall Width (Reinforcement Length), (B) =	20.0	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1050	ft
MSE Wall Effective Height, (h) =	28.0	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	19.3	°
Distance from Toe to Top of Backslope, (z) =	28.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	400	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.407	
Live Surcharge Load, (σ_{LS}) =	0	psf

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Bearing Soil Properties:

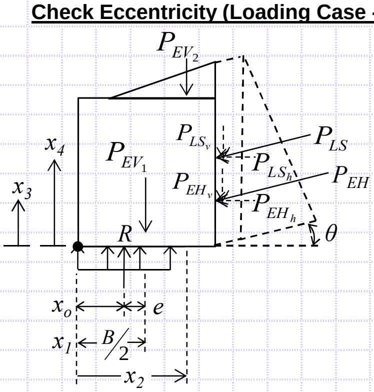
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	23.7	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.6.3.3



$$e = B/2 - x_o$$

$$x_o = \frac{M_V - M_H}{P_V}$$ = (782.73 kip·ft/ft - 253.26 kip·ft/ft) / (65.19 kip/ft) = 8.12 ft

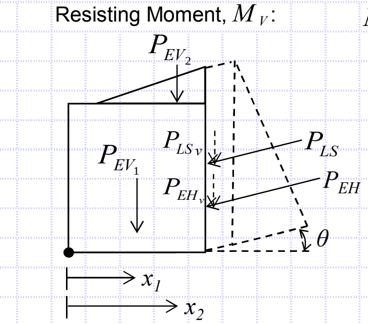
M_V = 782.73 kip·ft/ft
M_H = 253.26 kip·ft/ft } Defined below

$P_V = P_{EV_1} + P_{EV_2} + P_{EH}\sin\theta$ = 48 kip/ft + 7.69 kip/ft + (28.73 kip/ft)sin(19.3°) = 65.19 kip/ft

$e =$ (20.0 ft/ 2) - 8.12 ft = 1.88 ft

Resisting Moment, M_V:

$$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) + P_{EH}\sin\theta(B)$$ (Neglect P_{LS_V} for conservatism)



$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(20.0 ft)(20.0 ft)(1.00) = 48.00 kip/ft

$P_{EV_2} = \frac{1}{2}\gamma_{RS}(h-H)(B-l)\gamma_{EV}$ = ½(120 pcf)(28.0 ft - 20.0 ft)(20.0 ft - 4.0 ft)(1.00) = 7.69 kip/ft

$P_{EH} = \frac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH}$ = ½(120 pcf)(28.0 ft)²(0.407)(1.50) = 28.73 kip/ft

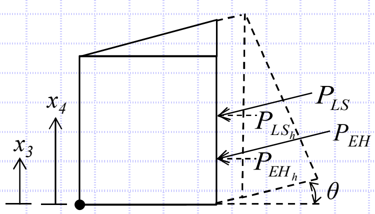
$x_1 = B/2$ = (20.0 ft) / 2 = 10.00 ft

$x_2 = l + \frac{2}{3}(B-l)$ = 4.0 ft + ⅔(20.0 ft - 4.0 ft) = 14.67 ft

M_V = (48 kip/ft)(10.00 ft) + (7.69 kip/ft)(14.67 ft) + (28.73 kip/ft)sin(19.3°)(20 ft) = 782.73 kip·ft/ft

Overturning Moment, M_H:

$$M_H = P_{EH}\cos\theta(x_3) + P_{LS}\cos\theta(x_4)$$



$P_{EH} = \frac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH}$ = ½(120 pcf)(28.0 ft)²(0.407)(1.50) = 28.73 kip/ft

$P_{LS} = \sigma_{LS} h K_a \gamma_{LS}$ = (0 psf)(28.0 ft)(0.407)(1.75) = 0.00 kip/ft

$x_3 = h/3$ = (28.0 ft) / 3 = 9.34 ft

$x_4 = h/2$ = (28.0 ft) / 2 = 14.01 ft

M_H = (28.73 kip/ft)cos(19.3°)(9.34 ft) + (0 kip/ft)cos(19.3°)(14.01 ft) = 253.26 kip·ft/ft

Check Eccentricity Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (20.0 ft) / 3 = 6.67 ft

$e < e_{max} \longrightarrow$ 1.88 ft < 6.67 ft **OK**

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	20.0	ft
MSE Wall Width (Reinforcement Length), (B) =	20.0	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1050	ft
MSE Wall Effective Height, (h) =	28.0	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	19.3	°
Distance from Toe to Top of Backslope, (z) =	28.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	400	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.407	
Live Surcharge Load, (σ_{LS}) =	0	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	23.7	ft

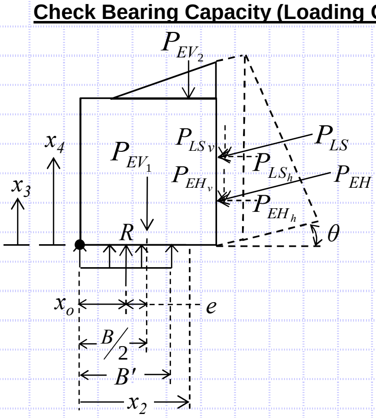
LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.6.3.2



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 20.0 ft - 2(1.30 ft) = 17.40 ft

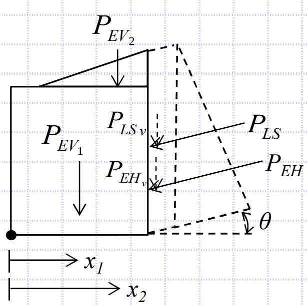
$e = B/2 - x_o$ = (20.0 ft / 2) - 8.7 ft = 1.30 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (990.19 kip·ft/ft - 253.26 kip·ft/ft) / 84.68 kip/ft = 8.70 ft

q_{eq} = (84.68 kip/ft) / (17.4 ft) = 4.87 ksf

Resisting Moment, M_V:

$$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) + P_{EH}\sin\theta(B)$$



$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(20.0 ft)(20.0 ft)(1.35) = 64.80 kip/ft

$P_{EV_2} = \frac{1}{2}\gamma_{RS}(h - H)(B - l)\gamma_{EV}$ = ½(120 pcf)(28.0 ft - 20.0 ft)(20.0 ft - 4.0 ft)(1.35) = 10.38 kip/ft

$P_{EH} = \frac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH}$ = ½(120 pcf)(28.0 ft)²(0.407)(1.50) = 28.73 kip/ft

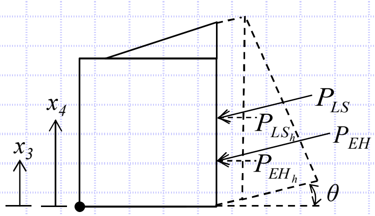
$x_1 = B/2$ = (20.0 ft) / 2 = 10.00 ft

$x_2 = l + \frac{2}{3}(B - l)$ = 4.0 ft + ⅔(20.0 ft - 4.0 ft) = 14.67 ft

M_V = (64.8 kip/ft)(10.00 ft) + (10.38 kip/ft)(14.7 ft) + (28.73 kip/ft)sin(19.3°)(20 ft) = 990.19 kip·ft/ft

Overturning Moment, M_H:

$$M_H = P_{EH}\cos\theta(x_3) + P_{LS}\cos\theta(x_4)$$



$P_{EH} = \frac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH}$ = ½(120 pcf)(28.0 ft)²(0.407)(1.50) = 28.73 kip/ft

$P_{LS} = \sigma_{LS} h K_a \gamma_{LS}$ = (0 psf)(28.0 ft)(0.407)(1.75) = 0.00 kip/ft

$x_3 = h/3$ = (28.0 ft) / 3 = 9.34 ft

$x_4 = h/2$ = (28.0 ft) / 2 = 14.01 ft

M_H = (28.73 kip/ft)cos(19.3°)(9.34 ft) + (0 kip/ft)cos(19.3°)(14.01 ft) = 253.26 kip·ft/ft

Vertical Forces, P_V:

$$P_V = P_{EV_1} + P_{EV_2} + P_{EH}\sin\theta$$

P_V = 64.8 kip/ft + 10.38 kip/ft + (28.73 kip/ft)sin(19.3°) = 84.68 kip/ft

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	20.0	ft
MSE Wall Width (Reinforcement Length), (B) =	20.0	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1050	ft
MSE Wall Effective Height, (h) =	28.0	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	19.3	°
Distance from Toe to Top of Backslope, (z) =	28.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	400	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.407	
Live Surcharge Load, (σ_{LS}) =	0	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	23.7	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 *(Continued)*

