Resource International, Inc.

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

DRAFT STRUCTURE FOUNDATION EXPLORATION REPORT

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

Prepared By:
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Rii Project No. B-10-020

August, 2013

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January 20, 2012 (Revised August 8, 2013)

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

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

Dear Mr. Kagel:

Resource International, Inc. (Rii) is pleased to submit this DRAFT 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. The proposed wall will be located south of the proposed HAM-561-7.01 Seymour Avenue over I-75 bridge structure on the north side of Cincinnati, 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.	Jonathan P. Sterenberg, P.E.
Project Engineer	Director of Geotechnical Services

Enclosure: DRAFT Structure Foundation Exploration Report

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EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a DRAFT structure foundation exploration for the design and construction of proposed Retaining Wall J as part of the HAM-75-7.85 project. It is understood that this wall will be connected to the rear abutment of the proposed HAM-561-7.01 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-75-7.01 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 soldier pile and lagging wall type which will connect to the southwest wingwall of the HAM-75-7.01 bridge structure. The total length of the MSE wall portion, referred to a Wall J1, is approximately 515 lineal feet, and the total length of the soldier pile and lagging wall, referred to a Wall J3, is approximately 30 lineal feet.

Exploration and Findings

Between September 27 and 29, 2011, seven (7) structural 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.

All of the 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.

Beneath the surface material in boring B-035, existing fill was encountered to a depth of 3.0 feet below the ground surface. The fill material consisted of brown gravel (ODOT A-1-a) with a lesser percentage of sand, silt and clay. Underlying the surface materials and existing fill in boring B-035, natural granular soils with intermittent seam 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 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 soldier pile and lagging wall type which will connect to the southwest wingwall of the HAM-75-7.01 bridge structure.

MSE Wall Recommendations

It is understood that a MSE retaining wall is being considered for use in supporting the proposed Ramp C from Paddock Road to I-75 southbound along the south portion of the Retaining Wall J alignment, and is referred to as Wall J1. Based upon the proposed plan and cross section information provided by the Rii design team, wall heights along the portion of the alignment that will consist of MSE wall are anticipated to range between 9.6 feet and 18.8 feet.

The anticipated bearing materials along the proposed alignment will primarily consist of loose to medium dense gravel and gravel and sand (ODOT A-1-a, A-1-b) and a small seam hard clay (ODOT A-7-6) was encountered in boring B-033 at the proposed bearing elevation of the wall. MSE wall foundations bearing on these soils or engineered fill, placed and compacted as described in Section 5.4 of the full report, 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. Based on the minimum length of reinforced soil mass presented in the table below and utilizing the soil parameters listed in Section 5.1.1 of the full report, the bearing pressure on the front portion of the wall **will not exceed** the factored nominal bearing resistance at the strength limit state at the rear abutment provided the subgrade is prepared as noted above.

Retaining Wall J Spread Footing Design Parameters

From Station [1]	To Station [1]	Representative Borings	Maximum Wall Height (ft)	Minimum Reinforcement Length [2]	Nominal Bearing Resistance (ksf)		Total Settlement [4] (in)
					Service	Strength [3]	
480+84	483+50	B-032 and B-033	18.8	0.70(H)	6.0	17.9	0.65 / 0.31
483+50	486+00	B-034 and B-035	12.3	0.73(H)	6.3	19.0	0.30 / 0.14

1. *Limits of wall determined from plan information provided by the Rii design team. 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, at the respective location.*
3. *The nominal bearing resistance at the strength limit state is unfactored. Rii recommends that a resistance factor of φ_b=0.65 be considered when calculating the factored nominal bearing resistance at the strength limit state.*
4. *The first value represents the anticipated total settlement at the center of the reinforced soil mass, and the second values represents the anticipated total settlement at the facing of the wall.*

For MSE walls bearing on soil, the limiting eccentricity is one-fourth of the base width of the wall. Based on the soil parameters listed in Section 5.1.1 of the full report, for an MSE wall designed with a minimum strap length as noted above, the calculated eccentricity of the resultant force **will not exceed** the limiting eccentricity at the strength limit state.

Based on the soil parameters listed in Section 5.1.1 of the full report for the foundation and reinforced soil backfill, a coefficient of sliding friction of 0.53 and 0.58 was utilized for design at the rear abutment. A geotechnical resistance factor of φ_τ=1.0 was considered when calculating the factored shear resistance between the foundation soil and reinforced soil backfill for sliding. Based on the minimum length of reinforced soil mass presented in above and utilizing the soil parameters listed in Section 5.1.1 of the full report for the for the foundation and reinforced soil backfill, the resultant horizontal forces on the back of the MSE wall **will not exceed** the factored shear resistance at the strength limit state.

Overall (global) stability for MSE walls supporting structural elements is satisfied when a minimum factor of safety of 1.5 is obtained under loading conditions at the service limit state. Based on the soil parameters listed in Section 5.1.1 of the full report, for MSE walls designed with minimum strap lengths as noted above, the resulting factor of safety under drained and undrained conditions was greater than 1.33.

Soldier Pile and Lagging Wall Recommendations

It is understood that a soldier pile and lagging retaining wall, referred to as Wall J3, is being considered for use along the north portion of the Retaining Wall J alignment where the existing embankment will be cut to accommodate the new configuration.

Based upon proposed plan and cross section information provided by the Rii design team, wall heights along the alignment are anticipated to range between 10.3 and 19.3 feet. Based on the subsurface conditions encountered and the maximum height of the wall, steel H-piles should be installed inside drilled shafts extending from the excavation bottom to the full wall height at each shaft location, and oriented with the web perpendicular to the wall alignment. Shafts and soldier piles employed for use in the retaining wall foundations may be proportioned based on the recommendations in the following table:

Drilled Shaft with Soldier Pile Foundation Recommendations

Wall Height (ft)	Proposed Elevations [1] (ft msl)			Shaft Spacing (ft)	Shaft Diameter (in)	Embedment Depth [2] (ft)	Pile Section
	Top	Ground	Tip				
H ≤ 19.3	550.3	531.0	511.0	4.0	24	20.0	HP 12x53

1. *Elevations estimated based on cross section information provided by the Rii design team. Actual elevations will vary along the alignment.*
2. *Embedment depth represents the length of the shaft required below the base of the wall.*

Provided drilled shafts are proportioned as outlined above, a nominal end bearing resistance of q_n = 40.0 ksf at the strength limit state may be utilized for design. A geotechnical resistance factor of φ_n = 0.50 should be considered when calculating the factored end bearing resistance. If additional resistance beyond the factored end bearing resistance is required, a nominal side resistance of q_s = 2,000 psf and geotechnical resistance factor of φ_s = 0.55 should be considered for these shafts.

An analysis of the lateral deflection was performed for the wall heights listed in the previous table. For the center to center spacing, embedment depth and section type specified, the deflection determined from the LPILE analysis met the criteria of less than 1.0 percent of the wall height, and the section utilized met the structural capacity requirements.

Per Section 11.6.2.3 of the 2010 AASHTO LRFD BDS, overall (global) stability for walls not supporting structural foundations on spread footings is satisfied when a minimum factor of safety of 1.33 is obtained. Using the parameters provided in Section 5.2.2 of the full report in the section analyzed, a resulting factor of safety of 3.80 was determined for the maximum wall height at Station 490+50, satisfying the minimum requirement of 1.33.

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 DRAFT report is a presentation of the structure foundation exploration performed for the design and construction of proposed Retaining Wall K 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-561-7.01 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-75-7.01 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 soldier pile and lagging wall type which will connect to the southwest wingwall of the HAM-75-7.01 bridge structure. The total length of the MSE wall portion, referred to a Wall J1, is approximately 515 lineal feet, and the total length of the soldier pile and lagging wall, referred to a Wall J3, is approximately 30 lineal feet.

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 proposed wall begins at Station 480+84 and continues north to Station 490+69 along the west side of I-75. 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) structural 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.

Table 1. Test Boring Summary

Boring Number	Station	Offset	Latitude	Longitude	Ground Elevation (feet)	Boring Depth
B-032-0-11	480+99.46	90.5' Lt.	39.191055614 °N	84.479969446 °W	532.7	50.0
B-033-0-11	483+15.31	101.2' Lt.	39.191518417 °N	84.479485137 °W	533.8	50.0
B-034-0-11	484+36.55	91.3' Lt.	39.191744711 °N	84.479169544 °W	535.2	50.0
B-035-0-11	485+91.35	105.8' Lt.	39.192084006 °N	84.478836739 °W	533.6	50.0
B-037-0-11	487+14.20	121.3' Lt.	39.192360602 °N	84.478582797 °W	534.3	25.0
B-038-0-11	488+43.87	109.0' Lt.	39.192599270 °N	84.478240581 °W	538.3	25.0
B-039-0-11	489+88.69	114.9' Lt.	39.192902551 °N	84.477909539 °W	545.2	50.0

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 an all-terrain vehicle (ATV)-mounted rotary drilling machine, utilizing a 4.25-inch inside diameter, continuous hollow-stem auger to advance the hole. The borings were terminated after achieving a minimum of 20 feet of 30-blow material below the anticipated bottom of footing elevation and were advanced to depths greater than 1.5 times the wall height below the proposed bottom of footing elevation per the current Ohio Department of Transportation (ODOT) Specifications for Geotechnical Explorations (SGE).

Standard penetration testing (SPT) and split spoon sampling were performed in the boring at 2.5-foot increments of depth to 30 feet 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 by letting a 140-pound hammer falling 30.0 inches to drive a 2.0-inch outer 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-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 ATV-mounted drill rig used for this project was calibrated on May 6, 2011, and has a drill rod energy ratio of 77.1 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	100
Plastic and Liquid Limits	AASHTO T89, T90	21
Sieve/Hydrometers	AASHTO T88	21

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. 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

All of the 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 surface material in boring B-035, existing fill was encountered to a depth of 3.0 feet below the ground surface. The fill material consisted of brown gravel (ODOT A-1-a) with a lesser percentage of sand, silt and clay.

Underlying the surface materials and existing fill in boring B-035, natural granular soils with intermittent seam 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 4 percent above their corresponding plastic limits. The moisture contents of the native soils are generally considered to be moderately below to moderately above the 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) [1]	Initial Groundwater		At Completion		Cave-in Depth	
		Depth	Elevation	Depth	Elevation	Depth	Elevation
B-032-0-11	533.1	29.5	503.6	N/A [2]	N/A	N/A [2]	N/A
B-033-0-11	534.0	29.0	505.0	N/A [2]	N/A	N/A [2]	N/A
B-034-0-11	535.3	34.3	501.0	N/A [2]	N/A	N/A [2]	N/A
B-035-0-11	533.9	34.2	499.7	25.4 [3]	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 [3]	514.5	17.7	527.2

1. *Ground elevation listed is the ground surface elevation at the boring location.*
2. *Groundwater at completion was not measured due to the addition of mud as a drilling fluid.*
3. *Groundwater level at completion was measured inside the auger stems.*

Groundwater was encountered initially during the drilling process in borings B-032 through B-035 and B-039 at depths ranging from 29.5 to 36.5 feet below the ground surface. At the completion of drilling and prior to removing the augers, groundwater accumulated in the auger stems in borings B-035 and B-039 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-032 and B-034 due to the addition of mud as a drilling fluid. 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 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 soldier pile and lagging wall type which will connect to the southwest wingwall of the HAM-75-7.01 bridge structure.

5.1 MSE Wall Recommendations

It is understood that a MSE retaining wall is being considered for use in supporting the proposed Ramp C from Paddock Road to I-75 southbound along the south portion of the Retaining Wall J alignment, and is referred to as 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 to the top of MSE wall. 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 feet whichever is greater. A non-structural bearing leveling pad consisting of a minimum of 6-inches of unreinforced concrete should be placed at the base of the wall for constructability purposes. Please note that the leveling pad is not a structural foundation.

Based upon the proposed plan and cross section information provided by the Rii design team, wall heights along the portion of the alignment that will consist of MSE wall are anticipated to range between 9.6 feet and 18.8 feet. Therefore, it is considered that the minimum reinforcement lengths and the effective foundation width (B) of the MSE wall for external stability calculations and global stability analysis will range from 8.0 and 13.2 feet along the 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 for various wall heights and subsurface conditions.

It is recommended that the foundation subgrade (reinforced soil mass) for the MSE wall be critically proof-rolled and stabilized to create a workable subgrade for the MSE wall reinforced soil mass. Unstable soils, primarily those containing silt (A-4a/A-4b), if encountered, may be stabilized as noted below:

- Undercut 24 inches +/- pending results of proof-roll;
- Place ODOT Item 712.09 Type D Geotextile Fabric;
- Placement of 24 inches of 703.16C Type C Granular Fill.

Please note that this recommendation for stabilization of unsuitable soils, as identified during the proof roll of the subgrade, are in addition to the foundation preparation measures provided in ODOT SS 840.

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 Stability Analyses

Material Type	Unit Weight, γ (pcf)	Effective Stress Parameters		Undrained Shear Strength, S_u (psf)
		φ' (°)	c' (psf)	
Reinforced Soil Backfill (Select granular backfill)	120	34	0	N/A
Embankment Fill (Fill material derived from onsite soils)	120	30	400	2,000
Loose to Very Dense Granular Soils (ODOT A-1-a, A-1-b, A-3a, A-3, A-4a)	120 to 130	28 to 35	0	N/A

Shear strength parameters for the reinforced soil backfill are provided in ODOT SS 840. Per SS 840, the select granular backfill in the reinforced zone must meet the shear strength requirements provided in Table 4. Shear strength parameters for new embankment fill were determined using ODOT Geotechnical Bulletin 6 (GB-6) as a guide. The shear strength parameters for the embankment fill listed in Table 4 above are the limiting values based on the assumption that the embankment fill utilized will consist of silt and clay, sandy silt (ODOT A-6a, A-4a) or granular material. The friction angle for the natural granular soil encountered was determined based on correlations with the N_{60} value from the SPT testing of the soil.

5.1.2 Bearing Stability

The anticipated bearing materials along the proposed alignment will primarily consist of loose to medium dense gravel and gravel and sand (ODOT A-1-a, A-1-b) and a small seam hard clay (ODOT A-7-6) was encountered in boring B-033 at the proposed bearing elevation of the wall. MSE wall foundations bearing on these soils or engineered fill, placed and compacted as described in Section 5.4, 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. The corresponding settlement values presented in the following tables were determined using the equivalent bearing pressure based on the net increase in stress due to the construction of the wall (the vertical change in grade from the existing condition at the wall location to the proposed profile grade at the top of the wall) and corresponding minimum reinforcement length as noted below for each section of the wall. Settlement calculations are provided in Appendix VI.

Table 5. Retaining Wall J Spread Footing Design Parameters

From Station [1]	To Station [1]	Representative Borings	Maximum Wall Height (ft)	Minimum Reinforcement Length [2]	Nominal Bearing Resistance (ksf)		Total Settlement [4] (in)
					Service	Strength [3]	
480+84	483+50	B-032 and B-033	18.8	0.70(H)	6.0	17.9	0.65 / 0.31
483+50	486+00	B-034 and B-035	12.3	0.73(H)	6.3	19.0	0.30 / 0.14

1. *Limits of wall determined from plan information provided by the Rii design team. 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, at the respective location.*
3. *The nominal bearing resistance at the strength limit state is unfactored. Rii recommends that a resistance factor of φ_b=0.65 be considered when calculating the factored nominal bearing resistance at the strength limit state.*
4. *The first value represents the anticipated total settlement at the center of the reinforced soil mass, and the second values represents the anticipated total settlement at the facing of the wall.*

Rii performed a verification of the bearing pressure exerted on the subgrade material for the maximum specified wall heights indicated in the previous tables. Based on the minimum lengths of reinforced soil mass presented, the bearing pressure exerted at the front of the wall **will not exceed** the factored nominal bearing resistance at the strength limit state.

Total settlements of 0.30 to 0.65 inches at the center of the reinforced soil mass and 0.14 to 0.31 inches at the facing of the wall are anticipated along the proposed wall alignment. 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 wall, maximum differential settlement in the longitudinal direction is anticipated to be less than 1/1000, which is within the tolerable limit of 1/100. If either the total or differential settlement predicted presents 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 wall. If preloading the site is not a desired option, then consideration could be given to ground improvement through the use of stone columns

5.1.3 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 2010 AASHTO LRFD BDS, for foundations bearing on soil or bedrock, the location of the resultant of the reaction forces shall be within the middle one-half of the base width. Therefore, the limiting eccentricity is one-fourth of the base width of the wall. Rii performed a verification of the eccentricity of the resultant force for the maximum specified wall height 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.

5.1.4 Sliding Stability

The resistance of the MSE walls to sliding will be dependent on the friction between the reinforced soil backfill and bearing soils per Section 11.10.5.3 of the 2010 AASHTO LRFD BDS. For MSE walls, 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 retained 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 when calculating the factored shear resistance between the reinforced soil backfill and foundation soil for sliding. 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.

5.1.5 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 external 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.

Per Section 11.6.2.3 of the 2010 AASHTO LRFD BDS, overall (global) stability for MSE walls not supporting structural foundations on spread footings 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 1.33 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 1.33. The wall was also evaluated under undrained conditions (short-term stability) to verify the stability of the wall during and immediately following construction. The resulting factor of safety along the alignment under undrained conditions was also greater than 1.33.

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

5.1.6 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 proposed profile grade of the roadway) for wall heights greater than 12.3 feet along the length of the wall alignment. For wall heights less than 12.3 feet, the recommended controlling strap length is 0.73 times the height of the MSE wall. Limiting eccentricity was the controlling factor in the determination of the recommended strap length of 73 percent of the wall height required for wall heights less than 12.3 feet.

5.2 Soldier Pile and Lagging Wall Recommendations

It is understood that a soldier pile and lagging retaining wall, referred to as Wall J3, is being considered for use along the north portion of the Retaining Wall J alignment where the existing embankment will be cut to accommodate the new configuration. Based upon proposed plan and cross section information provided by the Rii design team, wall heights along the alignment are anticipated to range between 10.3 and 19.3 feet. Based on the subsurface conditions encountered and the maximum height of the wall, steel H-piles should be installed inside drilled shafts extending from the excavation bottom to the full wall height at each shaft location, and oriented with the web perpendicular to the wall alignment. Shafts and soldier piles employed for use in the retaining wall foundations may be proportioned based on the recommendations in Table 6:

Table 6. Drilled Shaft with Soldier Pile Foundation Recommendations

Wall Height (ft)	Proposed Elevations [1] (ft msl)			Shaft Spacing (ft)	Shaft Diameter (in)	Embedment Depth [2] (ft)	Pile Section
	Top	Ground	Tip				
H ≤ 19.3	550.3	531.0	511.0	4.0	24	20.0	HP 12x53

1. *Elevations estimated based on cross section information provided by the Rii design team. Actual elevations will vary along the alignment.*
2. *Embedment depth represents the length of the shaft required below the base of the wall.*

The ground elevations listed in Table 6 coincide with the bottom of wall elevations, and the embedment depths reflect exclusively the length of the shaft in contact with the soil. The walls were evaluated to determine the center to center spacing required between the drilled shaft elements as well as the required embedment depth for the interval of wall heights listed in Table 6. Provided drilled shafts are proportioned as outlined above, a nominal end bearing resistance of q_n = 40.0 ksf at the strength limit state may be utilized for design. A geotechnical resistance factor of φ_n = 0.50 should be considered when calculating the factored end bearing resistance. If additional resistance beyond the factored end bearing resistance is required, a nominal side resistance of q_s = 2,000 psf and geotechnical resistance factor of φ_s = 0.55 should be considered for these shafts. Based on the above noted bearing resistance, a maximum settlement of the foundation is estimated to be 1.0-inch.

5.2.1 Lateral Design

The foundation elements for the soldier pile and lagging retaining wall was analyzed to verify that the pile section utilized has enough lateral and bending resistance to support the lateral load applied from the retained soil. It is understood that the maximum allowable lateral deflection is 1.0 percent of the wall height. Table 7 was used for lateral loading design:

Table 7. Lateral Design Parameters

Boring No.	Depth (feet)	Strata	Effective Unit Weight	Strength Parameter	k (soil)	ε_{50} (soil)
B-039-0-11	0.0 – 5.0	4	125 pcf	φ = 30º	90 pci	N/A
	5.0 – 23.5	4	135 pcf	φ = 35º	225 pci	N/A
	Below 23.5	4	72.6 pcf	φ = 35º	125 pci	N/A

1. *Depth listed represents the depth below the ground surface at the base of the wall (embedment depth). Loading above the wall was modeled using a triangular load distribution.*

In order to evaluate the lateral capacity, the LPILE Plus 5.0 program was utilized to determine the proper embedment depth and cross section to resist the lateral load for the given end condition and deflection criteria. Note that the table was prepared with a design groundwater elevation as indicated on the boring logs. The following table lists the eleven different soil types internal to the LPILE Plus 5.0 program. These strata were utilized in Table 7 for evaluating the soil layers.

Table 8. Soil Strata Description

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

Using the conditions and parameters in the previous tables, an analysis of the lateral deflection was performed for the wall heights listed in Table 6. For the center to center spacing, embedment depth and section type specified, the deflection determined from the LPILE analysis met the criteria of less than 1.0 percent of the wall height, and the section utilized met the structural capacity requirements.

5.2.2 Overall (Global) Stability

A slope stability analysis was performed to evaluate the global stability of the soldier pile and lagging retaining wall system. Global stability was checked at the maximum wall height of 19.3 feet, at Station 490+50. Soil parameters utilized in external stability analyses are presented in the following paragraphs. For the global stability condition, it was considered that the failure plane will not cross through the lagging, and that an increase in shear strength will occur due to soil arching between adjacent shafts where the soldier piles are embedded below the ground surface. The following long term strength parameters were utilized for the soil:

Table 9. Shear Strength Parameters Utilized in Stability Analyses

Material Type	Unit Weight, γ (pcf)	Long Term (Effective Stress) Parameters	
		φ' (°)	c' (psf)
Very Loose to Loose Coarse and Fine Sand (ODOT A-3a)	120	27	0
Medium Dense Gravel and Sand (ODOT A-1-b)	125	30	0
Dense to Very Dense Gravel and Sand (ODOT A-1-b)	135	35	0
Medium Dense to Dense Sandy Silt (ODOT A-4a) [1]	125	31	0
Very Stiff Silt and Clay [2] (ODOT A-6a)	120	27	235

1. *Based on laboratory consolidated undrained triaxial testing performed on an undisturbed sample of similar material from the HAM-75-11.09 project.*
2. *Based on laboratory consolidated undrained triaxial testing performed on an undisturbed sample of similar material from boring B-016-0-11 performed for Retaining Wall H.*

The soldier piles were modeled in the slope stability analysis by incorporating a soil layer with a width and depth equal to the diameter and embedment depth of the shafts, respectively. The following shear strength parameters were assigned to this layer to model the shear strength increase due to soil arching between the shafts.

- $\varphi = 40^{o}$
- c = 10,000 psf
- γ = 140 pcf

Per Section 11.6.2.3 of the 2010 AASHTO LRFD BDS, overall (global) stability for walls not supporting structural foundations on spread footings 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 1.33 is obtained. Using the parameters above in the section analyzed, a resulting factor of safety of 3.80 was determined for the maximum wall height at Station 490+50, satisfying the minimum requirement of 1.33.

Calculations for wall deflection, structural capacity and overall (global) stability of the soldier pile and lagging retaining wall system are provided in Appendix VIII.

5.2.3 Drilled Shaft Considerations

The minimum requirements for proper inspection of drilled shaft construction are as follows:

- A qualified inspector should record the material types being removed from the hole as excavation proceeds.
- The use of casing for drilled shafts is recommended if caving material and/or groundwater is encountered at any time during the drilling of the shaft, or if groundwater seepage occurs in the drilled shaft.
- The placement of all concrete for the drilled shafts shall follow the American Concrete Institute's Design and Construction of Drilled Piers (ACI 336.3R-93).
- Concrete placed freefall should not be allowed to hit the sidewalls of the excavation and should not pass through any water. Therefore, concrete should be placed by tremie method if groundwater is encountered during construction of the drilled shafts.
- If concrete is placed by tremie method, it must be done so with an adequate head to displace water or slurry if groundwater has entered the caisson (all tremie procedures shall follow applicable ACI specifications).
- The volume of concrete should be checked to ensure voids did not result during extraction of the casing.
- Pulling casing with insufficient concrete inside should be restricted.
- The bottom of drilled shaft excavation should be clean and free of loose material. Any loose material observed should be removed using a clean-out bucket (muck bucket).