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2}\gamma B' N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 27.9

N_c = 27.9
s_c = 1+(17.4 ft/1050 ft)(16.4/27.9) = 1.0
i_c = 1.0 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 18.0

N_q = 16.4
s_q = 1+(17.4 ft/1050 ft)tan(29°) = 1.0
d_q = 1+2tan(29°)[1-sin(29°)]²tan⁻¹(4.0 ft/17.4 ft)
= 1.1
i_q = 1.0 (Assumed)
C_{wq} = 23.7 ft > 4.0 ft = 1.0

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 19.3

N_γ = 19.3
s_γ = 1-0.4(17.4 ft/1050 ft) = 1.0
i_γ = 1.0 (Assumed)
$C_{w\gamma}$ = 23.7 ft < 1.5(17.4 ft) + 4.0 ft = 0.5

q_n = (0 psf)(27.9) + (120 pcf)(4.0 ft)(18.0)(1.0) + ½(120 pcf)(17.4 ft)(19.3)(0.5) = 18.73 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \leq q_n \cdot \phi_b$ ⟶ 4.87 ksf ≤ (18.73 ksf)(0.65) = 12.17 ksf ⟶ 4.87 ksf ≤ 12.17 ksf **OK**

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

Check Bearing Resistance - Undrained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2}\gamma B' N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 5.14

N_c = 5.14
s_c = 1+[17.4 ft/(5·1050 ft)] = 1.0
i_c = 1.0 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 1.0

N_q = 1.0
s_q = 1.0
d_q = 1+2tan(29°)[1-sin(29°)]²tan⁻¹(4.0 ft/17.4 ft)
= 1.0
i_q = 1.0 (Assumed)
C_{wq} = 23.7 ft > 4.0 ft = 1.0

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.0

N_γ = 0.0
s_γ = 1.0
i_γ = 1.0 (Assumed)
$C_{w\gamma}$ = 23.7 ft < 1.5(17.4 ft) + 4.0 ft = 0.5

q_n = (0 psf)(5.14) + (120 pcf)(4.0 ft)(1.0)(1.0) + ½(120 pcf)(17.4 ft)(0.0)(0.5) = N/A ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \leq q_n \cdot \phi_b$ ⟶ N/A ⟶ N/A

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	20.0	ft
MSE Wall Width (Reinforcement Length), (B) =	20.0	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1050	ft
MSE Wall Effective Height, (h) =	28.0	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	19.3	°
Distance from Toe to Top of Backslope, (z) =	28.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	400	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.407	
Live Surcharge Load, (σ_{LS}) =	0	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	29	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	23.7	ft

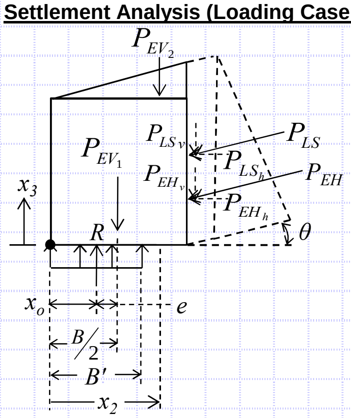
LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 20.0 ft - 2(1.12 ft) = 17.76 ft

$e = B/2 - x_o$ = (20.0 ft / 2) - 8.88 ft = 1.12 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (719.44 kip·ft/ft - 168.82 kip·ft/ft) / 62.02 kip/ft = 8.88 ft

q_{eq} = (62.02 kip/ft) / (17.76 ft) = 3.49 ksf

$$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) + P_{EH}\sin\theta(B) = (\gamma_{BF}HB\gamma_{EV})(\tfrac{1}{2}B) + (\tfrac{1}{2}\gamma_{RS}(h-H)(B-l)\gamma_{EV})(l + \tfrac{2}{3}(B-l)) + (\tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\sin\theta)(B)$$

M_V = [(120 pcf)(20.0 ft)(20.0 ft)(1.00)][½(20.0 ft)] + [½(120 pcf)(28.0 ft - 20.0 ft)(20.0 ft - 4.0 ft)(1.00)][4.0 ft + ⅔(20.0 ft - 4.0 ft)] + [½(120 pcf)(28.0 ft)²(0.407)(1.00)sin(19.3°)](20.0 ft) = 719.44 kip·ft/ft

$$M_H = P_{EH}\cos\theta(x_3) + P_{LS}\cos\theta(x_4) = (\tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\cos\theta)(h/3) + (\sigma_{LS}hK_a\gamma_{LS}\cos\theta)(h/2)$$

M_H = ½[(120 pcf)(28.0 ft)²(0.407)(1.00)cos(19.3°)](28.0 ft /3) + [(0 psf)(28.0 ft)(0.407)(1.00)cos(19.3°)](28.0 ft /2) = 168.82 kip·ft/ft

$$P_V = P_{EV_1} + P_{EV_2} + P_{EH}\sin\theta = (\gamma_{BF}HB\gamma_{EV}) + (\tfrac{1}{2}\gamma_{RS}(h-H)(B-l)\gamma_{EV}) + (\tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\sin\theta)$$

P_V = (120 pcf)(20.0 ft)(20.0 ft)(1.00) + ½(120 pcf)(28.0 ft - 20.0 ft)(20.0 ft - 4.0 ft)(1.00) + ½(120 pcf)(28.0 ft)²(0.407)(1.00)sin(19.3°) = 62.02 kip/ft

Settlement (See Attached Spreadsheet Calculations):

Total Settlement at Center of Reinforced Soil Mass: S_t = **3.002** in

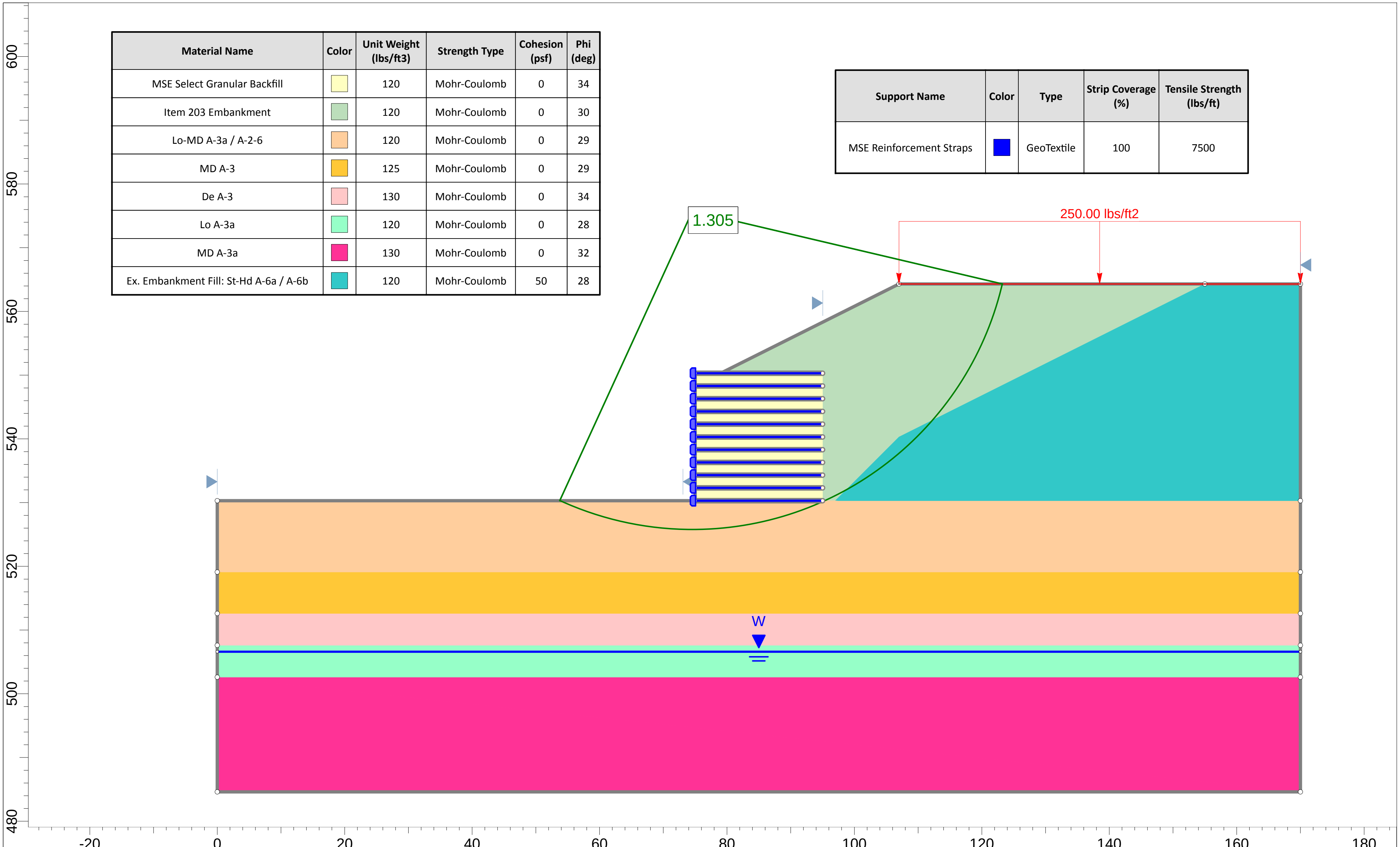
Total Settlement at Wall Facing: S_t = **2.351** in

Time Rate of Consolidation Settlement at Wall Facing (See Attached Spreadsheet Calculations):

$(S_c)_{100}$ = **2.351** in at **0** days following completion of construction

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Select Granular Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Lo-MD A-3a / A-2-6		120	Mohr-Coulomb	0	29
MD A-3		125	Mohr-Coulomb	0	29
De A-3		130	Mohr-Coulomb	0	34
Lo A-3a		120	Mohr-Coulomb	0	28
MD A-3a		130	Mohr-Coulomb	0	32
Ex. Embankment Fill: St-Hd A-6a / A-6b		120	Mohr-Coulomb	50	28

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		GeoTextile	100	7500



Project	HAM-75-7.85 - Retaining Wall J1 - Sta. 475+87 to 478+35 - MSE Wall Global Stability		
Analysis Description	20.0 ft Wall Height - 2:1 Backslope - Drained - Circular - Spencer		
Drawn By BRT	*Scale* 1:250	*Company* Resource International, Inc	
Date 7/20/2015	*File Name* Retaining Wall J1 - Sta. 475+87 to Sta. 478+35 - Global Stability.slim		

SLIDEINTERPRET 6.031

B-10-020 - HAM-75-7.85 - Retaining Wall J1
MSE Wall Settlement - Sta. 475+87 to Sta. 478+35

Calculated By: BRT Date: 7/20/2015
Checked By: JPS Date: 7/21/2015

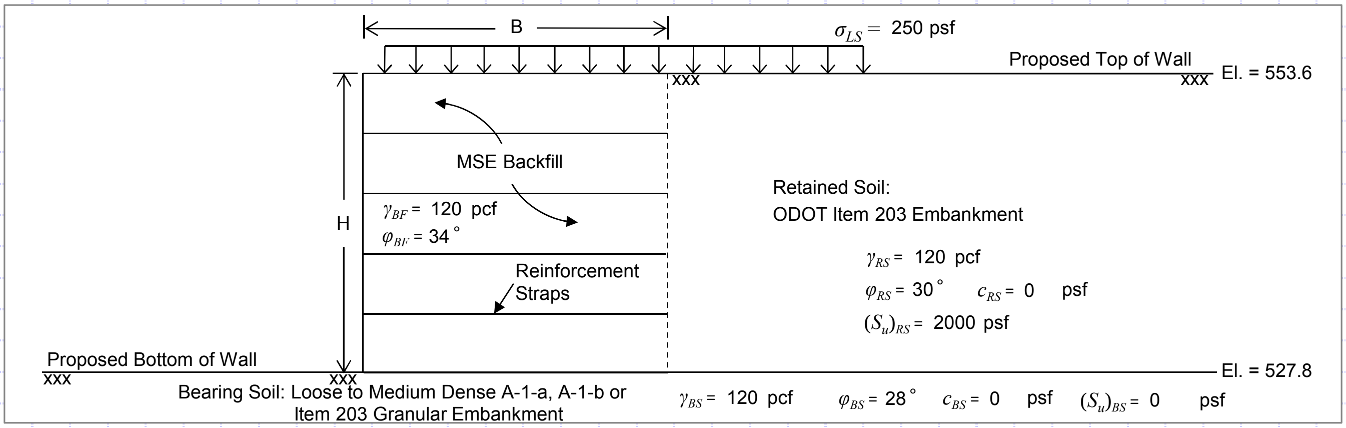
Borings B-031-1-13 and B-031-2-13

H=	20.0	ft	Total wall height
B'=	17.8	ft	Effective footing width due to eccentricity
D_w =	21.7	ft	Depth below bottom of footing
q_e =	3,490	psf	Equivalent bearing pressure at bottom of wall

																				Total Settlement at Center of Reinforced Soil Mass					Total Settlement at Facing of Wall				
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)	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)
1	A-3a	G	0.0	1.5	1.5	0.8	120	180	90	90	2,090					13	26	78	0.04	1.000	3,489	3,579	0.031	0.368	0.500	1,745	1,835	0.025	0.301
	A-3a	G	1.5	3.0	1.5	2.3	120	360	270	270	2,270					13	22	70	0.13	0.994	3,468	3,738	0.024	0.293	0.500	1,744	2,014	0.019	0.224
	A-3a	G	3.0	5.5	2.5	4.3	120	660	510	510	2,510					13	19	65	0.24	0.964	3,364	3,874	0.034	0.405	0.497	1,736	2,246	0.025	0.296
	A-3a	G	5.5	8.0	2.5	6.8	120	960	810	810	2,810					13	17	62	0.38	0.893	3,118	3,928	0.028	0.332	0.490	1,711	2,521	0.020	0.239
	A-3a	G	8.0	11.0	3.0	9.5	120	1,320	1,140	1,140	3,140					13	15	60	0.53	0.797	2,781	3,921	0.027	0.324	0.476	1,662	2,802	0.020	0.236
2	A-3	G	11.0	14.0	3.0	12.5	125	1,695	1,508	1,508	3,508					14	15	51	0.70	0.695	2,424	3,932	0.024	0.294	0.455	1,587	3,095	0.018	0.220
	A-3	G	14.0	17.5	3.5	15.8	125	2,133	1,914	1,914	3,914					14	14	49	0.88	0.600	2,094	4,008	0.023	0.273	0.427	1,492	3,405	0.018	0.213
3	A-3	G	17.5	20.0	2.5	18.8	130	2,458	2,295	2,295	4,295					45	43	101	1.05	0.529	1,845	4,140	0.006	0.076	0.401	1,398	3,693	0.005	0.061
	A-3	G	20.0	22.5	2.5	21.3	130	2,783	2,620	2,620	4,620					45	41	97	1.19	0.479	1,673	4,293	0.006	0.066	0.379	1,321	3,941	0.005	0.055
4	A-3a	G	22.5	25.0	2.5	23.8	120	3,083	2,933	2,805	4,805					6	5	46	1.33	0.437	1,527	4,331	0.010	0.122	0.357	1,248	4,052	0.009	0.104
	A-3a	G	25.0	27.5	2.5	26.3	120	3,383	3,233	2,949	4,949					6	5	46	1.47	0.402	1,402	4,350	0.009	0.110	0.338	1,178	4,127	0.008	0.095
5	A-3a	G	27.5	33.5	6.0	30.5	130	4,163	3,773	3,223	5,223					28	24	74	1.71	0.352	1,228	4,452	0.011	0.137	0.307	1,070	4,294	0.010	0.122
	A-3a	G	33.5	39.5	6.0	36.5	130	4,943	4,553	3,629	5,629					28	22	71	2.05	0.299	1,043	4,672	0.009	0.111	0.270	942	4,571	0.008	0.101
	A-3a	G	39.5	45.5	6.0	42.5	130	5,723	5,333	4,035	6,035					28	21	70	2.39	0.259	904	4,939	0.008	0.091	0.240	836	4,871	0.007	0.085
																						Total Settlement:		3.002 in			Total Settlement:		2.351 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 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 = 0.075(C_c); 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)