In addition, it is recommended that, if casing is used, it be pulled after the concrete is poured, allowing for reuse of the casing, and eliminating reduction of side resistance (between soil and concrete).

5.3 Lateral Earth Pressure

For the soil types encountered in the borings, the "in-situ" unit weight (γ), cohesion (c), effective angle of friction (φ'), and lateral earth pressure coefficients for at-rest conditions (k_o), active conditions (k_a), and passive conditions (k_p) have been estimated and are provided in Table 10 and Table 11.

Table 10. 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	125	1,500	0°	1.0	1.0	1.0
Compacted Granular Engineered Fill	135	0	33°	0.30	0.46	3.39

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

Table 11. 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	125	0	28°	0.36	0.53	2.77
Compacted Granular Engineered Fill	135	0	33°	0.30	0.46	3.39

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

These parameters are considered appropriate for the design of subsurface walls and excavation support systems. It is recommended that the retaining wall structure be designed based on active 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 based on cross section information provided by the Rii design team). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage.

5.4 Construction Considerations

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

Fill soil placed for foundation support should be placed in loose lifts not to exceed 8.0 inches. Fill soil placed under structures shall be compacted to not less than 100 percent of the maximum dry density obtained by the Standard Proctor Test (ASTM D698). Fill soil containing excess moisture shall be required to dry prior to or during compaction to a moisture content not greater than 3.0 percent above or below optimum. However, for material that displays pronounced elasticity or deformation under the action of loaded rubber tire construction equipment, the moisture content shall be reduced to optimum if necessary to secure stability. Drying of wet soil shall be expedited by the use of plows, discs, or by other approved methods when so ordered by the site geotechnical engineer.

Generally, materials utilized for engineered fill should free of waste construction debris and other deleterious materials and meet the following requirements:

- Maximum Dry Density per ASTM D698 > 110 pcf
- Liquid Limit < 40
- Plasticity Index < 15
- Organic Matter < 3 percent
- Maximum Particle Size < 3 inches
- Silt Content (between 0.075 and 0.005 mm) < 45 percent

Compacted granular fill shall meet the above specification and additionally shall have a maximum 35 percent passing the No. 200 sieve.

5.4.1 Excavation Considerations

All excavations should be shored / braced or laid back at a safe angle in accordance to Occupational Safety and Health Administration (OSHA) guidelines. During excavation, if slopes cannot be laid back to OSHA Standards due to adjacent structures or other obstructions, sheeting boxes 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 12. 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

5.4.2 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. In the case of drilled shafts, the utilization of casing will be required below the water table to maintain an open hole and prevent the sidewalls from collapse. In addition, concrete placed below the water table should be placed by tremie method as described in Section 5.2.3. 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 our recommendations.

Our 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 preliminary design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be brought to the attention of the geotechnical engineer to determine whether any changes in the foundation or earthwork recommendations are necessary. If deviations from the noted subsurface conditions are encountered during construction, they should also be brought to the attention of the geotechnical engineer.

The scope of our services does not include any environmental assessment or investigation for the presence or absence 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

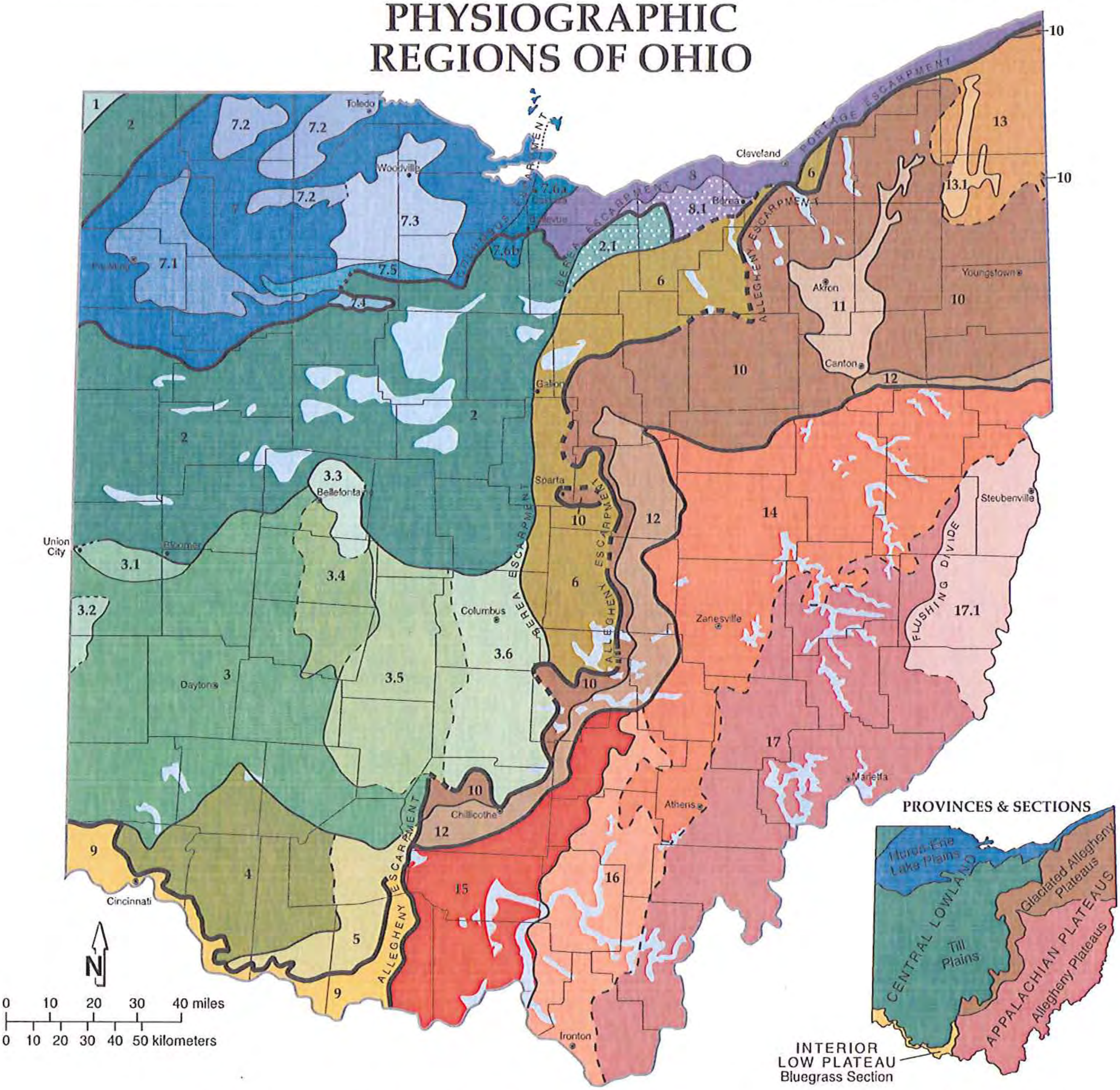
STATE GEOLOGY

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

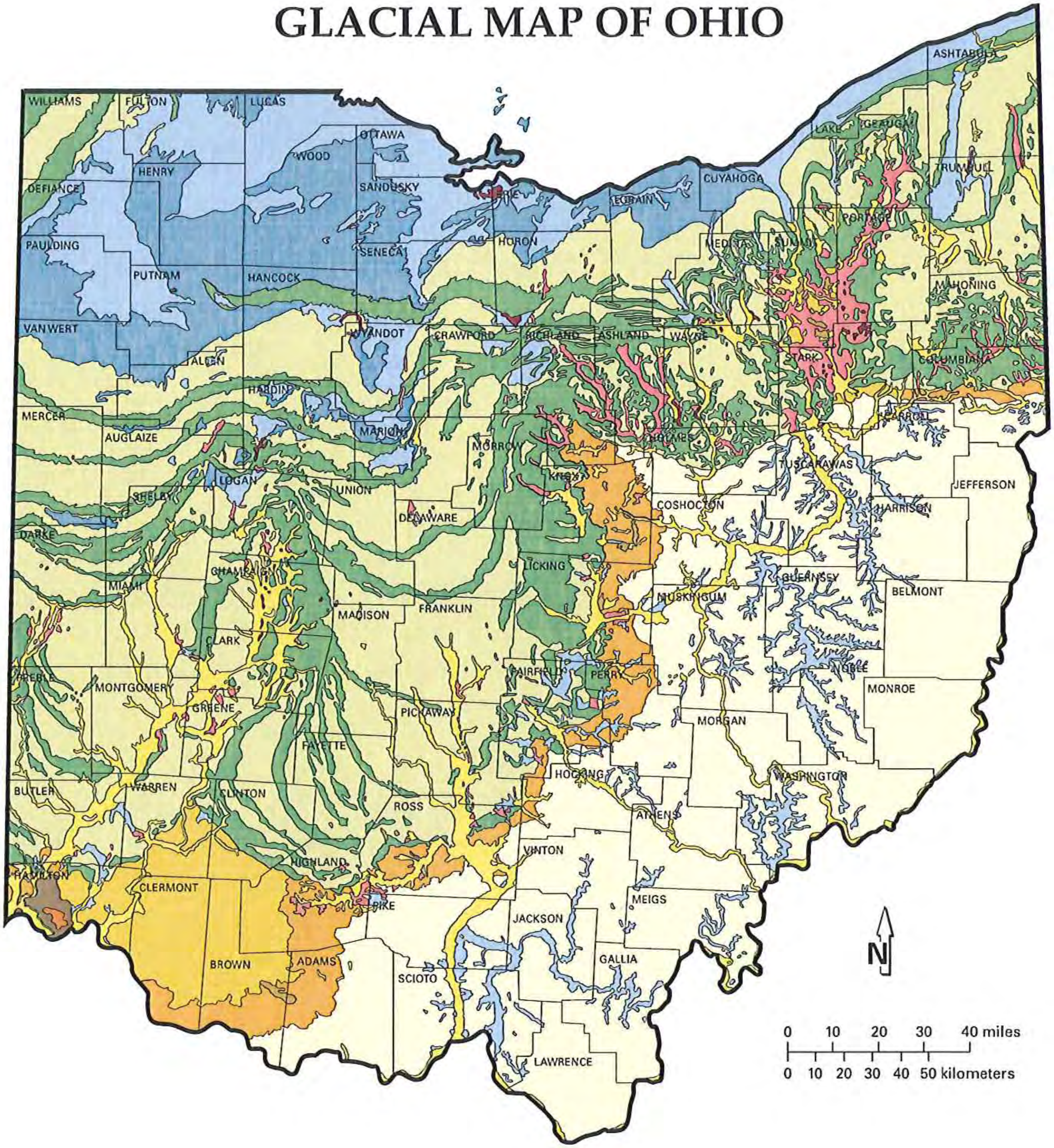
Recommended citation: Ohio Division of Geological Survey, 1998, Physiographic regions of Ohio: Ohio Department of Natural Resources, Division of Geological Survey, page-size map with text, 2 p., scale 1:2,100,00.

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)
- Ground moraine
- Wave-planed ground moraine
- End moraine

ILLINOIAN (130,000 to 300,000 years old)
- Ground moraine
- Dissected ground moraine
- Hummocky moraine

PRE-ILLINOIAN (older than 300,000 years)
- Ground moraine
- Dissected ground moraine

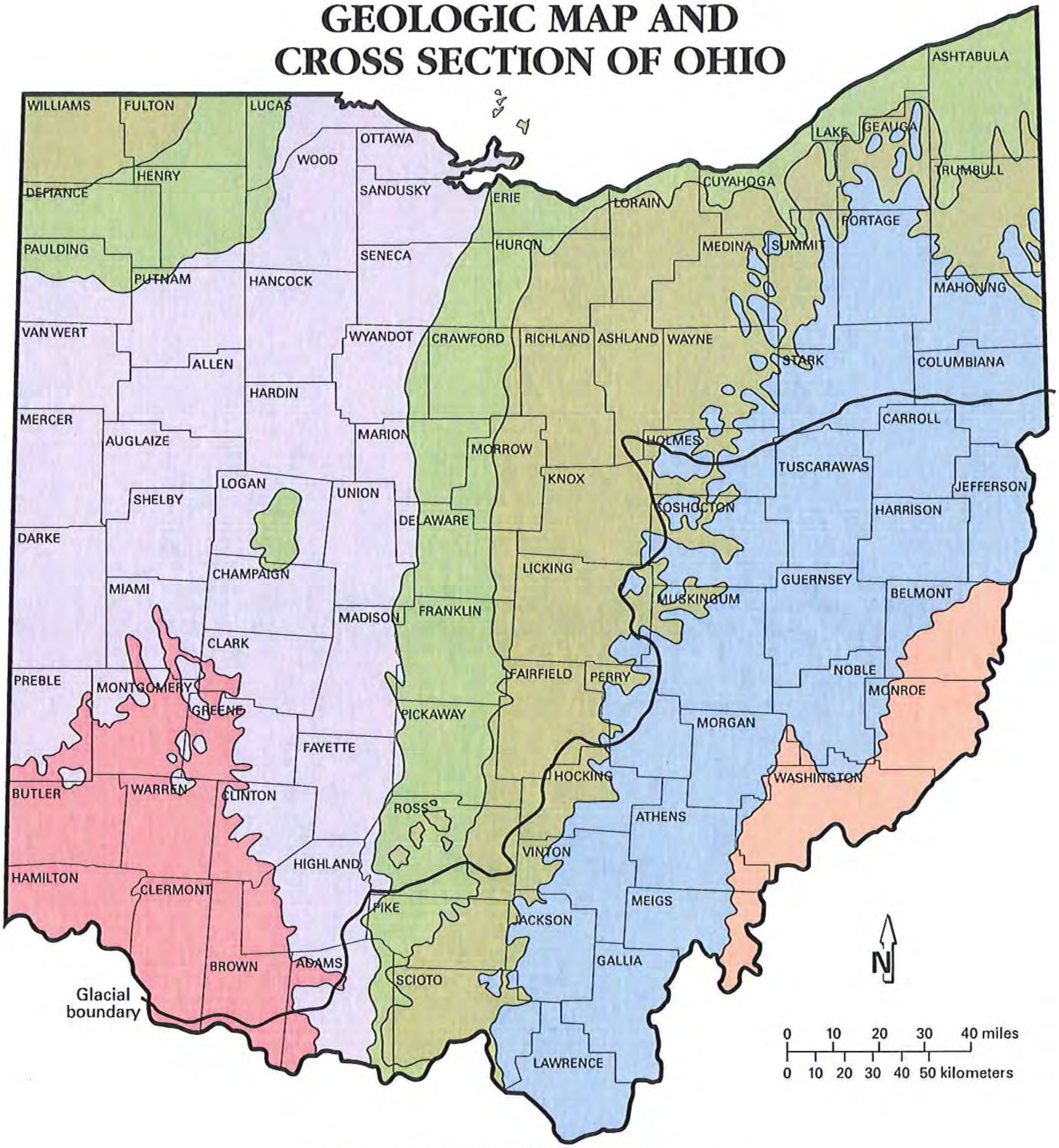
- Kames and eskers
- Outwash
- Lake deposits
- Peat
- Colluvium

STATE OF OHIO
Bob Taft, Governor

DEPARTMENT OF NATURAL RESOURCES
Samuel W. Speck, Director

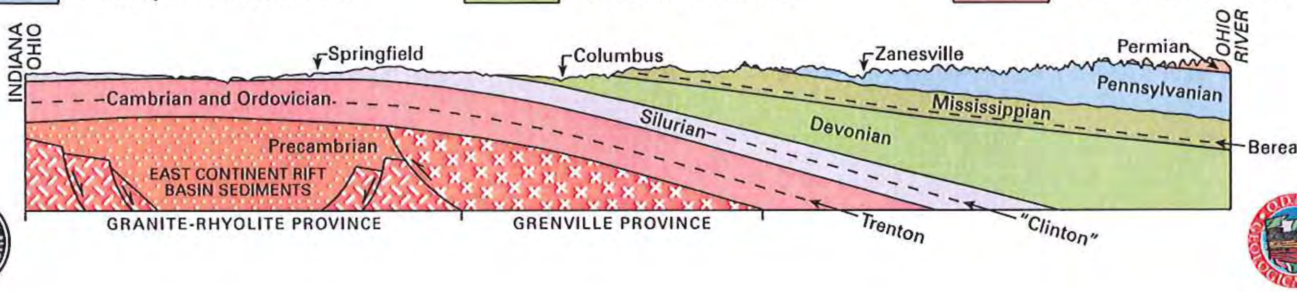
DIVISION OF GEOLOGICAL SURVEY
Thomas M. Berg, Chief

GEOLOGIC MAP AND CROSS SECTION OF OHIO



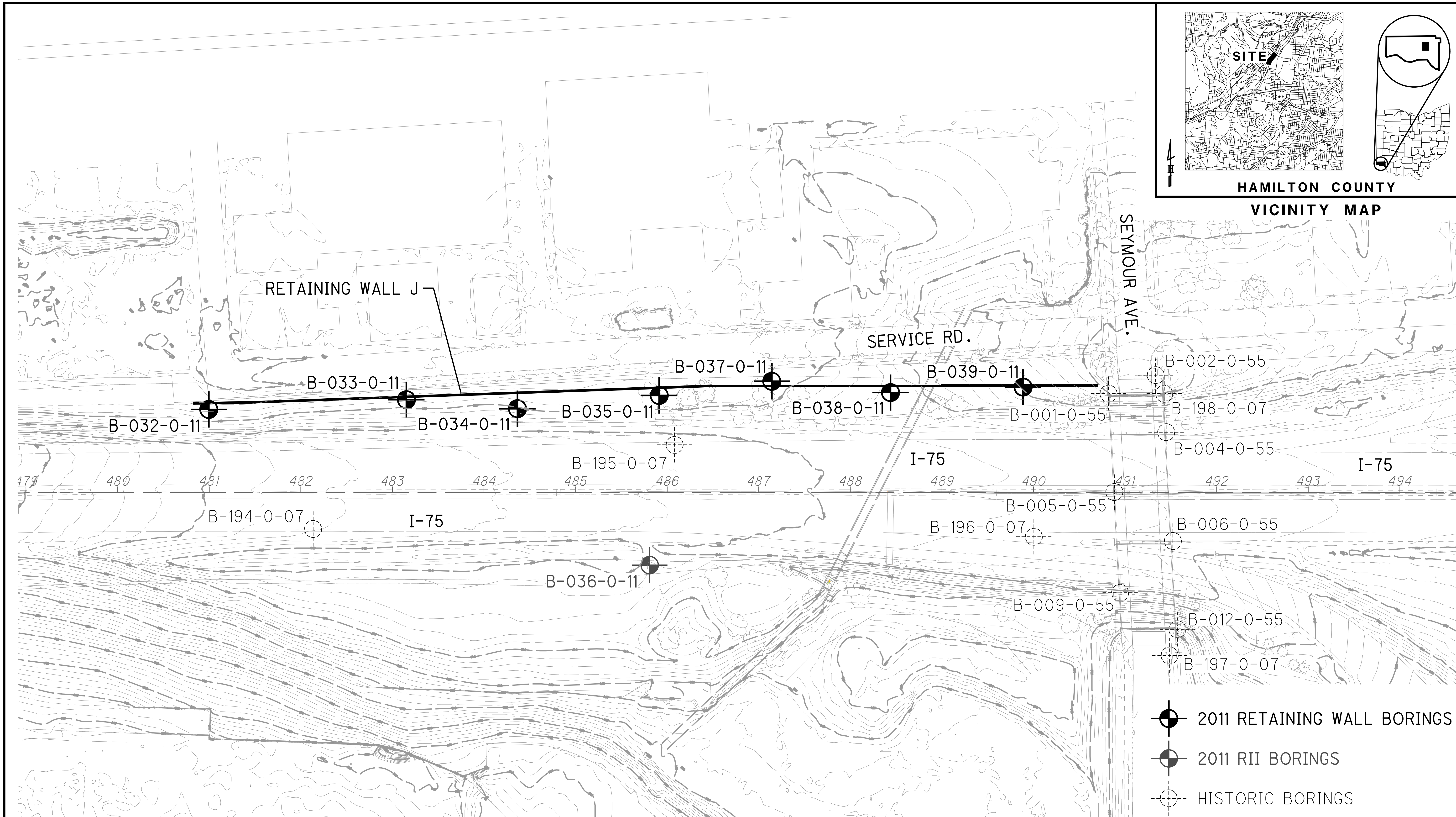
GEOLOGIC SYSTEM (million years before present)

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



BORING PLAN

HAM-75-7.85 RETAINING WALL J

HAMILTON COUNTY, OHIO

PROJECT NO. Rii B-10-020	DRAWN RRM	RESOURCE INTERNATIONAL, INC.
SCALE: 1"=100' (0 50 100)	REVIEWED BRT	
	DATE 6-9-12	

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	≥ 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	
	Fine Sand	A-3			51 Min.	10 Max.	NON-PLASTIC	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-032-0-11 through B-035-0-11 and
B-037-0-11 through B-039-0-11

Definitions of Abbreviations for Boring Logs

A	=	Adhesion (pounds per square foot)
AS	=	Auger Sample
BCP	=	Bentonite Chips or Pellets
C	=	Cohesion (pounds per square foot)
CB	=	Cased (Concentric) Boring
C/B	=	Neat Cement/Bentonite Grout
Cl^-	=	Chloride Ion Concentration (parts per million)
FA	=	Angle of Internal Friction (degrees)
FF	=	Friction Factor
GS	=	Geoprobe Sample
HSA	=	Hollow Stem Auger
HSB	=	High Solids Content Bentonite Grout
K	=	Modulus of Horizontal Subgrade Reaction (kips per cubic foot)
LOI	=	Percent Organic Content (by weight) as determined by ASTM D-2974 (loss on ignition test)
MD	=	Rotary Mud Drilling
NQ	=	Wireline Method (1.875-inch diameter rock core)
NX	=	Conventional Method (2.126-inch diameter rock core)
PC	=	Neat Portland Cement Grout
PID	=	Photo-Ionization Detector Reading (parts per million)
qh	=	Unconfined Compressive Strength of Soil as determined by a hand penetrometer (tons per square foot)
qr	=	Unconfined Compressive Strength of Intact Rock Core as determined by ASTM D-2938 (pounds per square inch)
qu	=	Unconfined Compressive Strength of Soil as determined by ASTM D-2166 (tons per square foot)
quu	=	Unconsolidated-Undrained Triaxial Compressive Strength as determined by ASTM D-2850 (pounds per square foot)
RC	=	Rock Coring
SO^{4-}	=	Sulfate Concentration
SFA	=	Solid Flight Auger
SS	=	Split Spoon Sample
3S	=	For instances of no recovery from standard SS interval, a 3.0 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 3S sampling are not correlated with N_{60} values.
ss	=	Soluble Salts (conductivity)
ST	=	Thin-walled (Shelby) Tube Sample
uw	=	"In-Situ" Unit Weight of Soil (pounds per cubic foot)
VIS	=	Visual classification only, no testing performed
WOH	=	Weight of Hammer and Drill Rods "pushed" split spoon sampler 6-inches.
WD	=	Rotary Wash Drilling

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
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.
START: 9/29/11	END: 9/29/11	SAMPLING METHOD:	SPT	ENERGY RATIO (%):	77.1	LAT / LONG:	39.191055614 ° N / 84.479969446 ° W

EXPLORATION ID B-032-0-11

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

DEPTHS (ft)	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)
1.0–2.5	3 7 5	15	78	SS-1	2.25	-	-	-	-	-	-	-	-	11	A-2-6 (V)
3.5–5.0	3 4 5	12	67	SS-2	2.00	8	28	33	14	17	33	17	16	12	A-2-6 (1)
6.0–7.5	4 4 3	9	44	SS-3	-	-	-	-	-	-	-	-	-	2	A-1-a (V)
8.5–10.0	5 9 13	28	61	SS-4	-	-	-	-	-	-	-	-	-	2	A-1-a (V)
11.0–12.5	11 11 13	31	78	SS-5	-	-	-	-	-	-	-	-	-	2	A-1-a (V)
13.5–15.0	5 8 9	22	83	SS-6	-	-	-	-	-	-	-	-	-	3	A-1-a (V)
16.0–17.5	8 12 10	28	78	SS-7	-	-	-	-	-	-	-	-	-	3	A-1-a (V)
18.5–20.0	6 10 12	28	78	SS-8	-	54	30	10	5	1	NP	NP	NP	3	A-1-a (0)
21.0–22.5	16 21 20	53	89	SS-9	-	-	-	-	-	-	-	-	-	3	A-1-a (V)
23.5–25.0	8 9 8	22	83	SS-10	-	-	-	-	-	-	-	-	-	4	A-1-a (V)
26.0–27.5	9 9 12	27	89	SS-11	-	-	-	-	-	-	-	-	-	4	A-1-a (V)

BACK FILL

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

MEDIUM DENSE TO DENSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE FINE GRAVEL, WET.

-INTRODUCED MUD @ 30.0'

-COBBLES PRESENT THROUGHOUT

ELEV. 504.7 (top) – 482.7 (bottom); groundwater symbol (W) at 29.5'; EOB at 50'

DEPTHS	SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
29–30	6 8 8	21	89	SS-12	-	-	-	-	-	-	-	-	-	20	A-3a (V)
34–35	2 8 12	26	100	SS-13	-	-	-	-	-	-	-	-	-	26	A-3a (V)
39–40	4 6 12	23	89	SS-14	-	1	4	80	12	3	NP	NP	NP	19	A-3a (0)
44–45	4 11 13	31	100	SS-15	-	-	-	-	-	-	-	-	-	24	A-3a (V)
49–50	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

PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 483+15.31 / 101.2' 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: 533.8 (MSL) EOB: 50.0 ft.
START: 9/28/11 END: 9/28/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG: 39.191518417 ° N / 84.479485137 ° W

EXPLORATION ID B-033-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV. 533.8
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
HARD, BROWN **CLAY**, AND COARSE TO FINE SAND, SOME SILT, TRACE FINE GRAVEL, DAMP. -COBBLES PRESENT THROUGHOUT	525.8
LOOSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY.	520.8
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY TO MOIST. -COBBLES PRESENT THROUGHOUT	505.8

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
1 / 2 / 3	6	50	SS-1	1.00	-	-	-	-	-	-	-	-	17	A-6a (V)
7 / 13 / 15	36	78	SS-2	4.50	1	28	30	13	28	41	16	25	12	A-7-6 (5)
17 / 13 / 7	26	67	SS-3	4.50	-	-	-	-	-	-	-	-	9	A-7-6 (V)
3 / 3 / 4	9	22	SS-4	-	-	-	-	-	-	-	-	-	2	A-1-b (V)
4 / 3 / 5	10	56	SS-5	-	-	-	-	-	-	-	-	-	4	A-1-b (V)
7 / 12 / 13	32	78	SS-6	-	-	-	-	-	-	-	-	-	2	A-1-b (V)
16 / 16 / 16	41	78	SS-7	-	-	-	-	-	-	-	-	-	2	A-1-b (V)
5 / 9 / 11	26	67	SS-8	-	28	43	21	7	1	NP	NP	NP	5	A-1-b (0)
7 / 12 / 15	35	89	SS-9	-	-	-	-	-	-	-	-	-	3	A-1-b (V)
12 / 28 / 25	68	50	SS-10	-	-	-	-	-	-	-	-	-	9	A-1-b (V)
16 / 16 / 19	45	78	SS-11	-	-	-	-	-	-	-	-	-	6	A-1-b (V)

DEPTHS: 1–27 ft; BACK FILL column.

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. (FS)		W 29 – 30	11 9 10	24	61	SS-12	-	-	-	-	-	-	-	-	-	19	A-3 (V)	
-INTRODUCED MUD @ 30.0'		31 – 33																
		34 – 35	9 11 14	32	100	SS-13	-	1	2	87	9	1	NP	NP	NP	23	A-3 (0)	
		36 – 38																
		39 – 40	8 11 14	32	100	SS-14	-	-	-	-	-	-	-	-	-	28	A-3 (V)	
-COBBLES PRESENT THROUGHOUT		41 – 43																
		44 – 45	11 12 11	30	100	SS-15	-	-	-	-	-	-	-	-	-	22	A-3 (V)	
		46 – 48																
	483.8	49 – 50 EOB	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	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
								GRADATION (%)					ATTERBERG					
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	1 - 2	1 2 2	5	33	SS-1	1.00	-	-	-	-	-	-	-	-	16	A-6a (V)	
LOOSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP.	529.7	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)	
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DRY TO DAMP.		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)	
	509.7	23.5 - 25	9 16 14	39	72	SS-10	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
VERY STIFF, BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, MOIST.	507.2	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)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG 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	32																
MEDIUM DENSE, BROWN **FINE SAND**, LITTLE COARSE SAND, TRACE SILT, TRACE CLAY, WET.		W 34–35	4 7 6	17	67	SS-13	-	-	-	-	-	-	-	-	-	25	A-3 (V)	
-INTRODUCED MUD @ 35.0'	498.2	37																
DENSE TO VERY DENSE, BROWN **FINE SAND**, LITTLE COARSE SAND, TRACE SILT, TRACE CLAY, WET.		39–40	9 19 24	55	89	SS-14	-	-	-	-	-	-	-	-	-	22	A-3 (V)	
		44–45	12 16 19	45	67	SS-15	-	-	-	-	-	-	-	-	-	22	A-3 (V)	
	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

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
START: 9/28/11 END: 9/28/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG: 39.192084006° N / 84.478836739° W	1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 533.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
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	1–2	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	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	6–7	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	10-8-9	22	39	SS-4	-	-	-	-	-	-	-	-	-	6	A-1-b (V)
		11–12	10-8-8	21	67	SS-5	-	-	-	-	-	-	-	-	-	6	A-1-b (V)
		14	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)
		19	18-27-31	75	22	SS-8	-	-	-	-	-	-	-	-	-	4	A-1-b (V)
	510.6	21–22	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 (water level ▼ ~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)

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

PID: 77889	BR ID: NA	PROJECT: HAM-75-7.85	STATION / OFFSET: 485+91.35 / 105.8' Lt	START: 9/28/11	END: 9/28/11	PG 2 OF 2	B-035-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV. 505.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MMEDIUM DENSE TO VERY DENSE, BROWN CHANGING TO GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST TO WET.		29	5 6 5	14	44	SS-12	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
		34 (W)	15 17 19	46	67	SS-13	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
-COBBLES PRESENT THROUGHOUT		39	12 10 8	23	33	SS-14	-	-	-	-	-	-	-	-	-	16	A-1-b (V)	
		44	11 17 18	45	44	SS-15	-	36	36	17	7	4	NP	NP	NP	14	A-1-b (0)	
	483.6	49 / EOB 50	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 1 OF 1
START: 9/27/11 END: 9/27/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG : 39.192360602 ° N / 84.478582797 ° W	

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

MATERIAL DESCRIPTION AND NOTES	ELEV. 538.3	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
0.5' - 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		1–2	2 3 3	8	50	SS-1	2.00	-	-	-	-	-	-	-	-	11	A-6a (V)	
	532.8	4–5	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	6–7	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.		9–10	5 5 4	12	50	SS-4	-	-	-	-	-	-	-	-	-	4	A-3a (V)	
		11–12	3 3 3	8	78	SS-5	-	4	30	49	15	2	NP	NP	NP	4	A-3a (0)	
		14–15	4 6 8	18	67	SS-6	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
		16–17	10 11 10	27	78	SS-7	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
		19–20	6 18 20	49	33	SS-8	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
	515.3	21–22	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	24–25 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	
PID: 77889 BR ID: NA	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 5/6/11	ELEVATION: 545.2 (MSL) EOB: 50.0 ft.	PAGE 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)	GR	CS	FS	SI	CL	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		4–5	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.		9–10	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.		14–15	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.		19–20	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		24–25	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)*		29	11 21 32	68	83	SS-12	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	
		30 ▼																
-COBBLES PRESENT THROUGHOUT		34	19 21 18	50	78	SS-13	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	
	508.7	36.5 W																
DENSE, BROWN **GRAVEL**, AND FINE TO COARSE SAND, TRACE SILT, TRACE CLAY, DRY. -COBBLES PRESENT THROUGHOUT		39	12 19 18	48	89	SS-14	-	57	30	7	5	1	NP	NP	NP	8	A-1-a (0)	
	503.2	42																
DENSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, MOIST.		44	9 17 20	48	50	SS-15	-	-	-	-	-	-	-	-	-	15	A-3a (V)	
	498.2	47																
VERY STIFF, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, MOIST.		49	7 9 8	22	44	SS-16	3.50	-	-	-	-	-	-	-	-	22	A-6a (V)	
	495.2	EOB 50																

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

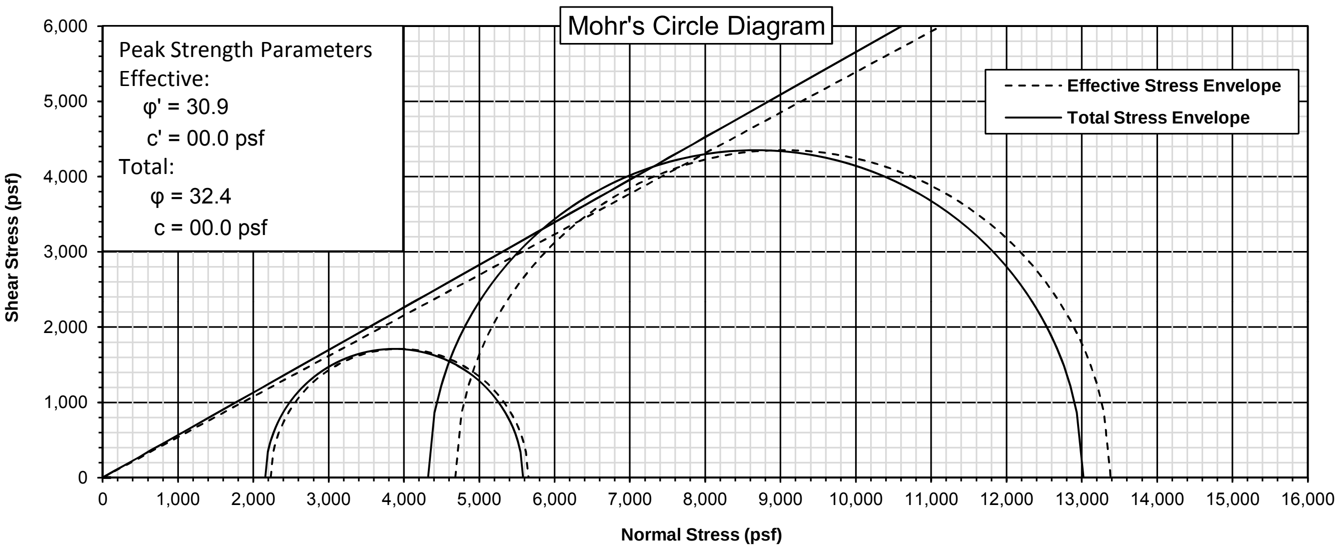
Consolidated, Undrained Triaxial Compression Test Report (ASTM D4767)

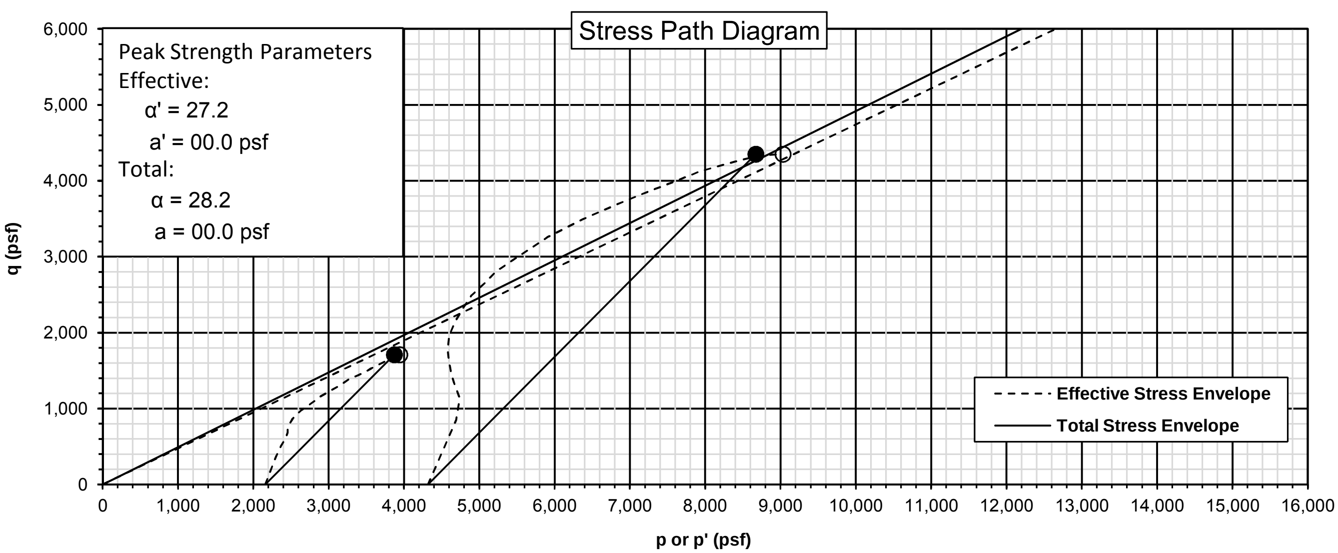
Project Number:	B-11-010	Boring Number:	B-004-0-11
Project Name:	HAM-75-11.09	Sample No. / Depth:	ST-2 and ST-3 / 9.5 ft to 11.4 ft
Project Location:	Hamilton County, Ohio	Date of Testing:	05/11/2012 to 05/17/2012
Client:	M•E Companies, Inc.	Technician:	JJH

Soil Description: Brown SILT, some clay, trace coarse to fine sand.
Soil Classification: ODOT A-4b

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	26	17	9	0	1	6	61	32

Stage	Boring No.	Sample No.	Depth (ft)	$(\sigma_3)_f$ (psf)	$(\sigma_1)_f$ (psf)	$(\sigma_3')_f$ (psf)	$(\sigma_1')_f$ (psf)	p'_f (psf)	q_f (psf)
1	B-004-0-11	ST-2	9.5	2,160.0	5,580.9	2,232.0	5,652.9	3,942.5	1,710.5
2	B-004-0-11	ST-3	11.4	4,320.0	13,022.3	4,680.0	13,382.3	9,031.2	4,351.2





Notes: Third point of test eliminated from final results. Physical properties listed based on testing performed on cuttings when samples were trimmed.

Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

Project Number:	B-11-010	Boring Number:	B-004-0-11
Project Name:	HAM-75-11.09	Sample No. / Depth:	ST-2 / 9.5 ft
Project Location:	Hamilton County, Ohio	Date of Testing:	5/11/2012
Client:	M•E Companies, Inc.	Technician:	JJH

Data for Specimen No. 1

Soil Description: Brown SILT, little clay, little fine sand, trace fine gravel.
Soil Classification: ODOT A-4b

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	25	18	7	1	0	17	63	19

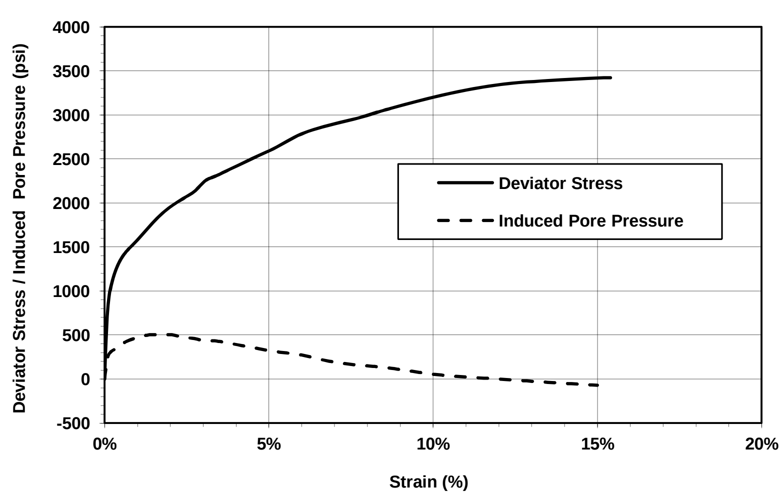
Diameter, D_0	2.836	in	Volume of Solids , V_s :	22.844	in^3
Area, A_0	6.315	in^2	Initial Volume of Voids, V_v :	14.495	in^3
Height, L_0	5.912	in	Initial Void Ratio, e_0 :	0.635	
Volume, V_0	37.339	in^3	Initial Degree of Saturation, S_0 :	106.037	%

Water Content BEFORE Test			Water Content AFTER Test (Total Specimen)		
Tin No.:	R-68	g	Tin No.:	ST	g
Wet Soil + Tin :	90.64	g	Wet Soil + Tin :	1399.80	g
Dry Soil + Tin :	77.67	g	Dry Soil + Tin :	1163.40	g
Tin Weight :	26.2	g	Tin Weight :	163.90	g
Dry Mass :	51.47	g	Dry Mass :	999.50	g
Weight of water :	12.97	g	Weight of water :	236.40	g
Moisture :	25.20	%	Moisture :	23.65	%
			Wet Density :	126.09	pcf
			Dry Density :	101.98	pcf

Consolidation Cell Pressure:	130.0	psi	Deviator Stress @ Failure, Ds:	3420.90	psf
Consolidation Back Pressure:	115.0	psi	Axial Strain @ Failure:	15.39	%
Effective Confining Stress, σ_3:	15.0	psi	Major Principal Stress @ Failure, σ_1:	5580.90	psf
	2160.00	psf	Induced Pore Pressure @ Failure:	-72.00	psf
Strain Rate:	0.0030	in/min	Effective Minor Principal Stress, σ'_3:	2232.00	psf
			Effective Major Principal Stress, σ'_1:	5652.90	psf

Failure Sketch

CU Compressive Strength and Induced Pore Pressure



Notes:

Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

Project Number:	B-11-010	Boring Number:	B-004-0-11
Project Name:	HAM-75-11.09	Sample No. / Depth:	ST-3 / 11.4 ft
Project Location:	Hamilton County, Ohio	Date of Testing:	5/17/2012
Client:	M•E Companies, Inc.	Technician:	JJH

Data for Specimen No. 2

Soil Description: Brown SILT, and clay, trace coarse to fine sand.

Soil Classification: ODOT A-4b

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	25	16	9	0	1	1	52	46

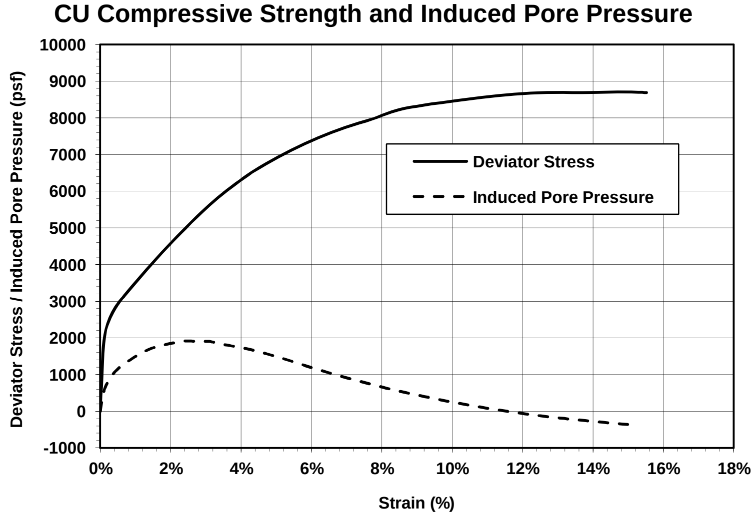
Diameter, D_0	2.843	in	Volume of Solids , V_s :	27.218	in^3
Area, A_0	6.347	in^2	Initial Volume of Voids, V_v :	10.265	in^3
Height, L_0	5.906	in	Initial Void Ratio, e_o :	0.377	
Volume, V_0	37.483	in^3	Initial Degree of Saturation, S_0 :	92.53	%

Water Content BEFORE Test			Water Content AFTER Test (Total Specimen)		
Tin No.:	T-26	g	Tin No.:	ST	g
Wet Soil + Tin :	123.78	g	Wet Soil + Tin :	1473.90	g
Dry Soil + Tin :	112.71	g	Dry Soil + Tin :	1309.00	g
Tin Weight :	28.01	g	Tin Weight :	118.10	g
Dry Mass :	84.7	g	Dry Mass :	1190.90	g
Weight of water :	11.07	g	Weight of water :	164.90	g
Moisture :	13.07	%	Moisture :	13.85	%
			Wet Density :	137.79	pcf
			Dry Density :	121.03	pcf

Consolidation Cell Pressure:	143.0	psi	Deviator Stress @ Failure, Ds:	8702.33	psf
Consolidation Back Pressure:	113.0	psi	Axial Strain @ Failure:	14.99	%
Effective Confining Stress, σ_3:	30.0	psi	Major Principal Stress @ Failure, σ_1:	13022.33	psf
	4320.00	psf	Induced Pore Pressure @ Failure:	-360.00	psf
Strain Rate:	0.0036	in/min	Effective Minor Principal Stress, σ'_3:	4680.00	psf
			Effective Major Principal Stress, σ'_1:	13382.33	psf

Failure Sketch

CU Compressive Strength and Induced Pore Pressure



Notes:

Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

Project Number:	B-11-010	Boring Number:	B-004-0-11
Project Name:	HAM-75-11.09	Sample No. / Depth:	ST-2 / 9.0 ft
Project Location:	Hamilton County, Ohio	Date of Testing:	5/15/2012
Client:	M•E Companies, Inc.	Technician:	JJH

Data for Specimen No. 3

Soil Description: Brown SILTY and CLAY, some coarse to fine sand, little fine gravel.
Soil Classification: ODOT A-6a

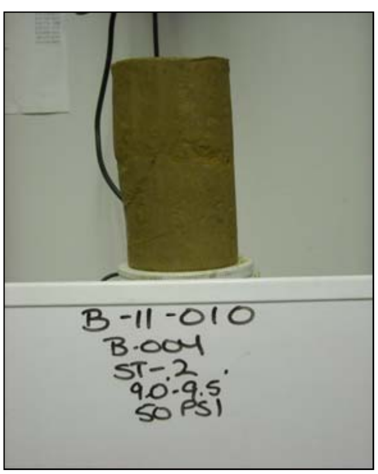
Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	27	15	12	11	9	14	38	28

Diameter, D_0	2.837	in	Volume of Solids , V_s :	22.794	in^3
Area, A_0	6.320	in^2	Initial Volume of Voids, V_v :	14.563	in^3
Height, L_0	5.911	in	Initial Void Ratio, e_o :	0.639	
Volume, V_0	37.357	in^3	Initial Degree of Saturation, S_0 :	99.713	%

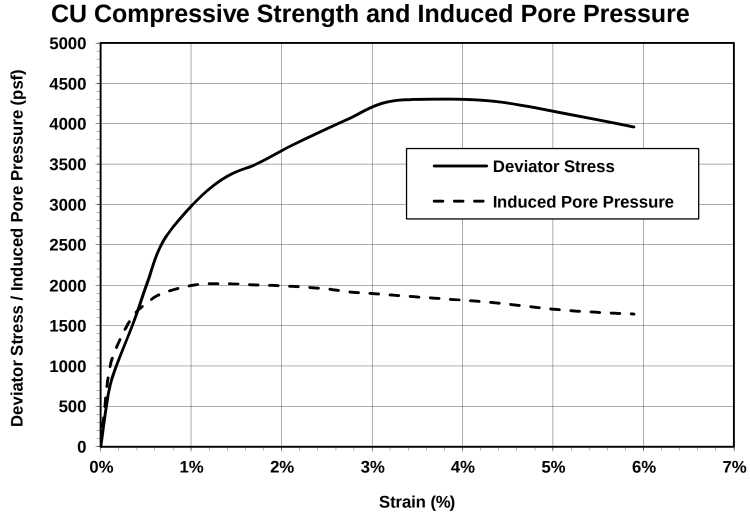
Water Content BEFORE Test			Water Content AFTER Test (Total Specimen)		
Tin No.:	T-33	g	Tin No.:	S	g
Wet Soil + Tin :	85.25	g	Wet Soil + Tin :	1356.80	g
Dry Soil + Tin :	74.1	g	Dry Soil + Tin :	1115.30	g
Tin Weight :	27.37	g	Tin Weight :	118.00	g
Dry Mass :	46.73	g	Dry Mass :	997.30	g
Weight of water :	11.15	g	Weight of water :	241.50	g
Moisture :	23.86047507	%	Moisture :	24.22	%
			Wet Density :	126.33	pcf
			Dry Density :	101.70	pcf

Consolidation Cell Pressure:	140.0	psi	Deviator Stress @ Failure, Ds:	4298.80	psf
Consolidation Back Pressure:	90.0	psi	Axial Strain @ Failure:	5.89	%
Effective Confining Stress, σ_3:	50.0	psi	Major Principal Stress @ Failure, σ_1:	11498.80	psf
	7200.00	psf	Induced Pore Pressure @ Failure:	1641.60	psf
Strain Rate:	0.0030	in/min	Effective Minor Principal Stress, σ'_3:	5558.40	psf
			Effective Major Principal Stress, σ'_1:	9857.20	psf

Failure Sketch



CU Compressive Strength and Induced Pore Pressure



Notes: Point classified as A-6a material type, which is different than the first two points of the test. Results of this point do not line up with remainder of points. Therefore, the results of this point are not utilized in the final results of the test.