Retaining Wall J1 - Sta. 478+35 to Sta. 483+50 - B-031-2-13, B-031-3-13, B-032-0-11 and B-033-0-11



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.8	ft
MSE Wall Width (Reinforcement Length), (B) =	18.1	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(S_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	22.1	ft

LRFD Load Factors

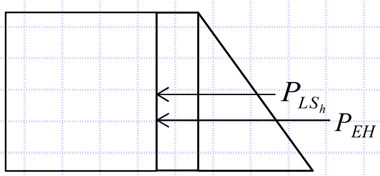
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3

Sliding Force:

$$P_H = P_{EH} + P_{LS_h}$$



$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \text{½(120 pcf)(25.8 ft)²(0.333)(1.5)} = 19.95 \text{ kip/ft}$$

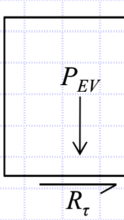
$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = \text{(250 psf)(25.8 ft)(0.333)(1.75)} = 3.76 \text{ kip/ft}$$

$$P_H = \text{19.95 kip/ft + 3.76 kip/ft} = 23.71 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:

$$R_\tau = P_{EV} \cdot \tan\delta$$



$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(25.8 ft)(18.1 ft)(1.00)} = 56.04 \text{ kip/ft}$$

$$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$$

$$\tan\delta = \tan(28) \le \tan(34) \longrightarrow 0.53 \le 0.67 \longrightarrow \tan\delta = 0.53$$

$$R_\tau = \text{(56.04 kip/ft)(0.53)} = 29.70 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$$P_H \le R_\tau \cdot \phi_\tau \longrightarrow \text{23.71 kip/ft} \le \text{(29.70 kip/ft)(1.0)} = \text{29.70 kip/ft} \longrightarrow \text{23.71 kip/ft} \le \text{29.70 kip/ft}$$

OK

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.8	ft
MSE Wall Width (Reinforcement Length), (B) =	18.1	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	22.1	ft

LRFD Load Factors

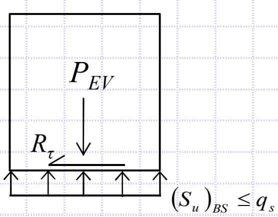
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 ***(Continued)***

Check Sliding Resistance - Undrained Condition

Nominal Sliding Resisting: $R_\tau = ((S_u)_{BS} \le q_s) \cdot B$



$(S_u)_{BS}$ = N/A ksf

$q_s = \sigma_v / 2$ = (3.10 ksf) / 2 = 1.55 ksf

$\sigma_v = P_{EV} / B$ = (56.04 kip/ft) / (18.1 ft) = 3.10 ksf

R_τ = (N/A ksf ≤ 1.55 ksf)(18.1 ft) = 28.06 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ N/A ⟶ N/A

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.8	ft
MSE Wall Width (Reinforcement Length), (B) =	18.1	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

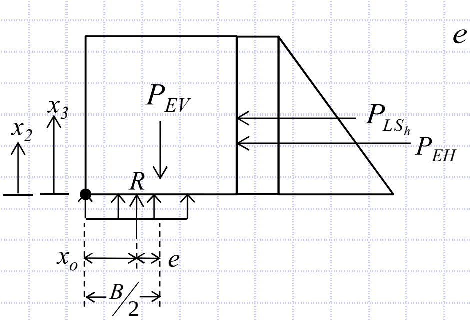
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	22.1	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.5



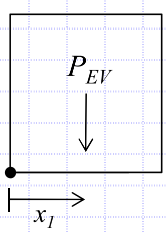
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (507.16 kip·ft/ft - 220.07 kip·ft/ft) / (56.04 kip/ft) = 5.12 ft

M_{EV} = 507.16 kip·ft/ft
M_H = 220.07 kip·ft/ft
P_{EV} = 56.04 kip/ft
(Defined below)

$e =$ (18.1 ft)/2 - 5.12 ft = 3.93 ft

Resisting Moment, M_{EV}:



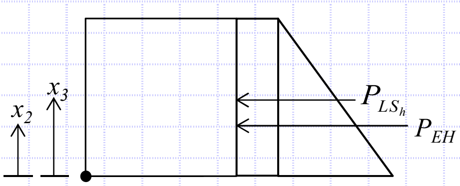
$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(25.8 ft)(18.1 ft)(1.00) = 56.04 kip/ft

$x_1 = B/2$ = (18.1 ft) / 2 = 9.05 ft

$M_{EV} =$ (56.04 kip/ft)(9.05 ft) = 507.16 kip·ft/ft

Overturning Moment, M_H:



$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$$

$P_{EH} = ½\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(25.8 ft)²(0.333)(1.5) = 19.95 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(25.8 ft)(0.333)(1.75) = 3.76 kip/ft

$x_2 = H/3$ = (25.8 ft) / 3 = 8.60 ft

$x_3 = H/2$ = (25.8 ft) / 2 = 12.90 ft

$M_H =$ (19.95 kip/ft)(8.6 ft) + (3.76 kip/ft)(12.90 ft) = 220.07 kip·ft/ft

Check Eccentricity

$e < e_{max} \longrightarrow$ 3.93 ft < 6.03 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (18.1 ft) / 3 = 6.03 ft

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.8	ft
MSE Wall Width (Reinforcement Length), (B) =	18.1	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

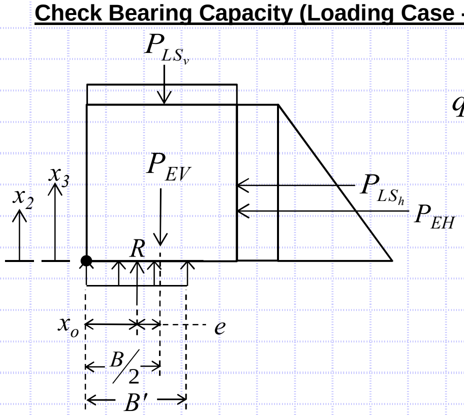
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	22.1	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 18.1 ft - 2(2.63 ft) = 12.84 ft

$e = B/2 - x_o$ = (18.1 ft) / 2 - 6.42 ft = 2.63 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (756.30 kip·ft/ft - 220.05 kip·ft/ft) / 83.57 kip/ft = 6.42 ft

q_{eq} = (83.57 kip/ft) / (12.84 ft) = 6.51 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

M_V = [(120 pcf)(25.8 ft)(18.1 ft)(1.35)](9.05 ft) + [(250 psf)(18.1 ft)(1.75)](9.05 ft) = 756.30 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

M_H = [½(120 pcf)(25.8 ft)²(0.333)(1.5)](8.6 ft) + [(250 psf)(25.8 ft)(0.333)(1.75)](12.9 ft) = 220.05 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

P_V = (120 pcf)(25.8 ft)(18.1 ft)(1.35) + (250 psf)(18.1 ft)(1.75) = 83.57 kip/ft

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 25.8 | $N_{qm} = N_q s_q d_q i_q$ = 16.2 | $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 16.7

N_c =	25.8	N_q =	14.7	N_γ =	16.7
s_c =	1.0	s_q =	1.0	s_γ =	1.0
i_c =	1.0	d_q =	1.1	i_γ =	1.0
		i_q =	1.0		

q_n = (0 psf)(25.8) + (120 pcf)(4.0 ft)(16.2)(1.0) + ½(120 pcf)(12.8 ft)(16.7)(0.5) = 14.19 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 6.51 ksf ≤ (14.19 ksf)(0.65) = 9.22 ksf ⟶ 6.51 ksf ≤ 9.22 ksf **OK**

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.8	ft
MSE Wall Width (Reinforcement Length), (B) =	18.1	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	22.1	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 ***(Continued)***

Check Bearing Resistance - Undrained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 5.14 $\quad$ $N_{qm} = N_q s_q d_q i_q$ = 1.0 $\quad$ $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.0

N_c = 5.14 $\quad$ N_q = 1.0 $\quad$ N_γ = 0.0
s_c = 1.0 $\quad$ s_q = 1.0 $\quad$ s_γ = 1.0
i_c = 1.0 $\quad$ d_q = 1.0 $\quad$ i_γ = 1.0
i_q = 1.0