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CONSOLIDATED, UNDRAINED TRIAXIAL

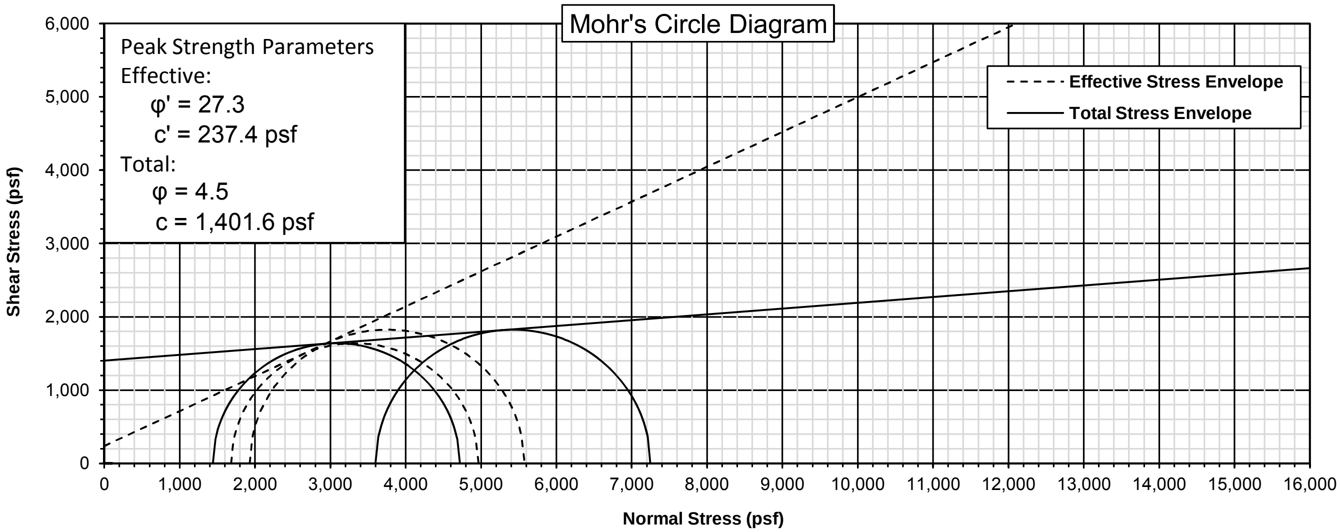
ASTM D-4767

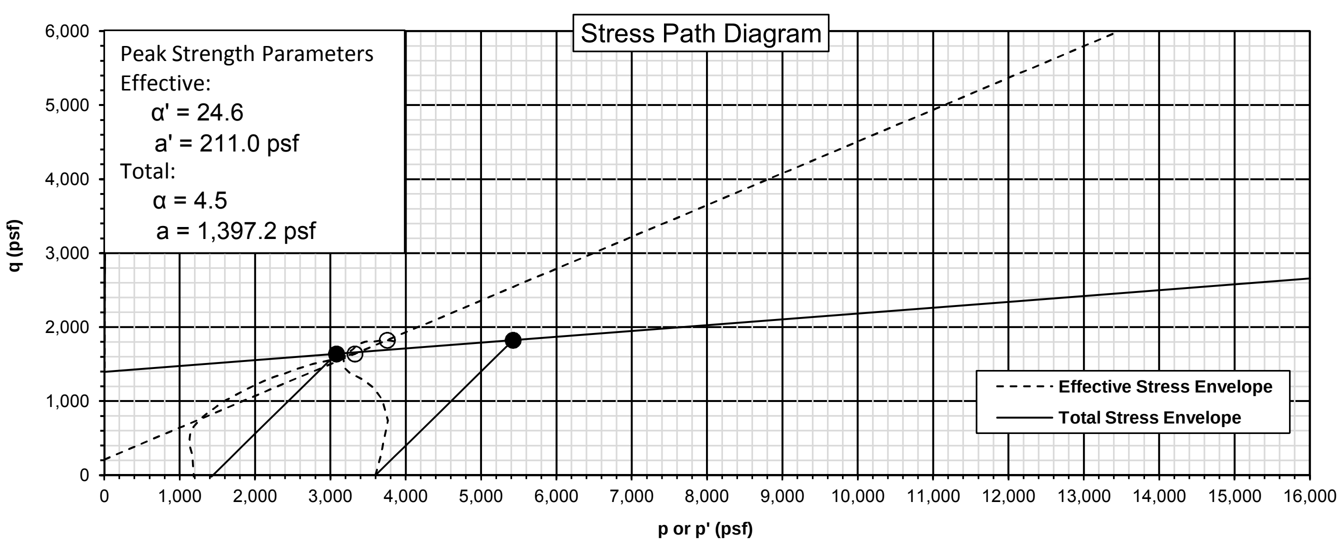
PROJECT NAME: HAM-75-7.85
JOB NUMBER: B-10-020
BORING NUMBER: B-016-0-11A
SAMPLE NUMBER: ST-3
SAMPLE DEPTH: 6.5 to 7.0 feet
DATE OF TESTING: 12/12/2011-12/28/11
TESTED BY: Hoyt

Soil Description: Brown SILT and CLAY, and coarse to fine sand, trace fine gravel.
Soil Classification: ODOT A-6a

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	29	14	15	7	9	32	29	23

Stage	Boring No.	Sample No.	Depth (ft)	$(\sigma_3)_f$ (psf)	$(\sigma_1)_f$ (psf)	$(\sigma_3')_f$ (psf)	$(\sigma_1')_f$ (psf)	p'_f (psf)	q_f (psf)
1	B-016-0-11A	ST-3	7.0	1,440.0	4,719.1	1,684.8	4,963.9	3,324.3	1,639.5
2	B-016-0-11A	ST-3	6.5	3,600.0	7,248.0	1,929.6	5,577.6	3,753.6	1,824.0





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CONSOLIDATED, UNDRAINED TRIAXIAL

ASTM D-4767

PROJECT NAME:	HAM-75-7.85
JOB NUMBER:	B-10-020
BORING NUMBER:	B-016-0-11A
SAMPLE NUMBER:	ST-3
SAMPLE DEPTH:	7.0
DATE OF TESTING:	12/28/2011
TESTED BY:	Hoyt

Data for Specimen No. 1

Soil Description: Brown SILT and CLAY, and coarse to fine sand, trace fine gravel.
Soil Classification: ODOT A-6a

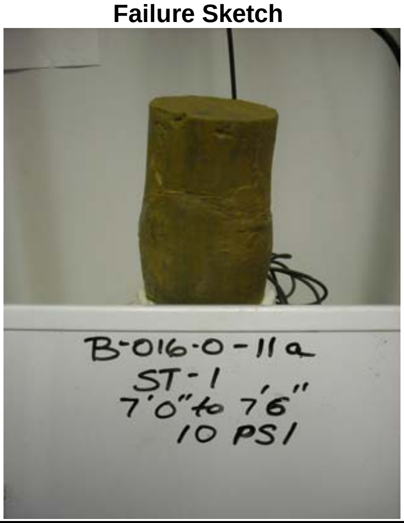
Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C.Sand%	F.Sand%	Silt%	Clay%
	29	14	15	7	9	32	29	23

Diameter, D_0	2.861	in	Volume of Solids , V_s :	25.349	in^3
Area, A_0	6.429	in^2	Initial Volume of Voids, V_v :	11.766	in^3
Height, L_0	5.773	in	Initial Void Ratio, e_o :	0.464	
Volume, V_0	37.115	in^3	Initial Degree of Saturation, S_0 :	111.729	%

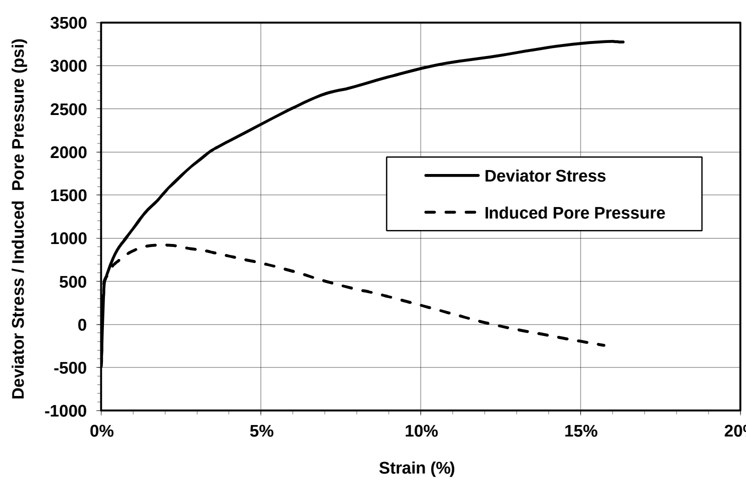
Water Content BEFORE Test			Water Content AFTER Test (Total Specimen)		
Tin No.:	WC-32	g	Tin No.:	BIG CAT	g
Wet Soil + Tin :	105.78	g	Wet Soil + Tin :	1393.10	g
Dry Soil + Tin :	94.18	g	Dry Soil + Tin :	1198.10	g
Tin Weight :	34.46	g	Tin Weight :	89.00	g
Dry Mass :	59.72	g	Dry Mass :	1109.10	g
Weight of water :	11.6	g	Weight of water :	195.00	g
Moisture :	19.42	%	Moisture :	17.58	%
			Wet Density :	133.85	pcf
			Dry Density :	113.84	pcf

Consolidation Cell Pressure:	145.0	psi	Deviator Stress @ Failure, Ds:	3279.09	psf
Consolidation Back Pressure:	135.0	psi	Axial Strain @ Failure:	15.74	%
Effective Confining Stress, σ_3:	10.0	psi	Major Principal Stress @ Failure, σ_1:	4719.09	psf
	1440.00	psf	Induced Pore Pressure @ Failure:	-244.80	psf
Strain Rate:	0.0040	in/min	Effective Minor Principal Stress, σ'_3:	1684.80	psf
			Effective Major Principal Stress, σ'_1:	4963.89	psf

Failure Sketch



CU Compressive Strength and Induced Pore Pressure



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CONSOLIDATED, UNDRAINED TRIAXIAL

ASTM D-4767

PROJECT NAME:	HAM-75-7.85
JOB NUMBER:	B-10-020
BORING NUMBER:	B-016-0-11A
SAMPLE NUMBER:	ST-3
SAMPLE DEPTH:	6.5
DATE OF TESTING:	12/23/2011
TESTED BY:	Hoyt

Data for Specimen No. 2

Soil Description: Brown SILT and CLAY, and coarse to fine sand, trace fine gravel.
Soil Classification: ODOT A-6a

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C.Sand%	F.Sand%	Silt%	Clay%
	29	14	15	7	9	32	29	23

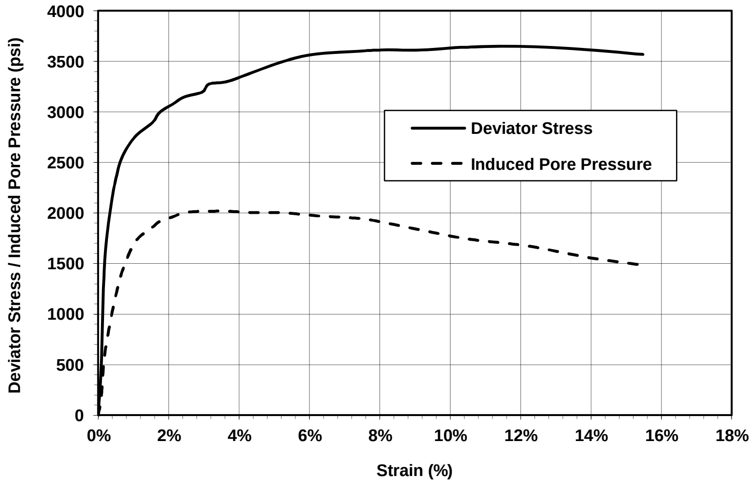
Diameter, D_0	2.843	in	Volume of Solids, V_s :	26.099	in^3
Area, A_0	6.350	in^2	Initial Volume of Voids, V_v :	11.933	in^3
Height, L_0	5.990	in	Initial Void Ratio, e_o :	0.457	
Volume, V_0	38.032	in^3	Initial Degree of Saturation, S_0 :	106.30	%

Water Content BEFORE Test			Water Content AFTER Test (Total Specimen)		
Tin No.:	WC-32	g	Tin No.:	OHIO	g
Wet Soil + Tin :	105.78	g	Wet Soil + Tin :	1445.60	g
Dry Soil + Tin :	94.18	g	Dry Soil + Tin :	1268.90	g
Tin Weight :	30.46	g	Tin Weight :	127.00	g
Dry Mass :	63.72	g	Dry Mass :	1141.90	g
Weight of water :	11.6	g	Weight of water :	176.70	g
Moisture :	18.20	%	Moisture :	15.47	%
			Wet Density :	132.08	pcf
			Dry Density :	114.38	pcf

Consolidation Cell Pressure:	118.0	psi	Deviator Stress @ Failure, Ds:	3648.02	psf
Consolidation Back Pressure:	93.0	psi	Axial Strain @ Failure:	12.24	%
Effective Confining Stress, σ_3:	25.0	psi	Major Principal Stress @ Failure, σ_1:	7248.02	psf
	3600.00	psf	Induced Pore Pressure @ Failure:	1670.40	psf
Strain Rate:	0.0030	in/min	Effective Minor Principal Stress, σ'_3:	1929.60	psf
			Effective Major Principal Stress, σ'_1:	5577.62	psf

Failure Sketch

CU Compressive Strength and Induced Pore Pressure



APPENDIX VI

SETTLEMENT CALCULATIONS

B-10-020 HAM-75-7.85 (Retaining Wall J)
MSE Wall - Consolidation Settlement

Calculated By: BRT Date: 8/8/2013
Checked By: NCK Date: 8/8/2013

Borings B-032 and B-033 - Sta. 480+84 to Sta. 483+50

15.0' MSE wall height net loading considered

H=	15.0	ft	
B=	13.0	ft	
γ_{BF} =	120	pcf	
D_w =	25.0	ft	depth below bottom of footing
γ_w =	62.4	pcf	
ΔP =	1800	psf	at surface

																Total Settlement at Center of Reinforced Soil Mass					Total Settlement at Facing of Wall				
Layer	Soil Type	Depth		Thickness	Depth to Midpoint	γ	LL	C_c	C_r	e_o	σ_p'	σ_{vo} Bottom	σ_{vo} Midpoint	σ_{vo}' Midpoint	z_f/B	I	$\Delta\sigma_v$	σ_{vf}' Midpoint	S_c (ft)	S_c (in)	I	$\Delta\sigma_v$	σ_{vf}' Midpoint	S_c (ft)	S_c (in)
1	A-1-a	0.0	4.0	4.0	2.0	120	Calculated Separately					480	240	240	0.15	Calculated Separately			0.007	0.084	Calculated Separately			0.003	0.041
2	A-1-a	4.0	24.0	20.0	12.0	125	Calculated Separately					2500	1500	1500	0.92	Calculated Separately			0.030	0.363	Calculated Separately			0.014	0.169
3	A-3a	24.0	44.0	20.0	22.0	125	Calculated Separately					2500	2750	2750	1.69	Calculated Separately			0.017	0.206	Calculated Separately			0.008	0.096

Settlement at Center of Reinforced Soil Mass: 0.653 in

Settlement at Facing of Wall: 0.305 in

B-10-020 HAM-75-7.85 (Retaining Wall J)
MSE Wall - Consolidation Settlement

Calculated By: BRT Date: 8/8/2013
Checked By: NCK Date: 8/8/2013

Boring B-034 and B-035 - Sta. 483+50 to Sta. 486+00

9.0' MSE wall height net loading considered

H=	9.0	ft	
B=	9.0	ft	
γ_{BF} =	120	pcf	
D_w =	28.8	ft	depth below bottom of footing
γ_w =	62.4	pcf	
ΔP =	1080	psf	at surface

Layer	Soil Type	Depth		Thickness	Depth to Midpoint	γ	LL	C_c	C_r	e_o	σ_p'	σ_{vo} Bottom	σ_{vo} Midpoint	σ_{vo}' Midpoint	Z_f/B	Total Settlement at Center of Reinforced Soil Mass: I	$\Delta\sigma_v$	σ_{vf}' Midpoint	S_c (ft)	S_c (in)	Total Settlement at Facing of Wall: I	$\Delta\sigma_v$	σ_{vf}' Midpoint	S_c (ft)	S_c (in)
1	A-1-b	0.0	10.0	10.0	5.0	125	Calculated Separately					1250	625	625	0.56	Calculated Separately			0.008	0.100	Calculated Separately			0.004	0.047
2	A-1-b	10.0	20.0	10.0	10.0	130	Calculated Separately					1300	1300	1300	1.11	Calculated Separately			0.007	0.083	Calculated Separately			0.003	0.039
3	A-4a	20.0	26.0	6.0	13.0	125	Calculated Separately					750	1625	1625	1.44	Calculated Separately			0.007	0.088	Calculated Separately			0.003	0.041
4	A-3	26.0	31.0	5.0	15.5	125	Calculated Separately					625	1938	1938	1.72	Calculated Separately			0.002	0.026	Calculated Separately			0.001	0.012
5	A-3	31.0	44.0	13.0	22.0	135	Calculated Separately					1755	2970	2970	2.44	Calculated Separately			0.000	0.003	Calculated Separately			0.000	0.002

Settlement at Center of Reinforced Soil Mass: 0.301 in

Settlement at Facing of Wall: 0.141 in

APPENDIX VII

MSE WALL CALCULATIONS

RESOURCE INTERNATIONAL, INC.
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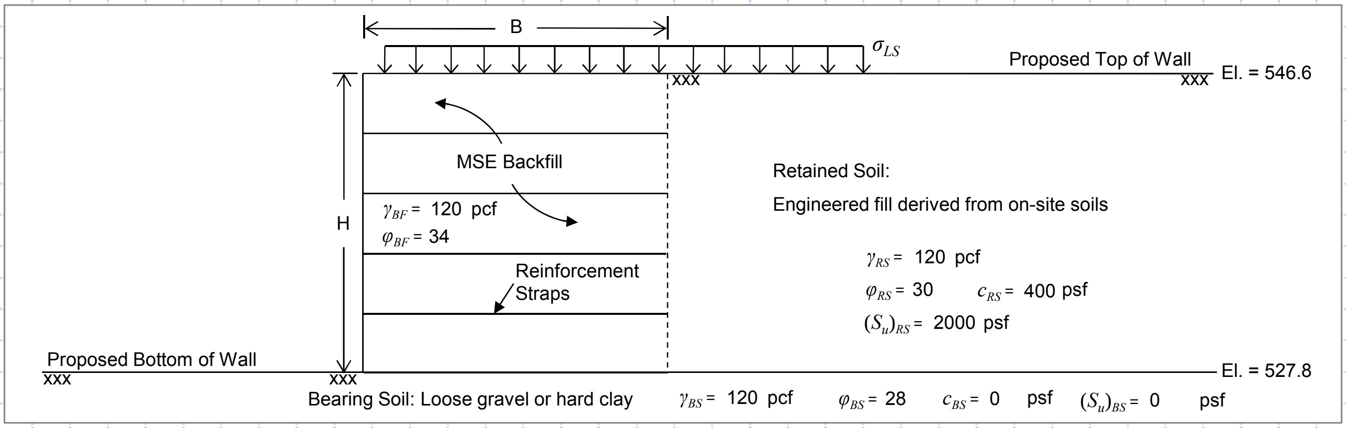
Retaining Wall J - MSE Wall - 18.8 ft. Maximum Wall Height - B-032-0-11 and B-033-0-11



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.8	ft
MSE Wall Width (Reinforcement Length), (B) =	13.2	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	400	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) =	3.0	ft

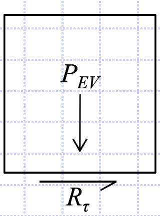
LRFD Load Factors

	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 Sections 11.6.3.6 and 11.10.5.3

Nominal Sliding Resistance: $R_\tau = P_{EV} \cdot \tan\delta$



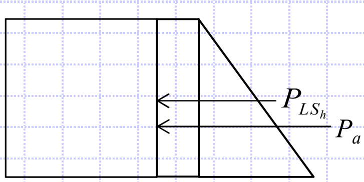
$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(18.8 ft)(13.16 ft)(1.00) = 29.69 kip/ft

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

$\tan\delta =$ tan(28) ≤ tan(34) ⟶ 0.53 ≤ 0.67 ⟶ $\tan\delta =$ 0.53

R_τ = (29.69 kip/ft)(0.53) = 15.74 kip/ft

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)(18.8 ft)²(0.333)(1.5) = 10.59 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (240 psf)(18.8 ft)(0.333)(1.75) = 2.63 kip/ft

P_H = 10.59 kip/ft + 2.63 kip/ft = 13.22 kip/ft

Check Sliding Resistance

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 13.22 kip/ft ≤ (15.74 kip/ft)(1.0) = 15.74 kip/ft ⟶ 13.22 kip/ft ≤ 15.74 kip/ft **OK**

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

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.8	ft
MSE Wall Width (Reinforcement Length), (B) =	13.2	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	400	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:

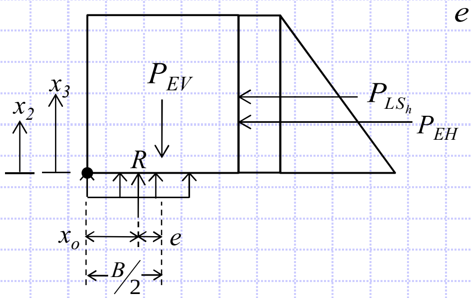
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D) =	3.0	ft

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



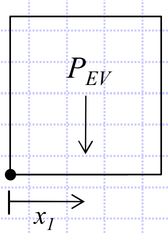
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (195.36 kip·ft/ft - 91.12 kip·ft/ft) / (29.69 kip/ft) = 3.51 ft

M_{EV}	=	195.36	kip·ft/ft	Defined below
M_H	=	91.12	kip·ft/ft	
P_{EV}	=	29.69	kip/ft	

$e =$ (13.16 ft)/2 - 3.51 ft = 3.07 ft

Resisting Moment, M_{EV}:



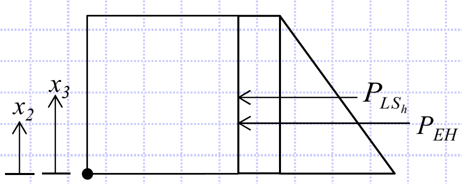
$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(18.8 ft)(13.16 ft)(1.00) = 29.69 kip/ft

$x_1 = B/2$ = (13.16 ft) / 2 = 6.58 ft

$M_{EV} =$ (29.69 kip/ft)(6.58 ft) = 195.36 kip·ft/ft

Overturning Moment, M_H:



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

$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(18.8 ft)²(0.333)(1.5) = 10.59 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (240 psf)(18.8 ft)(0.333)(1.75) = 2.63 kip/ft

$x_2 = H/3$ = (18.8 ft) / 3 = 6.27 ft

$x_3 = H/2$ = (18.8 ft) / 2 = 9.40 ft

$M_H =$ (10.59 kip/ft)(6.27 ft) + (2.63 kip/ft)(9.4 ft) = 91.12 kip·ft/ft

Limiting Eccentricity:

$e_{max} = B/4 \longrightarrow e_{max} =$ (13.16 ft) / 4 = 3.29 ft

Check Eccentricity

$e < e_{max} \longrightarrow$ 3.07 ft < 3.29 ft **OK**

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JOB	HAM-75-7.85	NO.	B-10-020
SHEET NO.	3	OF	5
CALCULATED BY	BRT	DATE	8/8/2013
CHECKED BY	NCK	DATE	8/8/2013

Retaining Wall J - Sta. 480+84 to Sta. 483+50

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.8	ft
MSE Wall Width (Reinforcement Length), (B) =	13.2	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	400	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:

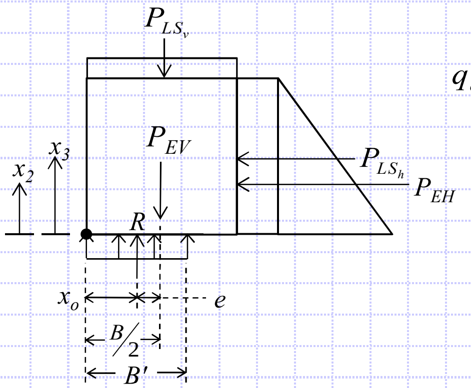
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D) =	3.0	ft

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 11.6.3.2



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

$B' = B - 2e$ = 13.2 ft - 2(2 ft) = 9.16 ft

$e = B/2 - x_o$ = (13.2 ft) / 2 - 4.58 ft = 2.00 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (300.10 kip·ft/ft - 91.13 kip·ft/ft) / 45.61 kip/ft = 4.58 ft

$q_{eq} =$ (45.61 kip/ft) / (9.16 ft) = 4.98 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)(18.8 ft)(13.16 ft)(1.35)](6.58 ft) + [(240 psf)(13.16 ft)(1.75)](6.58 ft) = 300.10 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)(18.8 ft)²(0.333)(1.5)](6.27 ft) + [(240 psf)(18.8 ft)(0.333)(1.75)](9.4 ft) = 91.13 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)(18.8 ft)(13.16 ft)(1.35) + (240 psf)(13.16 ft)(1.75) = 45.61 kip/ft

Nominal Bearing Resistance:

$q_n = cN_c + \gamma D N_q + \tfrac{1}{2}\gamma B N_\gamma$ = (0 psf)(31.6) + (120 pcf)(3.0 ft)(17.8) + ½(120 pcf)(13.16 ft)(14.6) = 17.9 ksf

N_c = 31.6 N_q = 17.8 N_γ = 14.6

Check Bearing Capacity

$q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 4.98 ksf ≤ (17.9 ksf)(0.65) = 11.64 ksf $\longrightarrow$ 4.98 ksf ≤ 11.64 ksf **OK**

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

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.8	ft
MSE Wall Width (Reinforcement Length), (B) =	13.2	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
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) =	0.333	
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) =	3.0	ft

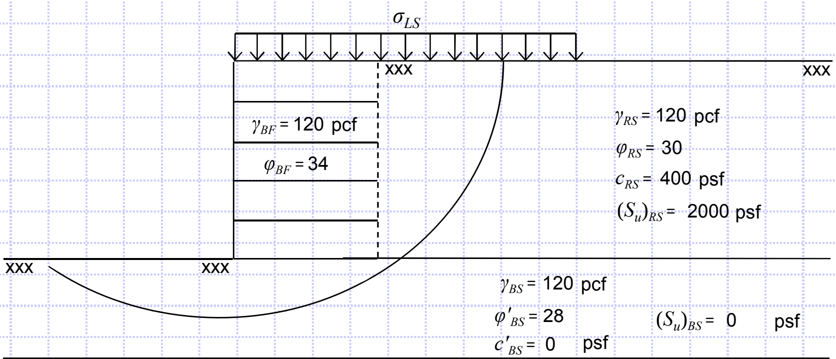
LRFD Load Factors

	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)

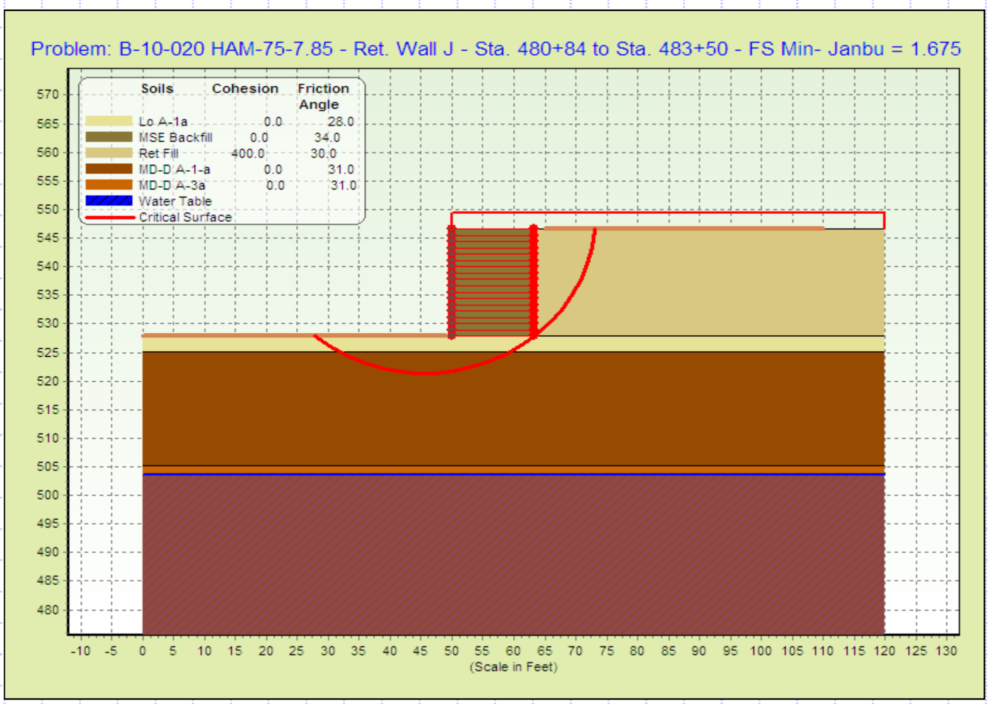
Check Overall (Global) Stability (Loading Case - Service I) - AASHTO LRFD BDM Sections 11.6.2.3 and 11.10.5.2

Long Term Stability - Drained Conditions



Loading scenario modeled as shown to the left and analyzed for slope stability using STABL for Windows software.

Graphical output shown below and tabular output results are provided as a separate attachment.



Check Overall (Global) Stability

$$1.0 \leq FS \cdot \phi_{GS} \quad \longrightarrow \quad 1.00 \leq (1.675)(0.75) = 1.26 \quad \longrightarrow \quad 1.00 \leq 1.26$$

OK

FS = **1.675** *(From STABL Slope Stability Analysis)*

Use φ_{GS} = **0.75** *(Per AASHTO LRFD BDM Section 11.6.2.3)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.8	ft
MSE Wall Width (Reinforcement Length), (B) =	13.2	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	400	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) =	3.0	ft

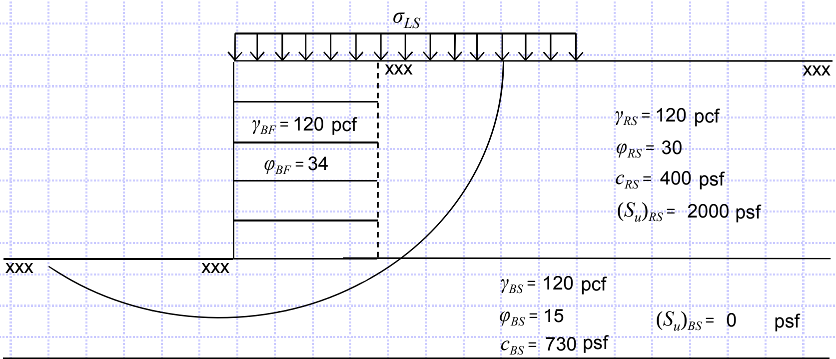
LRFD Load Factors

	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)

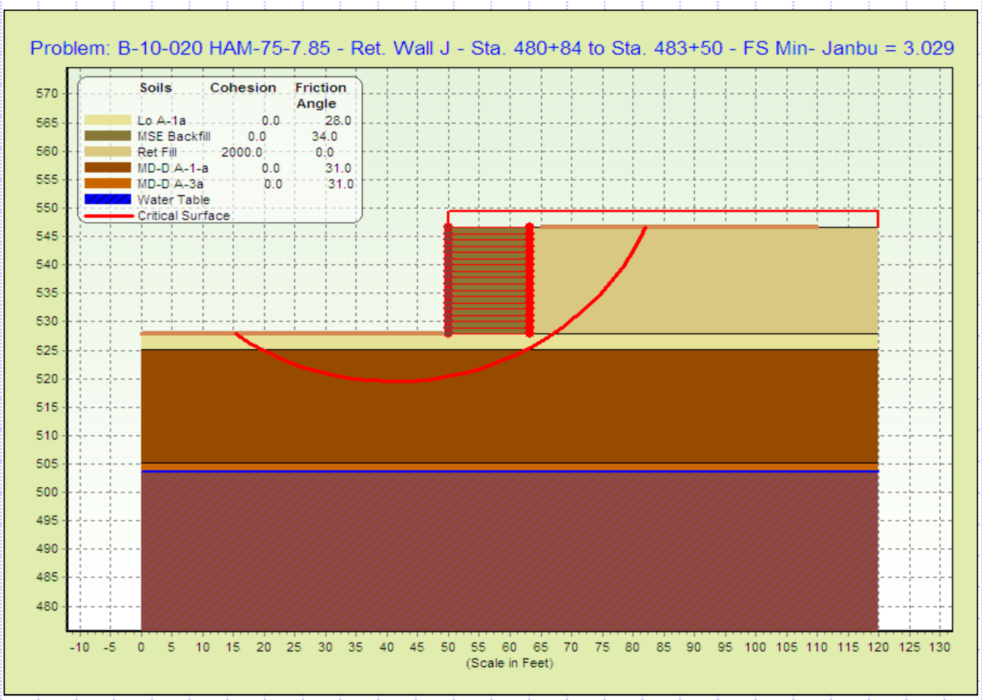
Check Overall (Global) Stability (Loading Case - Service I) - AASHTO LRFD BDM Sections 11.6.2.3 and 11.10.5.2 ***(Cont'd)***

Short Term Stability - Undrained Conditions



Loading scenario modeled as shown to the left and analyzed for slope stability using STABL PC software.

Graphical output shown below and tabular output results are provided as a separate attachment.



Check Overall (Global) Stability

$1.0 \leq FS \cdot \phi_{GS}$ ⟶ 1.00 ≤ (3.029)(0.75) = 2.27 ⟶ 1.00 ≤ 2.27 **OK**

FS = **3.029** *(From STABL Slope Stability Analysis)*

Use φ_{GS} = **0.75** *(Per AASHTO LRFD BDM Section 11.6.2.3)*

** STABL for WINDOWS **
by
Geotechnical Software Solutions

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: U.S.C.
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION B-10-020 HAM-75-7.85 - Ret. Wall J - Sta
. 480+84 to Sta. 483+50

BOUNDARY COORDINATES

4 Top Boundaries
9 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	527.80	50.00	527.80	3
2	50.00	527.80	50.10	546.60	1
3	50.10	546.60	63.30	546.60	1
4	63.30	546.60	120.00	546.60	2
5	50.00	527.80	63.20	527.80	3
6	63.20	527.80	63.30	546.60	2
7	63.20	527.80	120.00	527.80	3
8	0.00	525.10	120.00	525.10	4
9	0.00	505.10	120.00	505.10	5

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	125.0	0.0	34.0	0.00	0.0	1
2	120.0	130.0	400.0	30.0	0.00	0.0	1
3	120.0	125.0	0.0	28.0	0.00	0.0	1
4	125.0	130.0	0.0	31.0	0.00	0.0	1
5	125.0	130.0	0.0	31.0	0.00	0.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)

1	0.00	503.60
2	120.00	503.60

1

BOUNDARY LOAD(S)

1 Load(s) Specified

Load No.	X-Left (ft)	X-Right (ft)	Intensity (psf)	Deflection (deg)
1	50.10	120.00	240.0	1.0

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

GEOSYNTHETIC DATA

1 Geosynthetics(s) group(s) specified

Ngroup no	Bnr no	Y-top (ft)	Y-bot (ft)	Levels no	Length (ft)	Spacing (ft)	Efficiency	Tallow (lbs/ft)
1	2	546.6	527.8	18	13.2	1.11	1.0	7500.0

1

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

750 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 75 Points Equally Spaced
Along The Ground Surface Between X = 0.00 ft.
and X = 49.00 ft.

Each Surface Terminates Between X = 65.00 ft.
and X = 110.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =450.00 ft.

3.00 ft. Line Segments Define Each Trial Failure Surface.

Factor Of Safety Calculation Has Gone Through 30 Iterations,
without convergence

The Trial Failure Surface In Question Is Defined
By The Following 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	21.85	527.80
2	24.35	526.14
3	27.02	524.77
4	29.82	523.70
5	32.73	522.94

6	35.69	522.52
7	38.69	522.42
8	41.68	522.65
9	44.63	523.22
10	47.50	524.10
11	50.25	525.30
12	52.85	526.79
13	55.27	528.56
14	57.48	530.59
15	59.45	532.85
16	61.16	535.32
17	62.59	537.96
18	63.72	540.74
19	64.53	543.62
20	65.02	546.58
21	65.02	546.60

Factor Of Safety For The Preceding Specified Surface = -5.621

Factor Of Safety Calculation Has Gone Through 30 Iterations,
without convergence

The Trial Failure Surface In Question Is Defined
By The Following 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	25.82	527.80
2	28.43	526.31
3	31.19	525.14
4	34.07	524.30
5	37.03	523.80
6	40.03	523.66
7	43.02	523.86
8	45.97	524.42
9	48.83	525.31
10	51.57	526.54
11	54.15	528.07
12	56.53	529.90
13	58.68	531.99
14	60.56	534.32
15	62.17	536.86
16	63.46	539.57
17	64.43	542.41
18	65.06	545.34
19	65.18	546.60

Factor Of Safety For The Preceding Specified Surface = 1.669

Factor Of Safety Calculation Has Gone Through 30 Iterations,
without convergence

The Trial Failure Surface In Question Is Defined
By The Following 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	26.49	527.80
2	29.16	526.43

3	31.96	525.38
4	34.87	524.64
5	37.85	524.25
6	40.85	524.19
7	43.83	524.47
8	46.77	525.09
9	49.62	526.04
10	52.34	527.30
11	54.90	528.86
12	57.27	530.70
13	59.41	532.80
14	61.30	535.13
15	62.92	537.66
16	64.24	540.35
17	65.24	543.18
18	65.92	546.10
19	65.98	546.60

Factor Of Safety For The Preceding Specified Surface = -3.898

Factor Of Safety Calculation Has Gone Through 30 Iterations,
without convergence

The Trial Failure Surface In Question Is Defined
By The Following 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	27.15	527.80
2	29.73	526.27
3	32.48	525.07
4	35.35	524.20
5	38.31	523.68
6	41.30	523.52
7	44.29	523.72
8	47.24	524.27
9	50.10	525.18
10	52.84	526.42
11	55.40	527.97
12	57.76	529.83
13	59.88	531.95
14	61.73	534.31
15	63.28	536.88
16	64.52	539.61
17	65.42	542.47
18	65.97	545.42
19	66.05	546.60

Factor Of Safety For The Preceding Specified Surface = 1.765

Factor Of Safety Calculation Has Gone Through 30 Iterations,
without convergence

The Trial Failure Surface In Question Is Defined
By The Following 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	34.43	527.80

2	37.26	526.78
3	40.19	526.16
4	43.18	525.94
5	46.18	526.13
6	49.12	526.72
7	51.95	527.71
8	54.62	529.07
9	57.08	530.79
10	59.29	532.82
11	61.20	535.13
12	62.78	537.68
13	64.00	540.42
14	64.84	543.30
15	65.27	546.27
16	65.28	546.60

Factor Of Safety For The Preceding Specified Surface = 0.329

Factor Of Safety Calculation Has Gone Through 30 Iterations,
without convergence

The Trial Failure Surface In Question Is Defined
By The Following 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	39.07	527.80
2	41.95	526.97
3	44.92	526.54
4	47.92	526.52
5	50.89	526.91
6	53.79	527.70
7	56.54	528.89
8	59.11	530.44
9	61.44	532.33
10	63.50	534.51
11	65.23	536.96
12	66.61	539.63
13	67.61	542.45
14	68.22	545.39
15	68.30	546.60

Factor Of Safety For The Preceding Specified Surface =-12.356

Factor Of Safety Calculation Has Gone Through 30 Iterations,
without convergence

The Trial Failure Surface In Question Is Defined
By The Following 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.39	527.80
2	43.29	527.02
3	46.26	526.64
4	49.26	526.68
5	52.23	527.14
6	55.10	528.00
7	57.83	529.25

8	60.35	530.87
9	62.63	532.82
10	64.62	535.07
11	66.27	537.57
12	67.56	540.28
13	68.46	543.14
14	68.96	546.10
15	68.98	546.60

Factor Of Safety For The Preceding Specified Surface =-13.935

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	27.81	527.80
2	30.21	526.00
3	32.80	524.48
4	35.53	523.24
5	38.38	522.30
6	41.31	521.68
7	44.30	521.38
8	47.30	521.41
9	50.28	521.76
10	53.20	522.43
11	56.04	523.41
12	58.75	524.70
13	61.30	526.27
14	63.68	528.11
15	65.83	530.19
16	67.75	532.49
17	69.41	534.99
18	70.79	537.66
19	71.87	540.46
20	72.65	543.36
21	73.10	546.32
22	73.11	546.60

*** 1.675 ***

Individual data on the 28 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Force Norm (lbs)	Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	2.4	259.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.5	412.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.1	383.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.7	1310.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	2.9	1753.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	2.9	2091.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	3.0	2298.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3.0	2361.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	2.7	2068.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.1	187.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.2	535.2	0.0	0.0	0.0	0.0	0.0	0.0	42.8
12	2.9	8642.9	0.0	0.0	0.0	0.0	0.0	0.0	701.8
13	2.8	8084.5	0.0	0.0	0.0	0.0	0.0	0.0	680.2

14	2.7	7349.0	0.0	0.0	0.0	0.0	0.0	0.0	650.7
15	0.7	1709.7	0.0	0.0	0.0	0.0	0.0	0.0	157.5
16	1.9	4768.6	0.0	0.0	0.0	0.0	0.0	0.0	456.0
17	1.9	4458.8	0.0	0.0	0.0	0.0	0.0	0.0	455.0
18	0.1	184.0	0.0	0.0	0.0	0.0	0.0	0.0	19.5
19	0.0	41.9	0.0	0.0	0.0	0.0	0.0	0.0	4.5
20	0.4	839.0	0.0	0.0	0.0	0.0	0.0	0.0	90.0
21	2.2	4519.9	0.0	0.0	0.0	0.0	0.0	0.0	518.0
22	1.9	3515.2	0.0	0.0	0.0	0.0	0.0	0.0	460.8
23	1.7	2559.3	0.0	0.0	0.0	0.0	0.0	0.0	398.2
24	1.4	1699.6	0.0	0.0	0.0	0.0	0.0	0.0	330.9
25	1.1	979.3	0.0	0.0	0.0	0.0	0.0	0.0	259.7
26	0.8	435.3	0.0	0.0	0.0	0.0	0.0	0.0	185.4
27	0.5	96.1	0.0	0.0	0.0	0.0	0.0	0.0	109.0
28	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	2.9

Individual data on the 18 geosynthetics

Group	Level	Slice	Head Coordinates (ft)		End Coordinates (ft)		T (lbs)	Length (ft)	Tallow (lbs)	T/Tall %
1	1	0	50.0	527.8	63.2	527.8	0.0	13.2	7500.0	0.0
1	2	0	50.0	528.9	63.2	528.9	0.0	13.2	7500.0	0.0
1	3	0	50.0	530.0	63.2	530.0	0.0	13.2	7500.0	0.0
1	4	0	50.0	531.1	63.2	531.1	0.0	13.2	7500.0	0.0
1	5	0	50.0	532.2	63.2	532.2	0.0	13.2	7500.0	0.0
1	6	0	50.0	533.3	63.2	533.3	0.0	13.2	7500.0	0.0
1	7	0	50.0	534.4	63.2	534.4	0.0	13.2	7500.0	0.0
1	8	0	50.0	535.5	63.2	535.5	0.0	13.2	7500.0	0.0
1	9	0	50.0	536.6	63.2	536.6	0.0	13.2	7500.0	0.0
1	10	0	50.1	537.8	63.3	537.8	0.0	13.2	7500.0	0.0
1	11	0	50.1	538.9	63.3	538.9	0.0	13.2	7500.0	0.0
1	12	0	50.1	540.0	63.3	540.0	0.0	13.2	7500.0	0.0
1	13	0	50.1	541.1	63.3	541.1	0.0	13.2	7500.0	0.0
1	14	0	50.1	542.2	63.3	542.2	0.0	13.2	7500.0	0.0
1	15	0	50.1	543.3	63.3	543.3	0.0	13.2	7500.0	0.0
1	16	0	50.1	544.4	63.3	544.4	0.0	13.2	7500.0	0.0
1	17	0	50.1	545.5	63.3	545.5	0.0	13.2	7500.0	0.0
1	18	0	50.1	546.6	63.3	546.6	0.0	13.2	7500.0	0.0

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.12	527.80
2	33.58	526.09
3	36.22	524.66
4	39.01	523.54
5	41.90	522.73
6	44.86	522.26
7	47.85	522.12
8	50.85	522.32
9	53.80	522.85
10	56.67	523.72
11	59.43	524.89
12	62.04	526.37
13	64.47	528.14
14	66.68	530.16
15	68.65	532.42
16	70.36	534.89
17	71.78	537.53
18	72.89	540.32
19	73.69	543.21
20	74.15	546.18
21	74.17	546.60

*** 1.692 ***

1

Failure Surface Specified By 20 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.78	527.80
2	34.20	526.02
3	36.81	524.54
4	39.57	523.38
5	42.46	522.55
6	45.42	522.08
7	48.42	521.95
8	51.41	522.19
9	54.35	522.77
10	57.20	523.70
11	59.92	524.97
12	62.48	526.54
13	64.82	528.41
14	66.93	530.54
15	68.78	532.91
16	70.32	535.48
17	71.56	538.22
18	72.46	541.08
19	73.01	544.03
20	73.18	546.60

*** 1.719 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	25.16	527.80
2	27.46	525.87
3	29.94	524.19
4	32.59	522.78
5	35.37	521.65
6	38.26	520.83
7	41.21	520.32
8	44.21	520.13
9	47.20	520.25
10	50.17	520.68
11	53.08	521.43
12	55.89	522.48
13	58.57	523.82
14	61.10	525.44
15	63.44	527.32
16	65.57	529.43
17	67.46	531.76
18	69.10	534.27
19	70.47	536.94
20	71.54	539.74
21	72.31	542.64
22	72.77	545.60
23	72.82	546.60

*** 1.739 ***

1

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	26.49	527.80
2	29.14	526.40
3	31.89	525.21
4	34.73	524.24
5	37.64	523.50

6	40.60	523.00
7	43.59	522.72
8	46.59	522.69
9	49.58	522.89
10	52.55	523.33
11	55.47	524.00
12	58.33	524.90
13	61.11	526.02
14	63.80	527.36
15	66.37	528.91
16	68.81	530.65
17	71.10	532.58
18	73.24	534.69
19	75.20	536.96
20	76.98	539.38
21	78.56	541.93
22	79.93	544.60
23	80.77	546.60

*** 1.755 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.18	527.80
2	25.62	526.06
3	28.20	524.54
4	30.91	523.25
5	33.73	522.20
6	36.62	521.41
7	39.57	520.87
8	42.56	520.60
9	45.56	520.59
10	48.55	520.84
11	51.50	521.35
12	54.40	522.12
13	57.22	523.15
14	59.94	524.42
15	62.54	525.92
16	64.99	527.64
17	67.29	529.57
18	69.40	531.70
19	71.32	534.01
20	73.03	536.47
21	74.52	539.08
22	75.77	541.80
23	76.78	544.63
24	77.29	546.60

*** 1.756 ***

1

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.12	527.80
2	33.49	525.96
3	36.05	524.40
4	38.78	523.14
5	41.63	522.20
6	44.56	521.59
7	47.55	521.32
8	50.55	521.39
9	53.52	521.80
10	56.43	522.54

11	59.23	523.61
12	61.90	524.99
13	64.39	526.67
14	66.67	528.62
15	68.71	530.81
16	70.50	533.22
17	72.00	535.82
18	73.19	538.57
19	74.06	541.44
20	74.61	544.39
21	74.76	546.60

*** 1.773 ***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.78	527.80
2	34.41	526.36
3	37.17	525.16
4	40.02	524.22
5	42.94	523.55
6	45.91	523.14
7	48.91	523.01
8	51.90	523.16
9	54.88	523.57
10	57.80	524.26
11	60.64	525.21
12	63.39	526.42
13	66.01	527.87
14	68.49	529.56
15	70.81	531.47
16	72.94	533.58
17	74.87	535.88
18	76.58	538.34
19	78.06	540.95
20	79.29	543.69
21	80.27	546.52
22	80.29	546.60

*** 1.776 ***

1

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	39.73	527.80
2	42.44	526.51
3	45.28	525.55
4	48.22	524.95
5	51.21	524.71
6	54.21	524.83
7	57.17	525.32
8	60.05	526.16
9	62.80	527.35
10	65.39	528.87
11	67.77	530.69
12	69.92	532.78
13	71.80	535.13
14	73.37	537.68
15	74.63	540.40
16	75.54	543.26
17	76.10	546.21
18	76.13	546.60

*** 1.795 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.14	527.80
2	31.90	526.64
3	34.74	525.68
4	37.65	524.93
5	40.60	524.39
6	43.58	524.07
7	46.58	523.97
8	49.58	524.08
9	52.56	524.42
10	55.51	524.96
11	58.41	525.73
12	61.25	526.70
13	64.01	527.87
14	66.68	529.24
15	69.24	530.80
16	71.68	532.54
17	73.99	534.46
18	76.16	536.54
19	78.16	538.77
20	80.00	541.14
21	81.66	543.64
22	83.14	546.25
23	83.31	546.60

*** 1.809 ***

```
1
                     Y            A     X     I     S            F     T

                     0.00    127.93    255.86    383.78    511.71    639.64

          X      0.00 +---------+---------+---------+--------*+*--------+
                      -                                       .1
                      -                                       .G G/1
                      -                                       .g1g
                      -                                       ..55
                      -                                        ...
               127.93 +                                      * * *1/
                      -
                      -
                      -
                      -
                      -
          A    255.86 +
                      -
                      -
                      -
                      -
                      -
          X    383.78 +
                      -
                      -
                      -
                      -
                      -
          I    511.71 +
                      -
                      -
                      -
                      -
                      -
          S    639.64 +
```

```
               -
               -
               -
               -
               -
      767.57 +
               -
               -
               -
               -
               -
F     895.49 +
               -
               -
               -
               -
               -
T    1023.42 +
```

** STABL for WINDOWS **
by
Geotechnical Software Solutions

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: U.S.C.
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION B-10-020 HAM-75-7.85 - Ret. Wall J - Sta
. 480+84 to Sta. 483+50

BOUNDARY COORDINATES

4 Top Boundaries
9 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	527.80	50.00	527.80	3
2	50.00	527.80	50.10	546.60	1
3	50.10	546.60	63.30	546.60	1
4	63.30	546.60	120.00	546.60	2
5	50.00	527.80	63.20	527.80	3
6	63.20	527.80	63.30	546.60	2
7	63.20	527.80	120.00	527.80	3
8	0.00	525.10	120.00	525.10	4
9	0.00	505.10	120.00	505.10	5

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	125.0	0.0	34.0	0.00	0.0	1
2	120.0	130.0	2000.0	0.0	0.00	0.0	1
3	120.0	125.0	0.0	28.0	0.00	0.0	1
4	125.0	130.0	0.0	31.0	0.00	0.0	1
5	125.0	130.0	0.0	31.0	0.00	0.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)

1	0.00	503.60
2	120.00	503.60

1

BOUNDARY LOAD(S)

1 Load(s) Specified

Load No.	X-Left (ft)	X-Right (ft)	Intensity (psf)	Deflection (deg)
1	50.10	120.00	240.0	1.0

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

GEOSYNTHETIC DATA

1 Geosynthetics(s) group(s) specified

Ngroup no	Bnr no	Y-top (ft)	Y-bot (ft)	Levels no	Length (ft)	Spacing (ft)	Efficiency	Tallow (lbs/ft)
1	2	546.6	527.8	18	13.2	1.11	1.0	7500.0

1

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

750 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 75 Points Equally Spaced
Along The Ground Surface Between X = 0.00 ft.
and X = 49.00 ft.