$q_n =$ (0 psf)(5.14) + (120 pcf)(4.0 ft)(1.0)(1.0) + ½(120 pcf)(12.8 ft)(0.0)(0.5) = N/A ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ N/A $\longrightarrow$ N/A

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.8	ft
MSE Wall Width (Reinforcement Length), (B) =	18.1	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

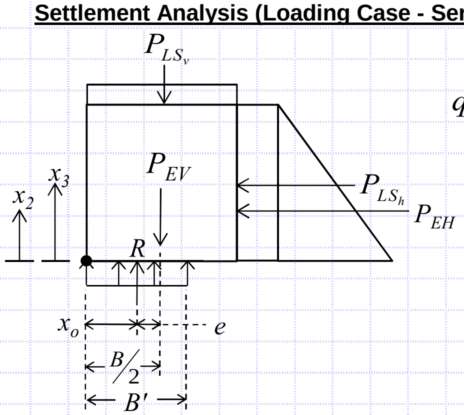
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	22.1	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



$$q_{eq} = P_V / B'$$

$$B' = B - 2e \quad = \quad 18.1 \text{ ft} - 2(2.35 \text{ ft}) \quad = \quad 13.40 \quad \text{ft}$$

$$e = B/2 - x_o \quad = \quad (18.1 \text{ ft}) / 2 - 6.7 \text{ ft} \quad = \quad 2.35 \quad \text{ft}$$

$$x_o = \frac{M_V - M_H}{P_V} \quad = \quad (548.09 \text{ kip·ft/ft} - 142.08 \text{ kip·ft/ft}) / 60.56 \text{ kip/ft} \quad = \quad 6.7 \quad \text{ft}$$

$$q_{eq} = \quad (60.56 \text{ kip/ft}) / (13.4 \text{ ft}) \quad = \quad 4.52 \quad \text{ksf}$$

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

$$M_V = \quad [(120 \text{ pcf})(25.8 \text{ ft})(18.1 \text{ ft})(1.00)](9.1 \text{ ft}) + [(250 \text{ psf})(18.1 \text{ ft})(1.00)](9.1 \text{ ft}) \quad = \quad 548.09 \quad \text{kip·ft/ft}$$

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

$$M_H = \quad [\tfrac{1}{2}(120 \text{ pcf})(25.8 \text{ ft})^2(0.333)(1.00)](8.6 \text{ ft}) + [(250 \text{ psf})(25.8 \text{ ft})(0.333)(1.00)](12.9 \text{ ft}) \quad = \quad 142.08 \quad \text{kip·ft/ft}$$

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

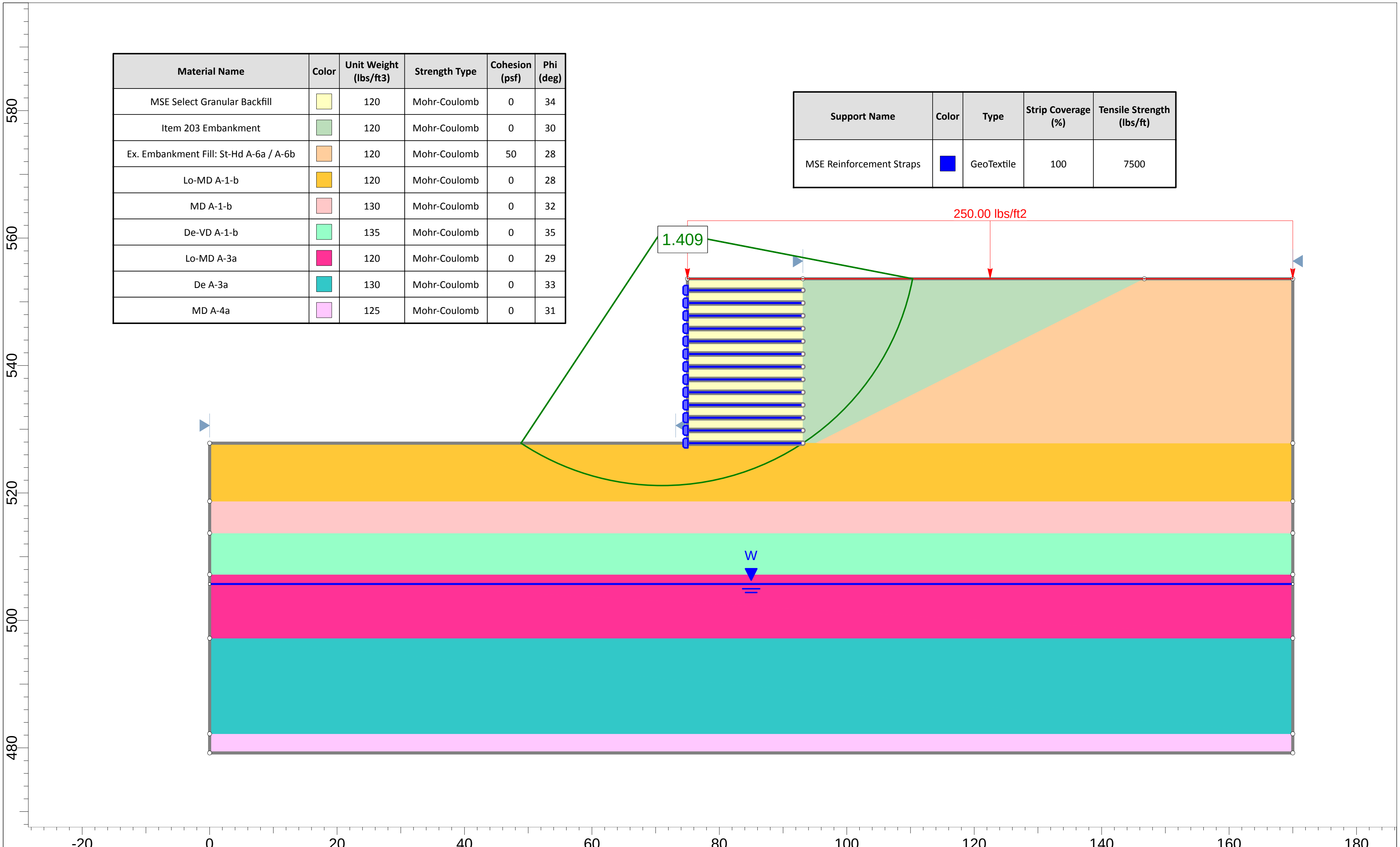
$$P_V = \quad (120 \text{ pcf})(25.8 \text{ ft})(18.1 \text{ ft})(1.00) + (250 \text{ psf})(18.1 \text{ ft})(1.00) \quad = \quad 60.56 \quad \text{kip/ft}$$

Settlement (See Attached Spreadsheet Calculations):

Total Settlement at Center of Reinforced Soil Mass:	S_t =	2.630	in
Total Settlement at Wall Facing:	S_t =	2.165	in

Time Rate of Consolidation Settlement at Wall Facing (See Attached Spreadsheet Calculations):

$(S_c)_{100}$ = **2.165** in at **0** days following completion of construction



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Select Granular Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Ex. Embankment Fill: St-Hd A-6a / A-6b		120	Mohr-Coulomb	50	28
Lo-MD A-1-b		120	Mohr-Coulomb	0	28
MD A-1-b		130	Mohr-Coulomb	0	32
De-VD A-1-b		135	Mohr-Coulomb	0	35
Lo-MD A-3a		120	Mohr-Coulomb	0	29
De A-3a		130	Mohr-Coulomb	0	33
MD A-4a		125	Mohr-Coulomb	0	31

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		GeoTextile	100	7500

rocscience

SLIDEINTERPRET 6.031

Project
HAM-75-7.85 - Retaining Wall J1 - Sta. 478+35 to 483+50 - MSE Wall Global Stability

Analysis Description
25.8 ft Wall Height - Drained - Circular - Spencer

Drawn By BRT | *Scale* 1:250 | *Company* Resource International, Inc.