Each Surface Terminates Between X = 65.00 ft.
and X = 110.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =450.00 ft.

3.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	15.23	527.80
2	17.73	526.14
3	20.33	524.65
4	23.03	523.33

5	25.81	522.21
6	28.66	521.27
7	31.57	520.53
8	34.52	519.98
9	37.50	519.64
10	40.49	519.50
11	43.49	519.56
12	46.48	519.82
13	49.44	520.29
14	52.37	520.95
15	55.24	521.81
16	58.05	522.86
17	60.79	524.10
18	63.43	525.52
19	65.97	527.11
20	68.40	528.87
21	70.70	530.80
22	72.87	532.87
23	74.89	535.09
24	76.76	537.43
25	78.47	539.90
26	80.00	542.48
27	81.36	545.15
28	81.98	546.60

*** 3.029 ***

Individual data on the 34 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Force Norm (lbs)	Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	2.5	249.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.8	473.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.8	279.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.7	1248.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	2.8	1710.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	2.9	2120.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	2.9	2468.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3.0	2742.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	3.0	2935.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	3.0	3042.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	3.0	3060.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	3.0	2989.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	3.0	2829.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.6	510.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.1	203.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	2.3	7107.2	0.0	0.0	0.0	0.0	0.0	0.0	544.8
17	2.9	8753.1	0.0	0.0	0.0	0.0	0.0	0.0	689.9
18	2.8	8221.2	0.0	0.0	0.0	0.0	0.0	0.0	674.4
19	2.7	7604.0	0.0	0.0	0.0	0.0	0.0	0.0	655.8
20	1.9	4932.8	0.0	0.0	0.0	0.0	0.0	0.0	448.0
21	0.5	1400.8	0.0	0.0	0.0	0.0	0.0	0.0	131.2
22	0.1	254.1	0.0	0.0	0.0	0.0	0.0	0.0	24.0
23	0.1	328.1	0.0	0.0	0.0	0.0	0.0	0.0	31.1
24	2.5	6185.2	0.0	0.0	0.0	0.0	0.0	0.0	609.8
25	0.9	2176.6	0.0	0.0	0.0	0.0	0.0	0.0	227.4
26	1.5	3243.4	0.0	0.0	0.0	0.0	0.0	0.0	355.2
27	2.3	4632.7	0.0	0.0	0.0	0.0	0.0	0.0	552.7
28	2.2	3841.3	0.0	0.0	0.0	0.0	0.0	0.0	520.3
29	2.0	3063.9	0.0	0.0	0.0	0.0	0.0	0.0	485.5
30	1.9	2319.0	0.0	0.0	0.0	0.0	0.0	0.0	448.5
31	1.7	1624.3	0.0	0.0	0.0	0.0	0.0	0.0	409.5
32	1.5	997.2	0.0	0.0	0.0	0.0	0.0	0.0	368.6
33	1.4	453.9	0.0	0.0	0.0	0.0	0.0	0.0	326.0
34	0.6	53.5	0.0	0.0	0.0	0.0	0.0	0.0	147.8

Individual data on the 18 geosynthetics

Group	Level	Slice	Head Coordinates (ft)	End Coordinates (ft)	T (lbs)	Length (ft)	Tallow (lbs)	T/Tall %

1	1	0	50.0	527.8	63.2	527.8	0.0	13.2	7500.0	0.0
1	2	0	50.0	528.9	63.2	528.9	0.0	13.2	7500.0	0.0
1	3	0	50.0	530.0	63.2	530.0	0.0	13.2	7500.0	0.0
1	4	0	50.0	531.1	63.2	531.1	0.0	13.2	7500.0	0.0
1	5	0	50.0	532.2	63.2	532.2	0.0	13.2	7500.0	0.0
1	6	0	50.0	533.3	63.2	533.3	0.0	13.2	7500.0	0.0
1	7	0	50.0	534.4	63.2	534.4	0.0	13.2	7500.0	0.0
1	8	0	50.0	535.5	63.2	535.5	0.0	13.2	7500.0	0.0
1	9	0	50.0	536.6	63.2	536.6	0.0	13.2	7500.0	0.0
1	10	0	50.1	537.8	63.3	537.8	0.0	13.2	7500.0	0.0
1	11	0	50.1	538.9	63.3	538.9	0.0	13.2	7500.0	0.0
1	12	0	50.1	540.0	63.3	540.0	0.0	13.2	7500.0	0.0
1	13	0	50.1	541.1	63.3	541.1	0.0	13.2	7500.0	0.0
1	14	0	50.1	542.2	63.3	542.2	0.0	13.2	7500.0	0.0
1	15	0	50.1	543.3	63.3	543.3	0.0	13.2	7500.0	0.0
1	16	0	50.1	544.4	63.3	544.4	0.0	13.2	7500.0	0.0
1	17	0	50.1	545.5	63.3	545.5	0.0	13.2	7500.0	0.0
1	18	0	50.1	546.6	63.3	546.6	0.0	13.2	7500.0	0.0

Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	13.24	527.80
2	15.85	526.31
3	18.53	524.97
4	21.29	523.78
5	24.10	522.75
6	26.97	521.88
7	29.89	521.17
8	32.84	520.63
9	35.82	520.25
10	38.81	520.04
11	41.81	520.00
12	44.81	520.13
13	47.79	520.43
14	50.75	520.90
15	53.69	521.53
16	56.58	522.33
17	59.42	523.28
18	62.21	524.40
19	64.92	525.67
20	67.57	527.09
21	70.12	528.66
22	72.59	530.37
23	74.95	532.22
24	77.21	534.19
25	79.35	536.29
26	81.37	538.51
27	83.27	540.84
28	85.02	543.27
29	86.64	545.80
30	87.10	546.60

*** 3.035 ***

1

Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	13.91	527.80
2	16.49	526.28
3	19.16	524.92
4	21.91	523.70
5	24.72	522.65
6	27.58	521.76
7	30.49	521.03
8	33.44	520.48
9	36.42	520.09

10	39.41	519.87
11	42.41	519.82
12	45.40	519.95
13	48.39	520.24
14	51.35	520.71
15	54.29	521.34
16	57.18	522.14
17	60.02	523.11
18	62.80	524.24
19	65.51	525.52
20	68.14	526.95
21	70.69	528.54
22	73.14	530.27
23	75.49	532.13
24	77.73	534.13
25	79.86	536.25
26	81.85	538.49
27	83.72	540.83
28	85.45	543.29
29	87.03	545.83
30	87.45	546.60

*** 3.036 ***

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	16.55	527.80
2	19.04	526.12
3	21.63	524.61
4	24.32	523.27
5	27.09	522.12
6	29.93	521.15
7	32.82	520.36
8	35.76	519.77
9	38.74	519.38
10	41.73	519.18
11	44.73	519.18
12	47.72	519.38
13	50.70	519.77
14	53.64	520.36
15	56.54	521.14
16	59.37	522.11
17	62.14	523.27
18	64.83	524.60
19	67.42	526.11
20	69.91	527.79
21	72.28	529.62
22	74.53	531.61
23	76.64	533.75
24	78.60	536.02
25	80.41	538.41
26	82.06	540.91
27	83.54	543.52
28	84.85	546.22
29	85.00	546.60

*** 3.037 ***

1

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	17.88	527.80
2	20.42	526.20

3	23.05	524.76
4	25.77	523.49
5	28.56	522.40
6	31.42	521.48
7	34.33	520.75
8	37.27	520.20
9	40.25	519.84
10	43.25	519.67
11	46.25	519.69
12	49.24	519.89
13	52.21	520.29
14	55.16	520.87
15	58.06	521.64
16	60.90	522.59
17	63.68	523.72
18	66.38	525.03
19	69.00	526.50
20	71.52	528.13
21	73.92	529.92
22	76.21	531.86
23	78.38	533.94
24	80.40	536.15
25	82.29	538.48
26	84.02	540.93
27	85.59	543.49
28	87.00	546.13
29	87.21	546.60

*** 3.041 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	11.92	527.80
2	14.39	526.10
3	16.96	524.55
4	19.62	523.16
5	22.35	521.93
6	25.16	520.87
7	28.03	519.99
8	30.94	519.28
9	33.89	518.74
10	36.87	518.39
11	39.87	518.22
12	42.87	518.23
13	45.86	518.42
14	48.84	518.80
15	51.79	519.35
16	54.70	520.08
17	57.56	520.99
18	60.36	522.07
19	63.08	523.32
20	65.73	524.73
21	68.29	526.29
22	70.75	528.01
23	73.10	529.88
24	75.33	531.89
25	77.43	534.02
26	79.41	536.28
27	81.24	538.66
28	82.92	541.14
29	84.45	543.72
30	85.82	546.39
31	85.91	546.60

*** 3.048 ***

1

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	25.16	527.80
2	27.80	526.38
3	30.54	525.15
4	33.36	524.13
5	36.25	523.31
6	39.19	522.71
7	42.16	522.32
8	45.16	522.15
9	48.16	522.20
10	51.15	522.46
11	54.11	522.94
12	57.02	523.64
13	59.88	524.55
14	62.67	525.66
15	65.37	526.97
16	67.96	528.48
17	70.44	530.17
18	72.79	532.03
19	75.00	534.06
20	77.05	536.25
21	78.94	538.58
22	80.66	541.04
23	82.19	543.62
24	83.53	546.31
25	83.65	546.60

*** 3.054 ***

Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	8.61	527.80
2	11.13	526.18
3	13.75	524.71
4	16.45	523.41
5	19.23	522.27
6	22.07	521.30
7	24.96	520.51
8	27.90	519.90
9	30.87	519.47
10	33.86	519.22
11	36.86	519.15
12	39.85	519.27
13	42.84	519.57
14	45.80	520.05
15	48.73	520.70
16	51.61	521.54
17	54.43	522.55
18	57.19	523.73
19	59.87	525.08
20	62.46	526.59
21	64.96	528.25
22	67.35	530.06
23	69.63	532.02
24	71.78	534.11
25	73.80	536.33
26	75.68	538.66
27	77.42	541.11
28	79.00	543.66
29	80.43	546.30
30	80.57	546.60

*** 3.055 ***

1

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	11.26	527.80
2	13.72	526.09
3	16.28	524.53
4	18.94	523.13
5	21.67	521.89
6	24.47	520.81
7	27.33	519.91
8	30.24	519.17
9	33.19	518.62
10	36.16	518.24
11	39.16	518.04
12	42.16	518.02
13	45.15	518.18
14	48.13	518.52
15	51.09	519.04
16	54.01	519.74
17	56.88	520.60
18	59.69	521.64
19	62.44	522.85
20	65.11	524.22
21	67.69	525.75
22	70.18	527.42
23	72.56	529.25
24	74.83	531.21
25	76.97	533.31
26	78.99	535.53
27	80.87	537.87
28	82.60	540.32
29	84.19	542.86
30	85.62	545.50
31	86.13	546.60

*** 3.055 ***

Failure Surface Specified By 23 Coordinate Points

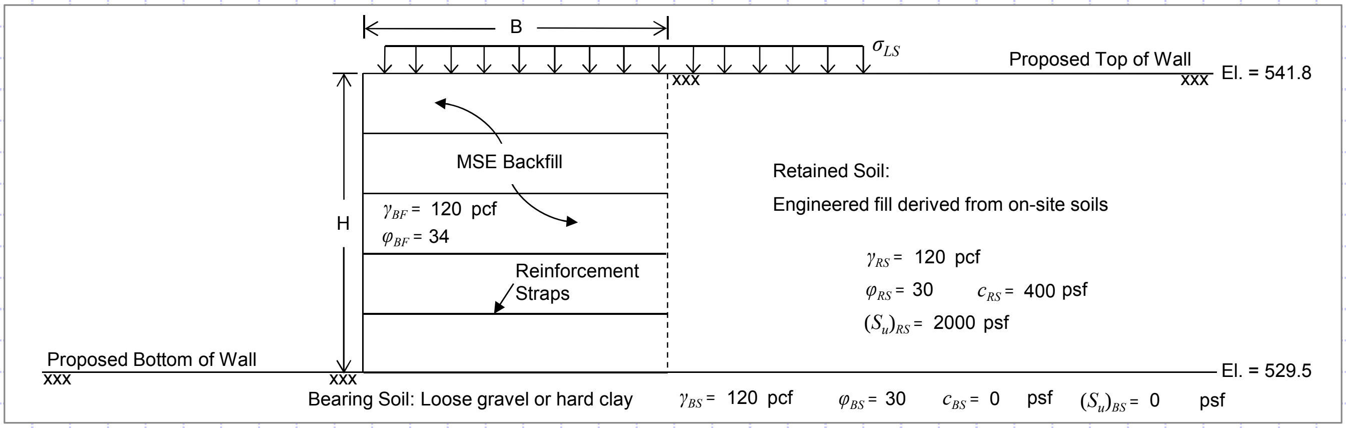
Point No.	X-Surf (ft)	Y-Surf (ft)
1	25.82	527.80
2	28.48	526.40
3	31.23	525.21
4	34.07	524.23
5	36.97	523.48
6	39.93	522.96
7	42.91	522.67
8	45.91	522.61
9	48.91	522.79
10	51.88	523.20
11	54.81	523.83
12	57.68	524.70
13	60.48	525.78
14	63.18	527.08
15	65.78	528.58
16	68.25	530.29
17	70.58	532.18
18	72.76	534.24
19	74.77	536.47
20	76.60	538.85
21	78.24	541.36
22	79.68	543.99
23	80.85	546.60

*** 3.056 ***

```
1
           Y           A     X     I     S           F     T

          0.00    127.93    255.86    383.78    511.71    639.64
X      0.00 +---------+---------+---------+--------*+*--------+
            -                                       .1
            -                                       9G G/1
            -                                       .g1g
            -                                       ..11
            -                                        ...
     127.93 +                                      * * *1/
            -
            -
            -
            -
            -
A    255.86 +
            -
            -
            -
            -
            -
X    383.78 +
            -
            -
            -
            -
            -
I    511.71 +
            -
            -
            -
            -
            -
S    639.64 +
            -
            -
            -
            -
            -
     767.57 +
            -
            -
            -
            -
            -
F    895.49 +
            -
            -
            -
            -
            -
T   1023.42 +
```

Retaining Wall J - MSE Wall - 14.0 ft. Maximum Wall Height - B-034-0-11 and B-035-0-11



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.3	ft
MSE Wall Width (Reinforcement Length), (B) =	9.0	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	400	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) =	3.0	ft

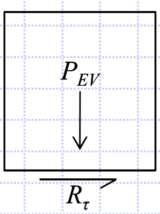
LRFD Load Factors

	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 Sections 11.6.3.6 and 11.10.5.3

Nominal Sliding Resistance: $R_\tau = P_{EV} \cdot \tan\delta$



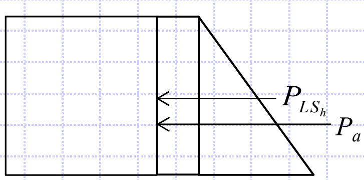
$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(12.3 ft)(9.0 ft)(1.00) = 13.28 kip/ft

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

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

R_τ = (13.28 kip/ft)(0.58) = 7.70 kip/ft

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)(12.3 ft)²(0.333)(1.5) = 4.53 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (240 psf)(12.3 ft)(0.333)(1.75) = 1.72 kip/ft

P_H = 4.53 kip/ft + 1.72 kip/ft = 6.25 kip/ft

Check Sliding Resistance

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 6.25 kip/ft ≤ (7.70 kip/ft)(1.0) = 7.70 kip/ft ⟶ 6.25 kip/ft ≤ 7.70 kip/ft **OK**

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

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COLUMBUS, OHIO 43231
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FAX: (614) 823-4990
WWW.RESOURCEINTERATIONAL.COM

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.3	ft
MSE Wall Width (Reinforcement Length), (B) =	9.0	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	400	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:

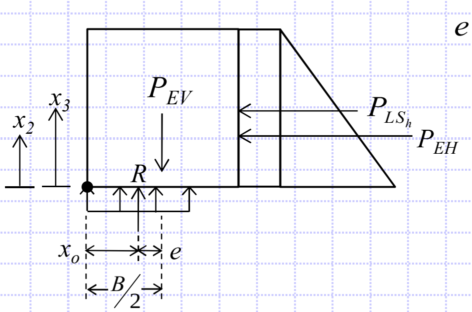
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	30	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	0	psf
Embedment Depth, (D) =	3.0	ft

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



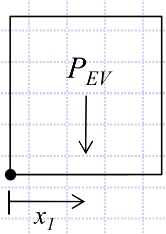
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (59.76 kip·ft/ft - 29.15 kip·ft/ft) / (13.28 kip/ft) = 2.30 ft

M_{EV} = 59.76 kip·ft/ft
M_H = 29.15 kip·ft/ft
P_{EV} = 13.28 kip/ft
(Defined below)

$e =$ (9 ft)/2 - 2.3 ft = 2.20 ft

Resisting Moment, M_{EV}:



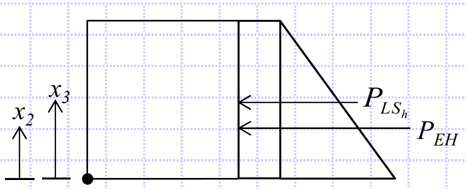
$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(12.3 ft)(9.0 ft)(1.00) = 13.28 kip/ft

$x_1 = B/2$ = (9.0 ft) / 2 = 4.50 ft

$M_{EV} =$ (13.28 kip/ft)(4.5 ft) = 59.76 kip·ft/ft

Overturning Moment, M_H:



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

$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(12.3 ft)²(0.333)(1.5) = 4.53 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (240 psf)(12.3 ft)(0.333)(1.75) = 1.72 kip/ft

$x_2 = H/3$ = (12.3 ft) / 3 = 4.10 ft

$x_3 = H/2$ = (12.3 ft) / 2 = 6.15 ft

$M_H =$ (4.53 kip/ft)(4.1 ft) + (1.72 kip/ft)(6.15 ft) = 29.15 kip·ft/ft

Limiting Eccentricity:

$e_{max} = B/4 \longrightarrow e_{max} =$ (9.0 ft) / 4 = 2.25 ft

Check Eccentricity

$e < e_{max} \longrightarrow$ 2.20 ft < 2.25 ft **OK**

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.3	ft
MSE Wall Width (Reinforcement Length), (B) =	9.0	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	400	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:

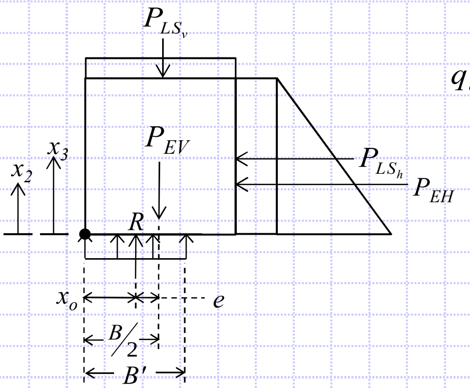
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	30	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	psf
Embedment Depth, (D) =	3.0	ft

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 11.6.3.2



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

$B' = B - 2e$ = 9.0 ft - 2(1.34 ft) = 6.32 ft

$e = B/2 - x_o$ = (9.0 ft) / 2 - 3.16 ft = 1.34 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (97.71 kip·ft/ft - 29.17 kip·ft/ft) / 21.71 kip/ft = 3.16 ft

$q_{eq} =$ (21.71 kip/ft) / (6.32 ft) = 3.44 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)(12.3 ft)(9.0 ft)(1.35)](4.5 ft) + [(240 psf)(9.0 ft)(1.75)](4.5 ft) = 97.71 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)(12.3 ft)²(0.333)(1.5)](4.1 ft) + [(240 psf)(12.3 ft)(0.333)(1.75)](6.15 ft) = 29.17 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)(12.3 ft)(9.0 ft)(1.35) + (240 psf)(9.0 ft)(1.75) = 21.71 kip/ft

Nominal Bearing Resistance:

$q_n = cN_c + \gamma D N_q + \tfrac{1}{2}\gamma B N_\gamma$ = (0 psf)(37.2) + (120 pcf)(3.0 ft)(22.5) + ½(120 pcf)(9.0 ft)(20.1) = 19.0 ksf

N_c = 37.2 N_q = 22.5 N_γ = 20.1

Check Bearing Capacity

$q_{eq} \le q_n \cdot \phi_b \longrightarrow$ 3.44 ksf ≤ (19.0 ksf)(0.65) = 12.35 ksf $\longrightarrow$ 3.44 ksf ≤ 12.35 ksf **OK**

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

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.3	ft
MSE Wall Width (Reinforcement Length), (B) =	9.0	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
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) =	0.333	
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) =	3.0	ft

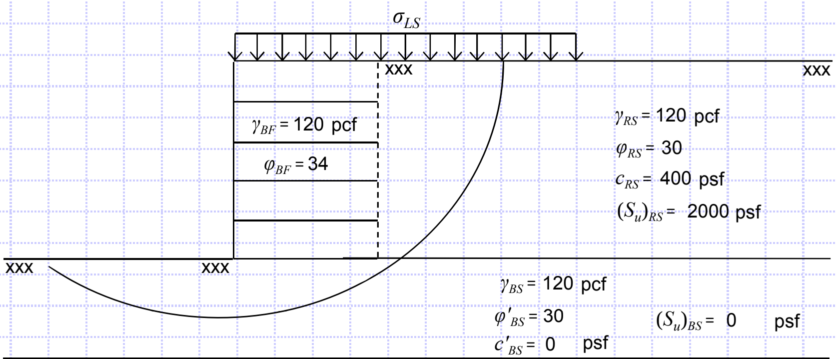
LRFD Load Factors

	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)

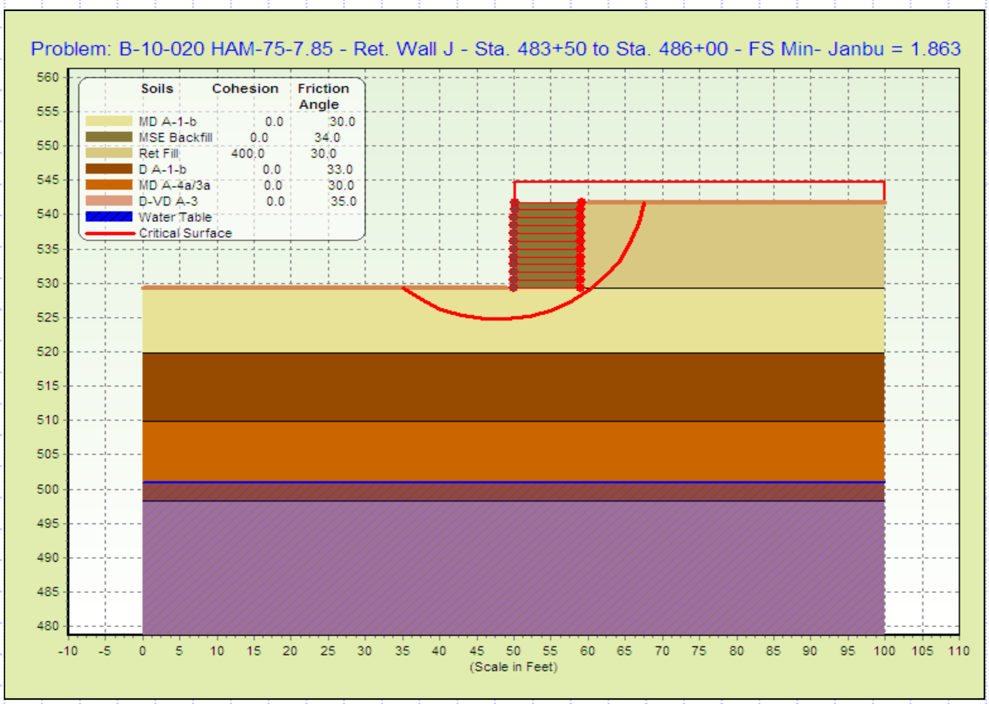
Check Overall (Global) Stability (Loading Case - Service I) - AASHTO LRFD BDM Sections 11.6.2.3 and 11.10.5.2

Long Term Stability - Drained Conditions



Loading scenario modeled as shown to the left and analyzed for slope stability using STABL for Windows software.

Graphical output shown below and tabular output results are provided as a separate attachment.



Check Overall (Global) Stability

$1.0 \leq FS \cdot \phi_{GS}$ → 1.00 ≤ (1.863)(0.75) = 1.40 → 1.00 ≤ 1.40 **OK**

FS = **1.863** *(From STABL Slope Stability Analysis)*

Use φ_{GS} = **0.75** *(Per AASHTO LRFD BDM Section 11.6.2.3)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	12.3	ft
MSE Wall Width (Reinforcement Length), (B) =	9.0	ft
Live Surcharge Load, (σ_{LS}) =	240	psf
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) =	0.333	
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) =	3.0	ft

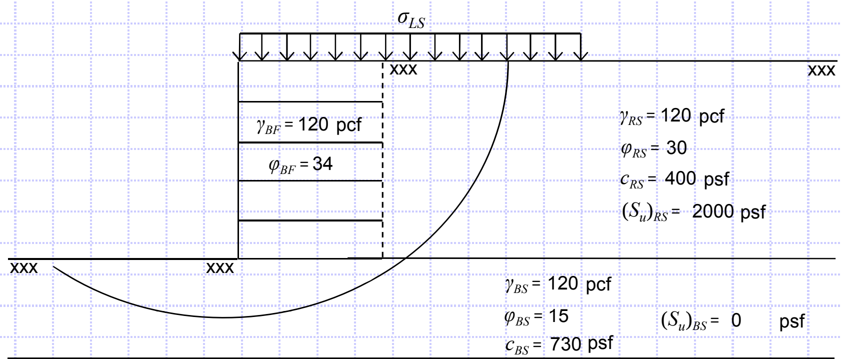
LRFD Load Factors

	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)

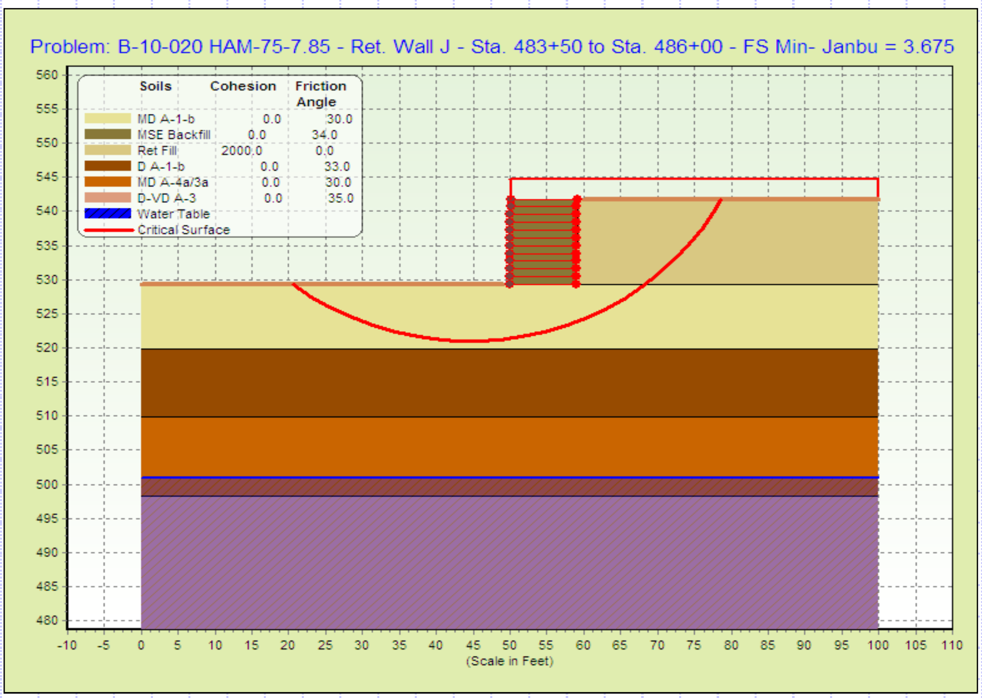
Check Overall (Global) Stability (Loading Case - Service I) - AASHTO LRFD BDM Sections 11.6.2.3 and 11.10.5.2 *(Cont'd)*

Short Term Stability - Undrained Conditions



Loading scenario modeled as shown to the left and analyzed for slope stability using STABL PC software.

Graphical output shown below and tabular output results are provided as a separate attachment.



Check Overall (Global) Stability

$1.0 \leq FS \cdot \phi_{GS}$ → 1.00 ≤ (3.675)(0.75) = 2.76 → 1.00 ≤ 2.76 **OK**

FS = **3.675** *(From STABL Slope Stability Analysis)*

Use φ_{GS} = **0.75** *(Per AASHTO LRFD BDM Section 11.6.2.3)*

** STABL for WINDOWS **
by
Geotechnical Software Solutions

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: U.S.C.
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION B-10-020 HAM-75-7.85 - Ret. Wall J - Sta
. 483+50 to Sta. 486+00

BOUNDARY COORDINATES

4 Top Boundaries
10 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	529.30	50.00	529.30	3
2	50.00	529.30	50.10	541.80	1
3	50.10	541.80	59.10	541.80	1
4	59.10	541.80	100.00	541.80	2
5	50.00	529.30	59.00	529.30	3
6	59.00	529.30	59.10	541.80	2
7	59.00	529.30	100.00	529.30	3
8	0.00	519.80	100.00	519.80	4
9	0.00	509.80	100.00	509.80	5
10	0.00	498.30	100.00	498.20	6

1

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	125.0	0.0	34.0	0.00	0.0	1
2	120.0	130.0	400.0	30.0	0.00	0.0	1
3	125.0	130.0	0.0	30.0	0.00	0.0	1
4	130.0	135.0	0.0	33.0	0.00	0.0	1
5	125.0	130.0	0.0	30.0	0.00	0.0	1
6	135.0	140.0	0.0	35.0	0.00	0.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 2 Coordinate Points

Point X-Water Y-Water

No.	(ft)	(ft)
1	0.00	501.00
2	100.00	501.00

1

BOUNDARY LOAD(S)

1 Load(s) Specified

Load No.	X-Left (ft)	X-Right (ft)	Intensity (psf)	Deflection (deg)
1	50.10	100.00	240.0	1.0

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

GEOSYNTHETIC DATA

1 Geosynthetics(s) group(s) specified

Ngroup no	Bnr no	Y-top (ft)	Y-bot (ft)	Levels no	Length (ft)	Spacing (ft)	Efficiency	Tallow (lbs/ft)
1	2	541.8	529.3	12	9.0	1.14	1.0	7500.0

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

750 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 75 Points Equally Spaced Along The Ground Surface Between X = 0.00 ft.
and X = 49.00 ft.

Each Surface Terminates Between X = 60.00 ft.
and X = 100.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y =450.00 ft.

3.00 ft. Line Segments Define Each Trial Failure Surface.

Factor Of Safety Calculation Has Gone Through 30 Iterations, without convergence

The Trial Failure Surface In Question Is Defined By The Following 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	27.15	529.30
2	29.82	527.93
3	32.64	526.92

4	35.58	526.29
5	38.57	526.04
6	41.56	526.19
7	44.52	526.72
8	47.37	527.63
9	50.09	528.90
10	52.62	530.52
11	54.91	532.45
12	56.94	534.67
13	58.66	537.12
14	60.04	539.78
15	60.78	541.80

Factor Of Safety For The Preceding Specified Surface = -0.590

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.10	529.30
2	37.54	527.56
3	40.22	526.21
4	43.07	525.28
5	46.03	524.79
6	49.03	524.74
7	52.00	525.15
8	54.88	526.00
9	57.60	527.27
10	60.09	528.94
11	62.31	530.96
12	64.19	533.29
13	65.71	535.88
14	66.82	538.67
15	67.50	541.59
16	67.51	541.80

*** 1.863 ***

Individual data on the 20 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Force Norm (lbs)	Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	2.4	265.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.7	807.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	2.9	1266.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3.0	1578.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	3.0	1700.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.0	544.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.1	130.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.9	3871.0	0.0	0.0	0.0	0.0	0.0	0.0	456.6
9	2.9	5655.0	0.0	0.0	0.0	0.0	0.0	0.0	690.5
10	2.7	4979.6	0.0	0.0	0.0	0.0	0.0	0.0	652.0
11	1.4	2378.9	0.0	0.0	0.0	0.0	0.0	0.0	336.9
12	0.1	163.2	0.0	0.0	0.0	0.0	0.0	0.0	24.0
13	1.0	1572.5	0.0	0.0	0.0	0.0	0.0	0.0	237.9
14	0.4	601.9	0.0	0.0	0.0	0.0	0.0	0.0	94.9
15	1.8	2549.9	0.0	0.0	0.0	0.0	0.0	0.0	437.0

16	1.9	2190.8	0.0	0.0	0.0	0.0	0.0	0.0	453.0
17	1.5	1311.8	0.0	0.0	0.0	0.0	0.0	0.0	363.8
18	1.1	602.4	0.0	0.0	0.0	0.0	0.0	0.0	266.3
19	0.7	135.9	0.0	0.0	0.0	0.0	0.0	0.0	162.8
20	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	3.9

Individual data on the 12 geosynthetics

Group	Level	Slice	Head Coordinates (ft)		End Coordinates (ft)		T (lbs)	Length (ft)	Tallow (lbs)	T/Tall %
1	1	0	50.0	529.3	59.0	529.3	0.0	9.0	7500.0	0.0
1	2	0	50.0	530.4	59.0	530.4	0.0	9.0	7500.0	0.0
1	3	0	50.0	531.6	59.0	531.6	0.0	9.0	7500.0	0.0
1	4	0	50.0	532.7	59.0	532.7	0.0	9.0	7500.0	0.0
1	5	0	50.0	533.8	59.0	533.8	0.0	9.0	7500.0	0.0
1	6	0	50.0	535.0	59.0	535.0	0.0	9.0	7500.0	0.0
1	7	0	50.1	536.1	59.1	536.1	0.0	9.0	7500.0	0.0
1	8	0	50.1	537.3	59.1	537.3	0.0	9.0	7500.0	0.0
1	9	0	50.1	538.4	59.1	538.4	0.0	9.0	7500.0	0.0
1	10	0	50.1	539.5	59.1	539.5	0.0	9.0	7500.0	0.0
1	11	0	50.1	540.7	59.1	540.7	0.0	9.0	7500.0	0.0
1	12	0	50.1	541.8	59.1	541.8	0.0	9.0	7500.0	0.0

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.78	529.30
2	34.15	527.46
3	36.75	525.96
4	39.53	524.83
5	42.44	524.09
6	45.42	523.75
7	48.42	523.82
8	51.38	524.31
9	54.25	525.19
10	56.97	526.45
11	59.49	528.07
12	61.77	530.03
13	63.76	532.27
14	65.42	534.77
15	66.73	537.47
16	67.66	540.32
17	67.92	541.80

*** 1.903 ***

1

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.39	529.30
2	43.10	528.01
3	45.97	527.15
4	48.95	526.76
5	51.95	526.83
6	54.90	527.38
7	57.73	528.37
8	60.36	529.80
9	62.74	531.63
10	64.81	533.80
11	66.51	536.28
12	67.80	538.98
13	68.64	541.80

*** 1.912 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.78	529.30
2	33.91	527.18
3	36.33	525.42
4	39.01	524.06
5	41.86	523.13
6	44.82	522.66
7	47.82	522.66
8	50.79	523.13
9	53.64	524.06
10	56.31	525.42
11	58.74	527.18
12	60.86	529.30
13	62.63	531.73
14	63.99	534.40
15	64.92	537.25
16	65.40	540.21
17	65.40	541.80

*** 1.924 ***

1

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	41.72	529.30
2	44.41	527.98
3	47.30	527.17
4	50.29	526.89
5	53.28	527.14
6	56.17	527.93
7	58.88	529.22
8	61.31	530.97
9	63.39	533.14
10	65.05	535.63
11	66.24	538.39
12	66.91	541.31
13	66.94	541.80

*** 1.926 ***

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	37.08	529.30
2	39.49	527.52
3	42.17	526.15
4	45.03	525.25
5	48.00	524.83
6	51.00	524.91
7	53.94	525.48
8	56.75	526.52
9	59.35	528.02
10	61.67	529.93
11	63.64	532.19
12	65.21	534.74

13	66.34	537.52
14	67.00	540.45
15	67.07	541.80

*** 1.933 ***

1

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	27.81	529.30
2	30.11	527.37
3	32.64	525.76
4	35.35	524.48
5	38.21	523.56
6	41.16	523.02
7	44.16	522.86
8	47.15	523.08
9	50.09	523.68
10	52.92	524.66
11	55.61	525.99
12	58.11	527.66
13	60.37	529.63
14	62.36	531.87
15	64.04	534.35
16	65.40	537.03
17	66.40	539.86
18	66.81	541.80

*** 1.937 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	39.07	529.30
2	41.80	528.06
3	44.67	527.20
4	47.64	526.73
5	50.64	526.67
6	53.62	527.02
7	56.52	527.76
8	59.31	528.88
9	61.91	530.37
10	64.29	532.20
11	66.40	534.33
12	68.20	536.73
13	69.67	539.35
14	70.64	541.80

*** 1.943 ***

1

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.76	529.30
2	38.39	527.87
3	41.18	526.76

4	44.08	526.00
5	47.05	525.59
6	50.05	525.53
7	53.04	525.84
8	55.96	526.50
9	58.79	527.51
10	61.47	528.85
11	63.98	530.50
12	66.27	532.44
13	68.31	534.64
14	70.07	537.07
15	71.53	539.69
16	72.39	541.80

*** 1.970 ***

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.78	529.30
2	34.20	527.52
3	36.82	526.05
4	39.59	524.92
5	42.49	524.13
6	45.46	523.70
7	48.46	523.64
8	51.44	523.95
9	54.37	524.62
10	57.18	525.65
11	59.86	527.01
12	62.34	528.69
13	64.60	530.66
14	66.61	532.89
15	68.32	535.36
16	69.72	538.01
17	70.78	540.82
18	71.02	541.80

*** 1.975 ***

1

```
           Y            A     X     I     S            F     T

           0.00    126.81    253.61    380.41    507.22    634.02

X      0.00 +---------+---------+---------+--------****-------+
            -                                       ..7
            -                                       .1GG/1
            -                                       .1gg
            -                                        ...
            -                                      *****1/
     126.81 +
            -
            -
            -
            -
            -
A    253.61 +
            -
            -
            -
            -
X    380.41 +
            -
            -
            -
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                -
                -
I     507.22 +
                -
                -
                -
                -
                -
S     634.02 +
                -
                -
                -
                -
                -
      760.83 +
                -
                -
                -
                -
                -
F     887.63 +
                -
                -
                -
                -
                -
T   1014.44 +
```

** STABL for WINDOWS **
by
Geotechnical Software Solutions

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: U.S.C.
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION B-10-020 HAM-75-7.85 - Ret. Wall J - Sta
. 483+50 to Sta. 486+00

BOUNDARY COORDINATES

4 Top Boundaries
10 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	529.30	50.00	529.30	3
2	50.00	529.30	50.10	541.80	1
3	50.10	541.80	59.10	541.80	1
4	59.10	541.80	100.00	541.80	2
5	50.00	529.30	59.00	529.30	3
6	59.00	529.30	59.10	541.80	2
7	59.00	529.30	100.00	529.30	3
8	0.00	519.80	100.00	519.80	4
9	0.00	509.80	100.00	509.80	5
10	0.00	498.30	100.00	498.20	6

1

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	125.0	0.0	34.0	0.00	0.0	1
2	120.0	130.0	2000.0	0.0	0.00	0.0	1
3	125.0	130.0	0.0	30.0	0.00	0.0	1
4	130.0	135.0	0.0	33.0	0.00	0.0	1
5	125.0	130.0	0.0	30.0	0.00	0.0	1
6	135.0	140.0	0.0	35.0	0.00	0.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 2 Coordinate Points

Point X-Water Y-Water

No.	(ft)	(ft)
1	0.00	501.00
2	100.00	501.00

1

BOUNDARY LOAD(S)

1 Load(s) Specified

Load No.	X-Left (ft)	X-Right (ft)	Intensity (psf)	Deflection (deg)
1	50.10	100.00	240.0	1.0

NOTE - Intensity Is Specified As A Uniformly Distributed Force Acting On A Horizontally Projected Surface.

GEOSYNTHETIC DATA

1 Geosynthetics(s) group(s) specified

Ngroup no	Bnr no	Y-top (ft)	Y-bot (ft)	Levels no	Length (ft)	Spacing (ft)	Efficiency	Tallow (lbs/ft)
1	2	541.8	529.3	12	9.0	1.14	1.0	7500.0

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

750 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 75 Points Equally Spaced Along The Ground Surface Between X = 0.00 ft. and X = 49.00 ft.

Each Surface Terminates Between X = 60.00 ft. and X = 100.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y =450.00 ft.

3.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	20.53	529.30
2	22.95	527.53

3	25.50	525.95
4	28.17	524.58
5	30.94	523.42
6	33.79	522.48
7	36.70	521.76
8	39.66	521.28
9	42.65	521.02
10	45.65	521.00
11	48.64	521.21
12	51.61	521.65
13	54.53	522.33
14	57.39	523.23
15	60.18	524.35
16	62.86	525.68
17	65.44	527.22
18	67.89	528.95
19	70.19	530.87
20	72.34	532.96
21	74.32	535.22
22	76.12	537.62
23	77.73	540.15
24	78.60	541.80

*** 3.675 ***

Individual data on the 28 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Force Norm (lbs)	Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	2.4	267.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.6	816.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	2.7	1344.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.8	1832.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	2.8	2260.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	2.9	2613.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	3.0	2878.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3.0	3045.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	3.0	3109.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	3.0	3065.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	1.4	1357.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.1	173.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	1.5	3722.7	0.0	0.0	0.0	0.0	0.0	0.0	361.7
14	2.9	7056.4	0.0	0.0	0.0	0.0	0.0	0.0	701.6
15	2.9	6627.0	0.0	0.0	0.0	0.0	0.0	0.0	686.9
16	1.6	3566.3	0.0	0.0	0.0	0.0	0.0	0.0	385.7
17	0.1	217.6	0.0	0.0	0.0	0.0	0.0	0.0	24.0
18	1.1	2309.7	0.0	0.0	0.0	0.0	0.0	0.0	258.3
19	2.7	5472.5	0.0	0.0	0.0	0.0	0.0	0.0	645.1
20	2.6	4782.5	0.0	0.0	0.0	0.0	0.0	0.0	618.2
21	2.4	4045.0	0.0	0.0	0.0	0.0	0.0	0.0	587.6
22	0.4	641.1	0.0	0.0	0.0	0.0	0.0	0.0	101.1
23	1.9	2649.5	0.0	0.0	0.0	0.0	0.0	0.0	452.3
24	2.1	2549.6	0.0	0.0	0.0	0.0	0.0	0.0	515.9
25	2.0	1832.2	0.0	0.0	0.0	0.0	0.0	0.0	475.2
26	1.8	1162.0	0.0	0.0	0.0	0.0	0.0	0.0	431.6
27	1.6	562.1	0.0	0.0	0.0	0.0	0.0	0.0	385.4
28	0.9	86.5	0.0	0.0	0.0	0.0	0.0	0.0	209.6

Individual data on the 12 geosynthetics

Group	Level	Slice	Head Coordinates (ft)		End Coordinates (ft)		T (lbs)	Length (ft)	Tallow (lbs)	T/Tall %
1	1	0	50.0	529.3	59.0	529.3	0.0	9.0	7500.0	0.0
1	2	0	50.0	530.4	59.0	530.4	0.0	9.0	7500.0	0.0
1	3	0	50.0	531.6	59.0	531.6	0.0	9.0	7500.0	0.0
1	4	0	50.0	532.7	59.0	532.7	0.0	9.0	7500.0	0.0
1	5	0	50.0	533.8	59.0	533.8	0.0	9.0	7500.0	0.0
1	6	0	50.0	535.0	59.0	535.0	0.0	9.0	7500.0	0.0
1	7	0	50.1	536.1	59.1	536.1	0.0	9.0	7500.0	0.0

1	8	0	50.1	537.3	59.1	537.3	0.0	9.0	7500.0	0.0
1	9	0	50.1	538.4	59.1	538.4	0.0	9.0	7500.0	0.0
1	10	0	50.1	539.5	59.1	539.5	0.0	9.0	7500.0	0.0
1	11	0	50.1	540.7	59.1	540.7	0.0	9.0	7500.0	0.0
1	12	0	50.1	541.8	59.1	541.8	0.0	9.0	7500.0	0.0

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	25.82	529.30
2	28.28	527.57
3	30.88	526.08
4	33.61	524.84
5	36.45	523.86
6	39.36	523.14
7	42.33	522.69
8	45.32	522.53
9	48.32	522.64
10	51.29	523.03
11	54.22	523.69
12	57.07	524.62
13	59.83	525.81
14	62.46	527.25
15	64.94	528.93
16	67.26	530.84
17	69.40	532.94
18	71.32	535.24
19	73.03	537.71
20	74.50	540.32
21	75.16	541.80

*** 3.690 ***

1

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.84	529.30
2	26.34	527.65
3	28.97	526.20
4	31.70	524.95
5	34.51	523.92
6	37.40	523.11
7	40.35	522.52
8	43.32	522.17
9	46.32	522.04
10	49.32	522.15
11	52.30	522.48
12	55.25	523.05
13	58.14	523.84
14	60.96	524.85
15	63.70	526.08
16	66.34	527.51
17	68.85	529.15
18	71.24	530.97
19	73.47	532.97
20	75.54	535.14
21	77.44	537.46
22	79.16	539.92
23	80.26	541.80