Date 7/20/2015 | *File Name* Retaining Wall J1 - Sta. 478+35 to Sta. 483+50 - Global Stability.slim

B-10-020 - HAM-75-7.85 - Retaining Wall J1

MSE Wall Settlement - Sta. 478+35 to Sta. 483+50

Calculated By: BRT Date: 7/20/2015

Checked By: JPS Date: 7/21/2015

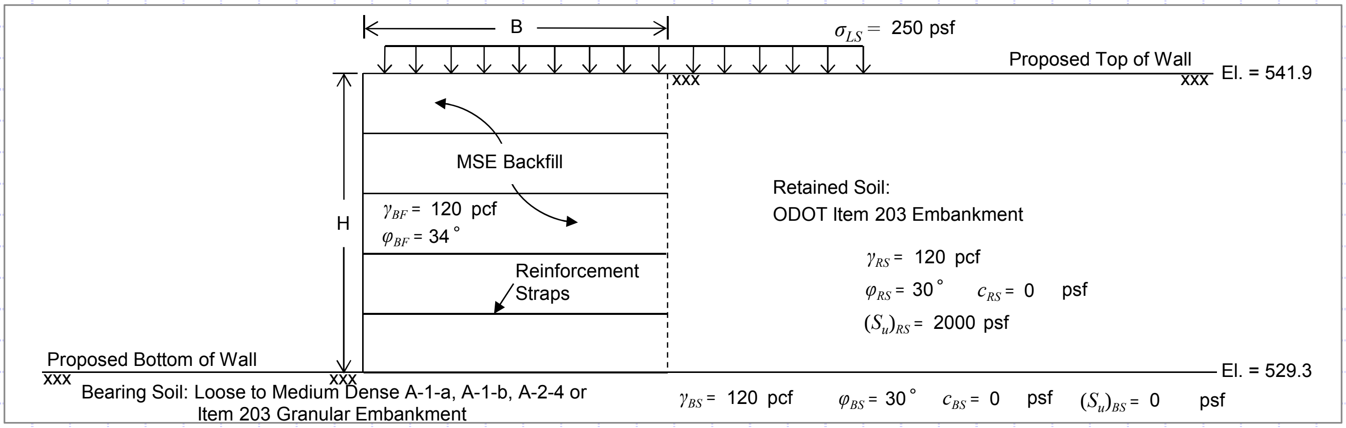
Borings B-031-2-13, B-031-3-13, B-032-0-11 and B-033-0-11

H=	25.8	ft	Total wall height
B'=	13.4	ft	Effective footing width due to eccentricity
D_w =	22.1	ft	Depth below bottom of footing
q_e =	4,520	psf	Equivalent bearing pressure at bottom of wall

																				Total Settlement at Center of Reinforced Soil Mass					Total Settlement at Facing of Wall				
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)	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)
1	A-1-b	G	0.0	2.0	2.0	1.0	120	240	120	120	2,120					12	23	82	0.07	0.999	4,514	4,634	0.039	0.466	0.500	2,260	2,380	0.032	0.381
	A-1-b	G	2.0	4.0	2.0	3.0	120	480	360	360	2,360					12	19	72	0.22	0.969	4,382	4,742	0.031	0.373	0.498	2,250	2,610	0.024	0.287
	A-1-b	G	4.0	6.5	2.5	5.3	120	780	630	630	2,630					12	17	68	0.39	0.886	4,004	4,634	0.032	0.385	0.489	2,211	2,841	0.024	0.290
	A-1-b	G	6.5	9.0	2.5	7.8	120	1,080	930	930	2,930					12	15	65	0.58	0.769	3,475	4,405	0.026	0.313	0.471	2,129	3,059	0.020	0.240
2	A-1-b	G	9.0	11.5	2.5	10.3	130	1,405	1,243	1,243	3,243					30	35	113	0.76	0.660	2,984	4,226	0.012	0.141	0.446	2,015	3,257	0.009	0.111
	A-1-b	G	11.5	14.0	2.5	12.8	130	1,730	1,568	1,568	3,568					30	32	106	0.95	0.570	2,577	4,145	0.010	0.119	0.417	1,884	3,452	0.008	0.097
3	A-1-b	G	14.0	17.0	3.0	15.5	135	2,135	1,933	1,933	3,933					46	47	155	1.16	0.492	2,222	4,155	0.006	0.077	0.384	1,737	3,670	0.005	0.065
	A-1-b	G	17.0	20.5	3.5	18.8	135	2,608	2,371	2,371	4,371					46	43	143	1.40	0.420	1,899	4,271	0.006	0.075	0.348	1,573	3,945	0.005	0.065
4	A-3a	G	20.5	25.5	5.0	23.0	120	3,208	2,908	2,851	4,851					13	11	54	1.72	0.351	1,588	4,440	0.018	0.214	0.306	1,385	4,236	0.016	0.192
	A-3a	G	25.5	30.5	5.0	28.0	120	3,808	3,508	3,139	5,139					13	11	53	2.09	0.294	1,327	4,466	0.014	0.173	0.266	1,202	4,342	0.013	0.159
5	A-3a	G	30.5	35.5	5.0	33.0	130	4,458	4,133	3,452	5,452					35	29	84	2.46	0.252	1,137	4,590	0.007	0.088	0.234	1,056	4,509	0.007	0.083
	A-3a	G	35.5	40.5	5.0	38.0	130	5,108	4,783	3,790	5,790					35	28	82	2.84	0.220	994	4,785	0.006	0.074	0.208	939	4,729	0.006	0.071
	A-3a	G	40.5	45.5	5.0	43.0	130	5,758	5,433	4,128	6,128					35	27	79	3.21	0.195	883	5,011	0.005	0.064	0.187	843	4,972	0.005	0.061
6	A-4a	G	45.5	48.5	3.0	47.0	125	6,133	5,945	4,391	6,391					27	20	40	3.51	0.179	809	5,201	0.006	0.067	0.172	779	5,170	0.005	0.064
																						Total Settlement:	2.630 in				Total Settlement:	2.165 in	

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 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. $C_r = 0.075(C_c)$; 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 (Cohesiv 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)

Retaining Wall J1 - Sta. 483+50 to Sta. 486+00 - B-034-0-11 and B-035-0-11



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.6	ft
MSE Wall Width (Reinforcement Length), (B) =	8.8	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	30	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(S_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	28.3	ft

LRFD Load Factors

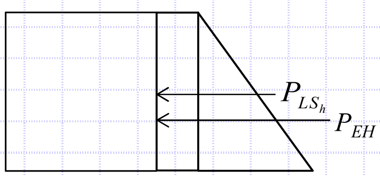
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3

Sliding Force:

$$P_H = P_{EH} + P_{LS_h}$$



$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(12.6 ft)²(0.333)(1.5) = 4.76 kip/ft

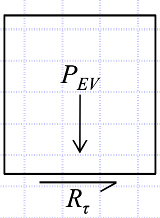
$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(12.6 ft)(0.333)(1.75) = 1.84 kip/ft

P_H = 4.76 kip/ft + 1.84 kip/ft = 6.60 kip/ft

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:

$$R_\tau = P_{EV} \cdot \tan\delta$$



$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(12.6 ft)(8.8 ft)(1.00) = 13.31 kip/ft

$$\tan\delta = (\tan\varphi_{BS} \leq \tan\varphi_{BF})$$

$\tan\delta =$ tan(30) ≤ tan(34) ⟶ 0.58 ≤ 0.67 ⟶ $\tan\delta =$ 0.58

R_τ = (13.31 kip/ft)(0.58) = 7.72 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$P_H \leq R_\tau \cdot \phi_\tau$ ⟶ 6.60 kip/ft ≤ (7.72 kip/ft)(1.0) = 7.72 kip/ft ⟶ 6.60 kip/ft ≤ 7.72 kip/ft **OK**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.6	ft
MSE Wall Width (Reinforcement Length), (B) =	8.8	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	30	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	28.3	ft

LRFD Load Factors

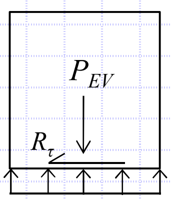
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 ***(Continued)***

Check Sliding Resistance - Undrained Condition

Nominal Sliding Resisting: $$R_\tau = ((S_u)_{BS} \leq q_s) \cdot B$$



$(S_u)_{BS} =$ N/A ksf

$q_s = \sigma_v / 2$ = (1.51 ksf) / 2 = 0.76 ksf

$\sigma_v = P_{EV} / B$ = (13.31 kip/ft) / (8.8 ft) = 1.51 ksf

R_τ = (N/A ksf ≤ 0.76 ksf)(8.8 ft) = 6.69 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \leq R_\tau \cdot \phi_\tau \longrightarrow$ N/A $\longrightarrow$ N/A

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.6	ft
MSE Wall Width (Reinforcement Length), (B) =	8.8	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

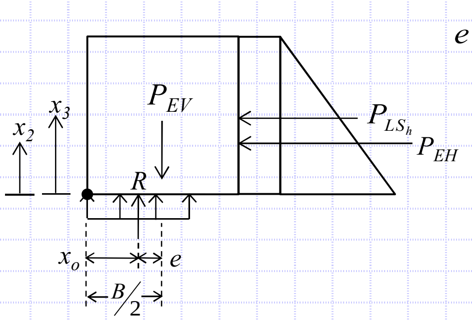
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	30	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	28.3	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.5



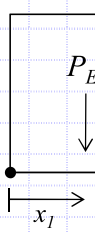
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (58.56 kip·ft/ft - 31.58 kip·ft/ft) / (13.31 kip/ft) = 2.03 ft

M_{EV} = 58.56 kip·ft/ft
M_H = 31.58 kip·ft/ft
P_{EV} = 13.31 kip/ft
(Defined below)

$e =$ (8.8 ft)/2 - 2.03 ft = 2.37 ft

Resisting Moment, M_{EV}:



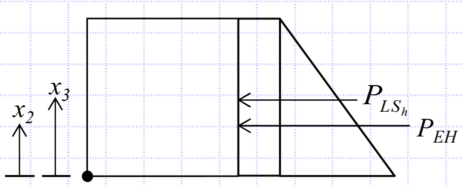
$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(12.6 ft)(8.8 ft)(1.00) = 13.31 kip/ft

$x_1 = B/2$ = (8.8 ft) / 2 = 4.40 ft

$M_{EV} =$ (13.31 kip/ft)(4.40 ft) = 58.56 kip·ft/ft

Overturning Moment, M_H:



$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$$

$P_{EH} = ½\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(12.6 ft)²(0.333)(1.5) = 4.76 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(12.6 ft)(0.333)(1.75) = 1.84 kip/ft

$x_2 = H/3$ = (12.6 ft) / 3 = 4.20 ft

$x_3 = H/2$ = (12.6 ft) / 2 = 6.30 ft

$M_H =$ (4.76 kip/ft)(4.2 ft) + (1.84 kip/ft)(6.30 ft) = 31.58 kip·ft/ft

Check Eccentricity

$e < e_{max} \longrightarrow$ 2.37 ft < 2.93 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (8.8 ft) / 3 = 2.93 ft

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.6	ft
MSE Wall Width (Reinforcement Length), (B) =	8.8	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

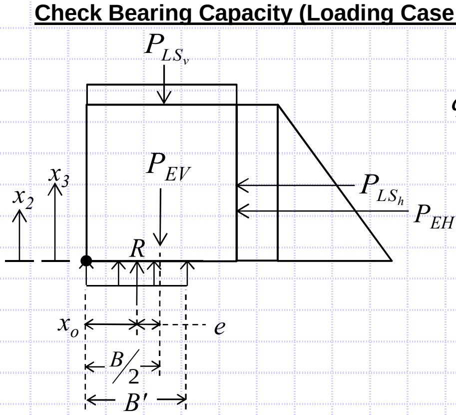
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	30	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	28.3	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 8.8 ft - 2(1.45 ft) = 5.90 ft

$e = B/2 - x_o$ = (8.8 ft) / 2 - 2.95 ft = 1.45 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (95.98 kip·ft/ft - 31.55 kip·ft/ft) / 21.81 kip/ft = 2.95 ft

$q_{eq} =$ (21.81 kip/ft) / (5.9 ft) = 3.70 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

$M_V =$ [(120 pcf)(12.6 ft)(8.8 ft)(1.35)](4.4 ft) + [(250 psf)(8.8 ft)(1.75)](4.4 ft) = 95.98 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

$M_H =$ [½(120 pcf)(12.6 ft)²(0.333)(1.5)](4.2 ft) + [(250 psf)(12.6 ft)(0.333)(1.75)](6.3 ft) = 31.55 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

$P_V =$ (120 pcf)(12.6 ft)(8.8 ft)(1.35) + (250 psf)(8.8 ft)(1.75) = 21.81 kip/ft

---

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 30.1 $N_{qm} = N_q s_q d_q i_q$ = 20.2 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 22.4

N_c =	30.1	N_q =	18.4	N_γ =	22.4
s_c =	1.0	s_q =	1.0	s_γ =	1.0
i_c =	1.0	d_q =	1.1	i_γ =	1.0
		i_q =	1.0		

$q_n =$ (0 psf)(30.1) + (120 pcf)(4.0 ft)(20.2)(1.0) + ½(120 pcf)(5.9 ft)(22.4)(1.0) = 17.64 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 3.70 ksf ≤ (17.64 ksf)(0.65) = 11.47 ksf ⟶ 3.70 ksf ≤ 11.47 ksf **OK**

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.6	ft
MSE Wall Width (Reinforcement Length), (B) =	8.8	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	30	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	28.3	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 *(Continued)*

Check Bearing Resistance - Undrained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 5.14 $N_{qm} = N_q s_q d_q i_q$ = 1.0 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.0

N_c =	5.14	N_q =	1.0	N_γ =	0.0
s_c =	1.0	s_q =	1.0	s_γ =	1.0
i_c =	1.0	d_q =	1.0	i_γ =	1.0
		i_q =	1.0		

$q_n =$ (0 psf)(5.14) + (120 pcf)(4.0 ft)(1.0)(1.0) + ½(120 pcf)(5.9 ft)(0.0)(1.0) = N/A ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ N/A $\longrightarrow$ N/A

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.6	ft
MSE Wall Width (Reinforcement Length), (B) =	8.8	ft
MSE Wall Length, (L) =	1050	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.333	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

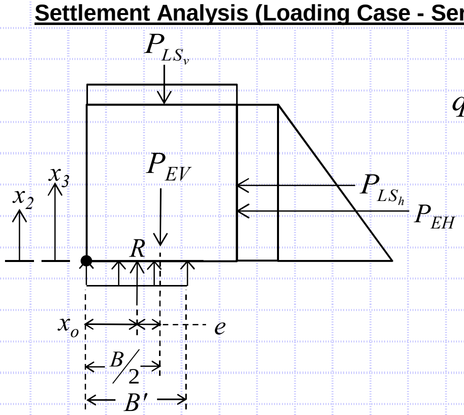
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	30	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	28.3	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 8.8 ft - 2(1.29 ft) = 6.22 ft

$e = B/2 - x_o$ = (8.8 ft) / 2 - 3.11 ft = 1.29 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (68.22 kip·ft/ft - 19.93 kip·ft/ft) / 15.51 kip/ft = 3.11 ft

$q_{eq} =$ (15.51 kip/ft) / (6.22 ft) = 2.49 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

$M_V =$ [(120 pcf)(12.6 ft)(8.8 ft)(1.00)](4.4 ft) + [(250 psf)(8.8 ft)(1.00)](4.4 ft) = 68.22 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

$M_H =$ [½(120 pcf)(12.6 ft)²(0.333)(1.00)](4.2 ft) + [(250 psf)(12.6 ft)(0.333)(1.00)](6.3 ft) = 19.93 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

$P_V =$ (120 pcf)(12.6 ft)(8.8 ft)(1.00) + (250 psf)(8.8 ft)(1.00) = 15.51 kip/ft

Settlement (See Attached Spreadsheet Calculations):

Total Settlement at Center of Reinforced Soil Mass: S_t = **1.006** in

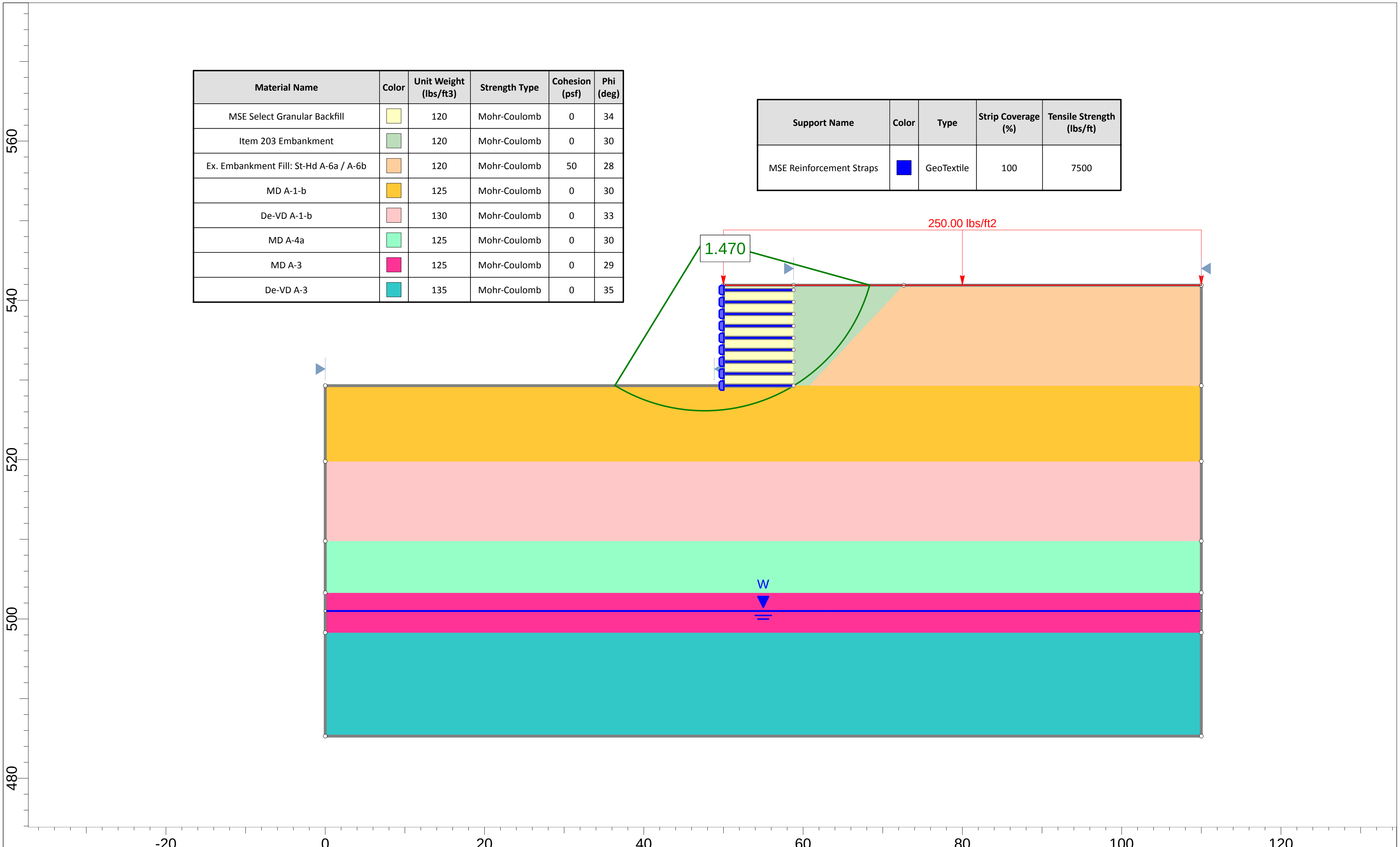
Total Settlement at Wall Facing: S_t = **0.858** in

Time Rate of Consolidation Settlement at Wall Facing (See Attached Spreadsheet Calculations):

$(S_c)_{100}$ = **0.858** in at **0** days following completion of construction

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Select Granular Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Ex. Embankment Fill: St-Hd A-6a / A-6b		120	Mohr-Coulomb	50	28
MD A-1-b		125	Mohr-Coulomb	0	30
De-VD A-1-b		130	Mohr-Coulomb	0	33
MD A-4a		125	Mohr-Coulomb	0	30
MD A-3		125	Mohr-Coulomb	0	29
De-VD A-3		135	Mohr-Coulomb	0	35

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		GeoTextile	100	7500



Project	HAM-75-7.85 - Retaining Wall J1 - Sta. 483+50 to 486+00 - MSE Wall Global Stability
Analysis Description	12.6 ft Wall Height - Drained - Circular - Spencer
Drawn By	BRT
Scale	1:200
Company	Resource International, Inc.
Date	7/20/2015
File Name	Retaining Wall J1 - Sta. 483+50 to Sta. 486+00 - Global Stability.slim

SLIDEINTERPRET 6.031

B-10-020 - HAM-75-7.85 - Retaining Wall J1
MSE Wall Settlement - Sta. 483+50 to Sta. 486+00

Calculated By: BRT Date: 7/20/2015
Checked By: JPS Date: 7/21/2015

Borings B-034-0-11 and B-035-0-11

H=	12.6	ft	Total wall height
B'=	6.2	ft	Effective footing width due to eccentricity
D_w =	28.3	ft	Depth below bottom of footing
q_e =	2,490	psf	Equivalent bearing pressure at bottom of wall

																				Total Settlement at Center of Reinforced Soil Mass					Total Settlement at Facing of Wall				
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)	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)
1	A-1-b	G	0.0	2.0	2.0	1.0	125	250	125	125	2,125					23	44	147	0.16	0.987	2,459	2,584	0.018	0.215	0.499	1,243	1,368	0.014	0.170
	A-1-b	G	2.0	4.5	2.5	3.3	125	563	406	406	2,406					23	35	115	0.52	0.803	1,999	2,406	0.017	0.202	0.477	1,188	1,594	0.013	0.155
	A-1-b	G	4.5	7.0	2.5	5.8	125	875	719	719	2,719					23	31	102	0.93	0.581	1,446	2,165	0.012	0.142	0.421	1,048	1,766	0.010	0.115
	A-1-b	G	7.0	9.5	2.5	8.3	125	1,188	1,031	1,031	3,031					23	28	94	1.33	0.438	1,092	2,123	0.008	0.100	0.358	891	1,923	0.007	0.087
2	A-1-b	G	9.5	12.0	2.5	10.8	130	1,513	1,350	1,350	3,350					38	43	142	1.73	0.348	867	2,217	0.004	0.046	0.304	758	2,108	0.003	0.041
	A-1-b	G	12.0	14.5	2.5	13.3	130	1,838	1,675	1,675	3,675					38	40	132	2.14	0.288	716	2,391	0.003	0.035	0.262	651	2,326	0.003	0.032
	A-1-b	G	14.5	17.0	2.5	15.8	130	2,163	2,000	2,000	4,000					38	38	124	2.54	0.244	608	2,608	0.002	0.028	0.228	567	2,567	0.002	0.026
	A-1-b	G	17.0	19.5	2.5	18.3	130	2,488	2,325	2,325	4,325					38	36	118	2.94	0.212	528	2,853	0.002	0.023	0.201	501	2,826	0.002	0.022
3	A-4a	G	19.5	22.5	3.0	21.0	125	2,863	2,675	2,675	4,675					22	20	40	3.39	0.185	461	3,136	0.005	0.063	0.178	443	3,118	0.005	0.060
	A-4a	G	22.5	26.0	3.5	24.3	125	3,300	3,081	3,081	5,081					22	19	38	3.91	0.161	401	3,482	0.005	0.059	0.156	389	3,470	0.005	0.057
4	A-3	G	26.0	31.0	5.0	28.5	125	3,925	3,613	3,600	5,600					17	14	49	4.60	0.137	342	3,942	0.004	0.049	0.134	334	3,934	0.004	0.048
5	A-3	G	31.0	35.0	4.0	33.0	135	4,465	4,195	3,902	5,902					50	39	93	5.32	0.119	296	4,198	0.001	0.016	0.117	291	4,193	0.001	0.016
	A-3	G	35.0	39.0	4.0	37.0	135	5,005	4,735	4,192	6,192					50	38	90	5.97	0.106	264	4,457	0.001	0.014	0.105	261	4,453	0.001	0.014
	A-3	G	39.0	44.0	5.0	41.5	135	5,680	5,343	4,519	6,519					50	36	88	6.69	0.095	236	4,755	0.001	0.015	0.094	233	4,752	0.001	0.015
																						Total Settlement:		1.006 in			Total Settlement:		0.858 in

1. $\sigma_p' = \sigma_{vo}'+\sigma_m$; Estimate σ_m of 2,000 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. $C_r = 0.075(C_c)$; 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 $C_N = [0.77\log(40/\sigma_{vo}')] \le 2.0$ 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 $\sigma_p' \le \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \le \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv 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)