*** 3.693 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	19.87	529.30
2	22.19	527.40
3	24.66	525.70
4	27.25	524.19
5	29.96	522.91
6	32.77	521.84
7	35.65	521.01
8	38.59	520.41
9	41.57	520.04
10	44.56	519.92
11	47.56	520.04
12	50.54	520.41
13	53.48	521.01
14	56.36	521.84
15	59.16	522.91
16	61.87	524.19
17	64.47	525.70
18	66.94	527.40
19	69.26	529.30
20	71.42	531.38
21	73.41	533.63
22	75.21	536.03
23	76.81	538.56
24	78.20	541.22
25	78.45	541.80

*** 3.697 ***

1

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	18.54	529.30
2	21.08	527.70
3	23.72	526.28
4	26.45	525.04
5	29.27	524.00
6	32.14	523.15
7	35.07	522.51
8	38.04	522.07
9	41.03	521.83
10	44.03	521.81
11	47.03	521.99
12	50.00	522.38
13	52.94	522.98
14	55.83	523.77
15	58.66	524.77
16	61.42	525.96
17	64.08	527.34
18	66.64	528.90
19	69.09	530.63
20	71.42	532.53
21	73.60	534.58
22	75.64	536.79
23	77.52	539.12
24	79.23	541.59
25	79.36	541.80

*** 3.705 ***

Failure Surface Specified By 23 Coordinate Points

Point X-Surf Y-Surf

No.	(ft)	(ft)
1	18.54	529.30
2	20.95	527.51
3	23.49	525.92
4	26.16	524.56
5	28.94	523.42
6	31.80	522.51
7	34.73	521.85
8	37.70	521.44
9	40.69	521.27
10	43.69	521.36
11	46.67	521.69
12	49.62	522.27
13	52.50	523.10
14	55.30	524.17
15	58.01	525.46
16	60.60	526.98
17	63.05	528.71
18	65.35	530.63
19	67.48	532.74
20	69.43	535.02
21	71.18	537.46
22	72.72	540.04
23	73.58	541.80

*** 3.707 ***

1

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	16.55	529.30
2	19.04	527.62
3	21.64	526.12
4	24.34	524.82
5	27.13	523.70
6	29.99	522.79
7	32.90	522.09
8	35.86	521.59
9	38.85	521.31
10	41.85	521.24
11	44.84	521.38
12	47.82	521.74
13	50.77	522.31
14	53.67	523.08
15	56.50	524.06
16	59.26	525.24
17	61.93	526.62
18	64.49	528.18
19	66.93	529.91
20	69.25	531.82
21	71.42	533.89
22	73.44	536.11
23	75.30	538.46
24	76.99	540.94
25	77.48	541.80

*** 3.708 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	27.81	529.30
2	30.26	527.56

3	32.86	526.06
4	35.58	524.81
5	38.41	523.81
6	41.32	523.09
7	44.29	522.63
8	47.28	522.46
9	50.28	522.56
10	53.26	522.94
11	56.18	523.60
12	59.04	524.52
13	61.79	525.71
14	64.43	527.15
15	66.91	528.82
16	69.24	530.72
17	71.37	532.83
18	73.30	535.12
19	75.01	537.59
20	76.48	540.20
21	77.19	541.80

*** 3.713 ***

1

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.80	529.30
2	32.37	527.76
3	35.09	526.48
4	37.92	525.49
5	40.83	524.78
6	43.81	524.38
7	46.80	524.27
8	49.80	524.47
9	52.76	524.96
10	55.65	525.75
11	58.45	526.83
12	61.13	528.19
13	63.65	529.80
14	66.00	531.67
15	68.15	533.76
16	70.08	536.06
17	71.77	538.53
18	73.20	541.17
19	73.47	541.80

*** 3.745 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	15.23	529.30
2	17.73	527.64
3	20.34	526.16
4	23.05	524.88
5	25.85	523.79
6	28.72	522.91
7	31.64	522.25
8	34.61	521.79
9	37.60	521.56
10	40.60	521.54
11	43.59	521.74
12	46.56	522.16
13	49.49	522.79
14	52.37	523.63

```
             15         55.18      524.68
             16         57.91      525.93
             17         60.54      527.38
             18         63.06      529.01
             19         65.45      530.82
             20         67.70      532.80
             21         69.80      534.94
             22         71.75      537.23
             23         73.52      539.65
             24         74.86      541.80

                ***     3.746   ***


1

                     Y            A     X     I     S            F     T


                     0.00    126.81    253.61    380.41    507.22    634.02

          X      0.00 +---------+---------+---------+--------****-------+
                      -                                       .11
                      -                                       .1GG/1
                      -                                       .1gg
                      -                                        .11
                      -                                      *****1/
               126.81 +
                      -
                      -
                      -
                      -
                      -
          A    253.61 +
                      -
                      -
                      -
                      -
                      -
          X    380.41 +
                      -
                      -
                      -
                      -
                      -
          I    507.22 +
                      -
                      -
                      -
                      -
                      -
          S    634.02 +
                      -
                      -
                      -
                      -
                      -
               760.83 +
                      -
                      -
                      -
                      -
                      -
          F    887.63 +
                      -
                      -
                      -
                      -
                      -
          T   1014.44 +
```

APPENDIX VIII

SOLDIER PILE AND LAGGING WALL CALCULATIONS

RESOURCE INTERNATIONAL, INC.
6350 PRESIDENTIAL GATEWAY
COLUMBUS, OHIO 43231
PHONE: (614) 823-4949
FAX: (614) 823-4990
WWW.RESOURCEINTERATIONAL.COM

Retaining Wall and Soil Parameters

Retaining Wall Height, (H) =	19.3	ft
Soil Friction Angle, (φ') =	28	°
Soil Total Unit Weight, (γ) =	120	pcf
Backslope Angle, (β) =	18.4	°
Live Surcharge Load, (σ_{LS}) =	0	psf
Shaft Spacing, (S) =	4.0	ft O.C.
Shaft diameter, (b) =	24	in

Rankine Active Earth Pressures

$$K_a = \cos\beta\left(\frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\varphi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\varphi}}\right)$$

k_a = 0.44

$$P_a = k_a \gamma H$$

P_a = 1019 psf

LRFD Load Factors

	EH	LS
Strength I	1.50	1.75
Service I	1.00	1.00

(AASHTO LRFD BDM Tab. 3.4.1-1, 3.4.1-2 - Active Earth Pressure)

p-y Reduction Factor

$$\beta_a = 0.5292\left(\frac{S}{b}\right)^{0.5659}$$

β_a = 0.7834

Stuructural Element Properties

Section Type: HP 12x53

E =	29,000	ksi	d =	11.8	in	I_x =	393	in^4	Z_x =	74.0	in^3
A_s =	15.5	in^2	t_w =	0.435	in	I_x =	98.3	in^4 per ft	Z_x =	18.5	in^3 per ft
f_y =	50	ksi	t_f =	0.435	in	r_s =	5.03	in	T =	9.5	in
									S =	66.8	in^3

Anchor Tieback Setup

1		=	Row(s) of Anchors
5.0	ft	=	Distance Between Top of Wall Row of Anchors, (H_1)
14.3	ft	=	Distance Row of Anchors and Bottom of Excavation, (H_2)
20	°	=	Inclination of Anchors, (θ)

Factored Horizontal Tieback and Resultant Loads by Tributary Area Method

$$T_1 = \gamma_{LS}\left[k_a\sigma_{LS}\left(H_1 + \tfrac{1}{2}H_2\right)S\right] + \gamma_{EH}\left[\tfrac{1}{2}\left(\tfrac{2}{3}H_1\right)P_aS + \left(H_1 - \tfrac{2}{3}H_1 - \tfrac{2}{3}H_2\right)P_aS + \left(\tfrac{2}{3}H_2 - \tfrac{1}{2}H_1\right)\tfrac{7}{8}P_aS\right]$$

T_1 = 62,298 lb

$$R = \gamma_{LS}\left[k_a\sigma_{LS}\left(\tfrac{1}{2}H_2\right)S\right] + \gamma_{EH}\left[\tfrac{1}{2}\left(\tfrac{1}{2}H_2\right)\tfrac{3}{4}P_aS\right]$$

R = 16,400 lb

$V_{max(from\ embedded,\ LPILE)}$ = 16,400 lb

$V_{max(from\ cantilever,\ calculated)}$ = 41,910 lb

Factored Moment at Ground Surface

$$M = \gamma_{EH}\left[\tfrac{1}{2}\left(\tfrac{2}{3}\right)H_1\left(H - \tfrac{2}{3}\left(\tfrac{2}{3}\right)H_1\right) + \left(H - \tfrac{2}{3}H_1 - \tfrac{2}{3}H_2\right)\left(\tfrac{2}{3}H_2 + \tfrac{1}{2}\left(H - \tfrac{2}{3}H_1 - \tfrac{2}{3}H_2\right)\right) + \tfrac{1}{2}\left(\tfrac{2}{3}H_2\right)\left(\tfrac{2}{3}\left(\tfrac{2}{3}\right)H_2\right)\right]P_aS + \gamma_{LS}k_a\sigma_{LS}HS - T_1(H_2)$$

M = -29,779 lb-ft

-357,345 lb-in

$M_{max(from\ embedded,\ LPILE)}$ = 53,372 lb-ft

$M_{max(from\ cantilever,\ calculated)}$ = 107,950 lb-ft

Factored Vertical Component from Anchor and Structural Loads

$$P_{max} = \left(\frac{T_1}{\cos\theta}\right)\sin\theta$$

P_{max} = 22,675 lb

Factored Axial Load from Structure P_{SL} = 0 lb

Capacity Verification

φ_f = 1.00 φ_c = 0.70 φ_v = 1.00 , C= 1.0

Maximum Factored Bending Moment, M_u =	107.9	kip-ft per section
Maximum Factored Axial Force, P_u =	22.7	kip per section (Anchor and Structural Axial Load)
Maximum Factored Shear Force, V_u =	41.9	kip per section

			Check			
Factored Flexural Resistance, $\varphi_f M_n$ =	308.3	kip-ft per section	M_u	less than	$\varphi_f M_n$	OK
Factored Axial Resistance, $\varphi_c P_n$ =	498.6	kip per section	P_u	less than	$\varphi_c P_n$	OK
Factored Shear Resistance, $\varphi_v V_n$ =	137.6	kip per section	V_u	less than	$\varphi_v V_n$	OK
Required Section Modulus, S_{Req} =	25.9	in^3	S_{Req}	less than	$S_{Section}$	OK

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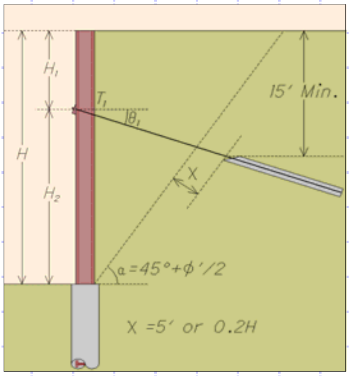
Anchor Diagram



Per AASHTO Bridge Design Specification 11.9:

Anchor tiebacks must have an unbonded length of the greater of:

1) Length to bonded segment equal to a distance x beyond the active wedge angle.
2) Overburden cover must be a minimum of 15 ft before bonding.
3) Must be a minimum of 15 ft.

Anchor tiebacks must have the capacity to resist pullout of the bonded length.

Active Wedge Angle, (α) = 59.0 °
Min. Length Behind Active Wedge, (x) = 5.0 ft

Unbonded Anchor Length

$$L_{u,T1} = (15 - H_1)\left(\frac{\sin(90-\beta)}{\sin(\beta+\theta)}\right) = 15.28 \text{ ft}$$ For min. overburden

$$L_{u,T1} = (H_2)\left(\frac{\sin(90-\alpha)}{\sin(\alpha+\theta)}\right) + x = 12.5 \text{ ft}$$ For min. x behind active wedge

$L_{u,T1}$ = **15.28** ft

Bonded Anchor Length

Anchor Pullout Capacity (AASHTO 11.9.4.2)

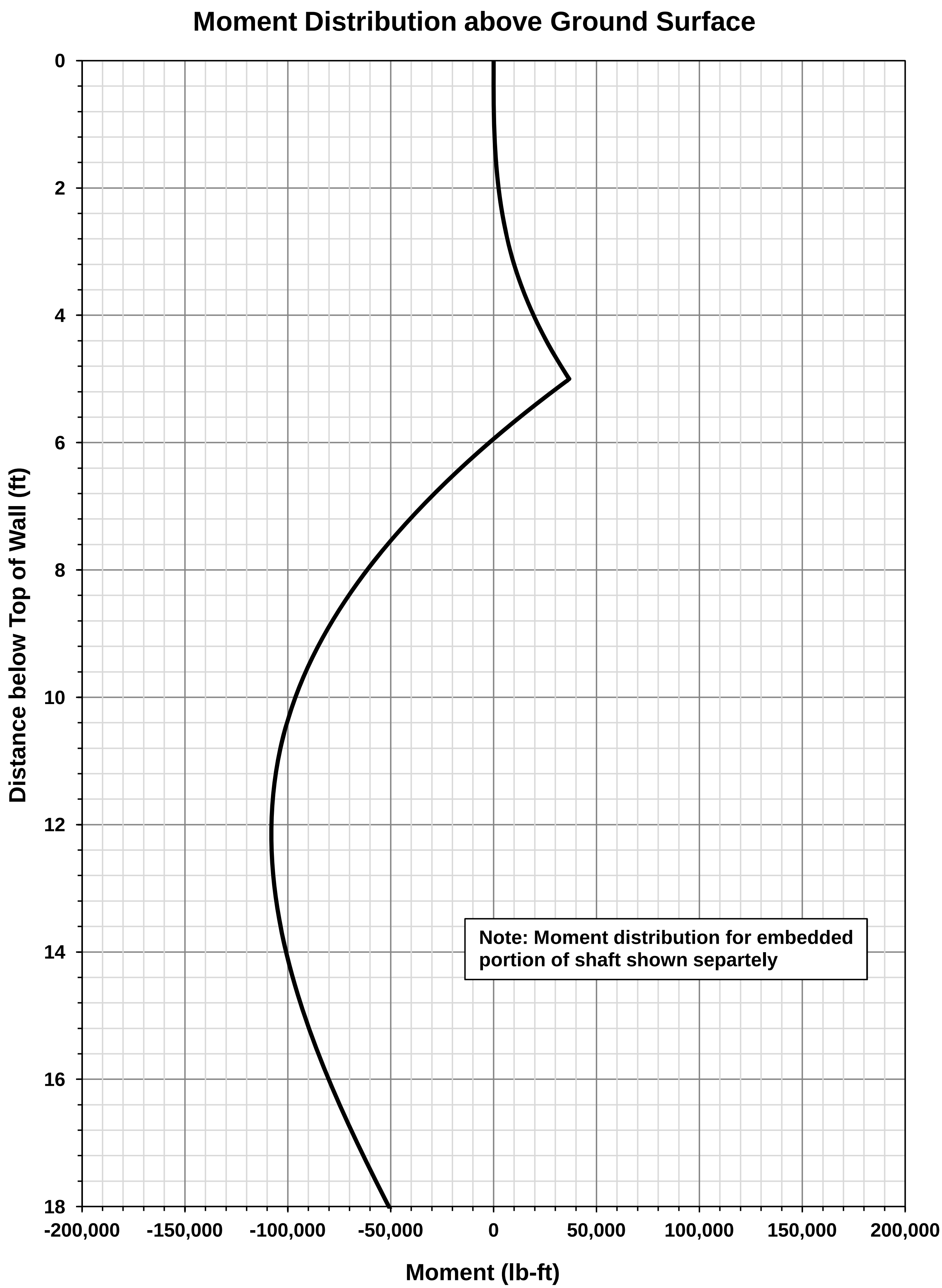
$$Q_R = \phi Q_n = \phi \pi d \tau_n L_b$$

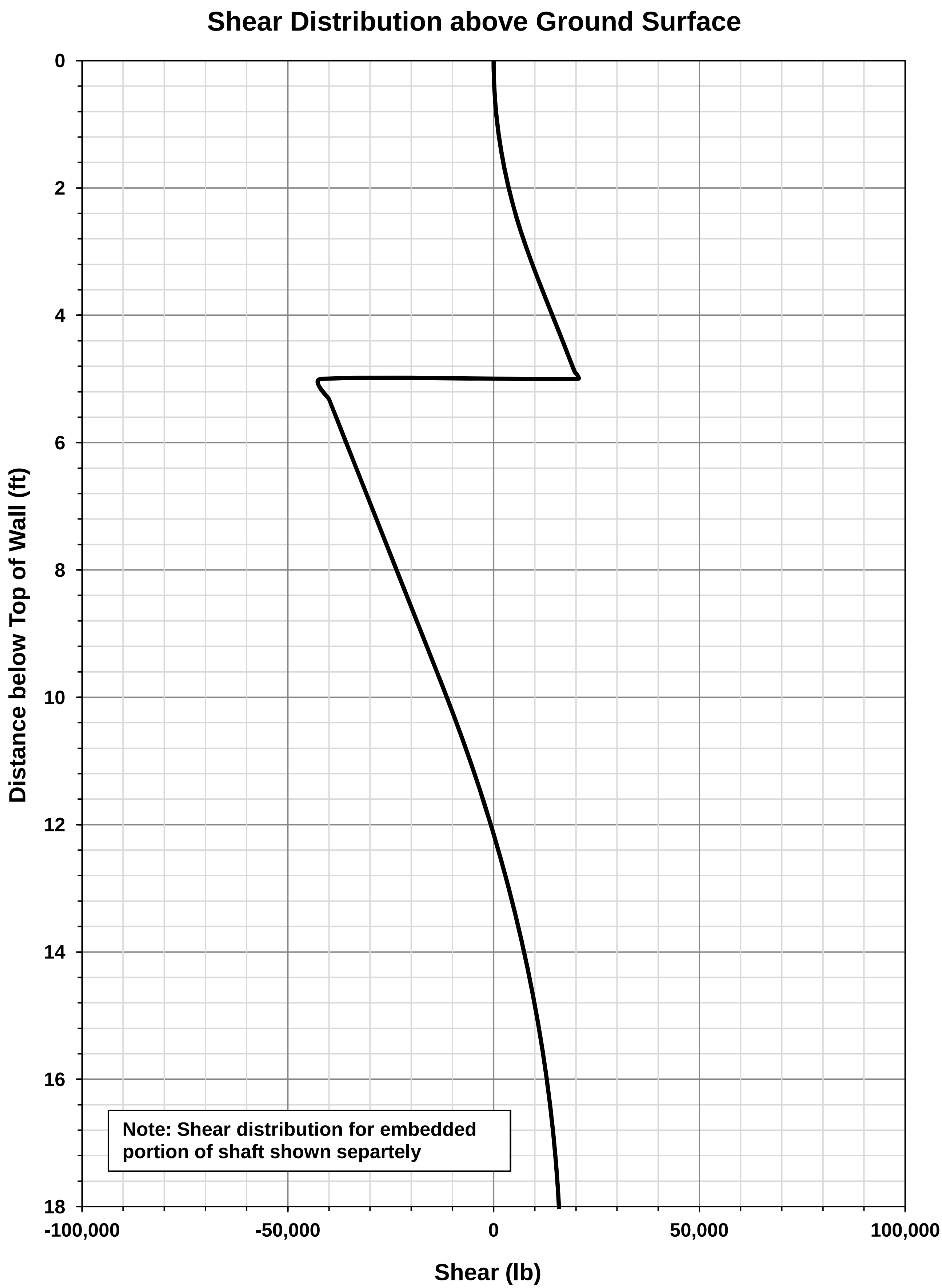
φ = 0.65 Per table 11.5.6-1
d = 6.0 in
τ_n = 3.5 ksf Per Table C11.9.4.2-2 for medium dense to dense fine to medium sand and silty sand (N_{60} = 11-30 bpf)
ϕQ_n = T

$$L_{b,T1} = \frac{T_1}{\phi \pi d \tau_n}$$

T_1 = 66,296 lb

$L_{b,T1}$ = **17.43** ft


Moment Distribution above Ground Surface
Distance below Top of Wall (ft)
0
2
4
6
8
10
12
14
16
18
-200,000
-150,000
-100,000
-50,000
0
50,000
100,000
150,000
200,000
Moment (lb-ft)
Note: Moment distribution for embedded portion of shaft shown separtely



Shear Distribution above Ground Surface
Distance below Top of Wall (ft)
0
2
4
6
8
10
12
14
16
18
-100,000
-50,000
0
50,000
100,000
Shear (lb)
Note: Shear distribution for embedded portion of shaft shown separtely

```
===============================================================================

               LPILE Plus for Windows, Version 5.0 (5.0.39)

              Analysis of Individual Piles and Drilled Shafts
             Subjected to Lateral Loading Using the p-y Method

                        (c) 1985-2007 by Ensoft, Inc.
                             All Rights Reserved

===============================================================================


This program is licensed to:




Path to file locations:      J:\GEOTECH\Projects\2010\B-10-020 HAM-75-7.85\HAM-75-7.85 PID 77889 -
Mainline\Analysis\Retaining Wall J\Pile and Lagging - 1-Tieback - 19.3 ft Wall Ht\
Name of input data file:     Pile and Lagging - 1-Tieback - 19.3 ft Wall Ht.lpd
Name of output file:         Pile and Lagging - 1-Tieback - 19.3 ft Wall Ht.lpo
Name of plot output file:    Pile and Lagging - 1-Tieback - 19.3 ft Wall Ht.lpp
Name of runtime file:        Pile and Lagging - 1-Tieback - 19.3 ft Wall Ht.lpr


-------------------------------------------------------------------------------
                          Time and Date of Analysis
-------------------------------------------------------------------------------

              Date:  August 11, 2013     Time:  22:30:14


-------------------------------------------------------------------------------
                                Problem Title
-------------------------------------------------------------------------------

HAM-75-7.85 - Retaining Wall J - Pile and Lagging - 1-Tieback - 19.3 ft Wall Ht


-------------------------------------------------------------------------------
                                Program Options
-------------------------------------------------------------------------------

Units Used in Computations - US Customary Units: Inches, Pounds

Basic Program Options:

Analysis Type 1:
- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:
- Only internally-generated p-y curves used in analysis
- Analysis uses p-y multiplers for group action
- Analysis assumes no shear resistance at pile tip
- Analysis for fixed-length pile or shaft only
- No computation of foundation stiffness matrix elements
- Output pile response for full length of pile
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:
- Number of pile increments            =          100
- Maximum number of iterations allowed =          100
- Deflection tolerance for convergence =   1.0000E-05 in
- Maximum allowable deflection         =   1.0000E+02 in

Printing Options:
- Values of pile-head deflection, bending moment, shear force, and
  soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) =  1


-------------------------------------------------------------------------------
                    Pile Structural Properties and Geometry
-------------------------------------------------------------------------------

Pile Length                               =     240.00 in
```

Depth of ground surface below top of pile = .00 in

Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 2 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq.in	Modulus of Elasticity lbs/Sq.in
1	0.0000	24.00000000	16286.0000	452.0000	3604997.
2	240.0000	24.00000000	16286.0000	452.0000	3604997.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974
Distance from top of pile to top of layer = .000 in
Distance from top of pile to bottom of layer = 60.000 in
p-y subgrade modulus k for top of soil layer = 60.000 lbs/in**3
p-y subgrade modulus k for bottom of layer = 60.000 lbs/in**3

Layer 2 is sand, p-y criteria by Reese et al., 1974
Distance from top of pile to top of layer = 60.000 in
Distance from top of pile to bottom of layer = 282.000 in
p-y subgrade modulus k for top of soil layer = 225.000 lbs/in**3
p-y subgrade modulus k for bottom of layer = 225.000 lbs/in**3

Layer 3 is sand, p-y criteria by Reese et al., 1974
Distance from top of pile to top of layer = 282.000 in
Distance from top of pile to bottom of layer = 500.000 in
p-y subgrade modulus k for top of soil layer = 125.000 lbs/in**3
p-y subgrade modulus k for bottom of layer = 125.000 lbs/in**3

(Depth of lowest layer extends 260.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Effective unit weight of soil with depth defined using 6 points

Point No.	Depth X in	Eff. Unit Weight lbs/in**3
1	.00	.07200
2	60.00	.07200
3	60.00	.07800
4	282.00	.07800
5	282.00	.04200
6	500.00	.04200

Shear Strength of Soils

Shear strength parameters with depth defined using 6 points

Point No.	Depth X in	Cohesion c lbs/in**2	Angle of Friction Deg.	E50 or k_rm	RQD %
1	.000	.00000	30.00	------	------
2	60.000	.00000	30.00	------	------
3	60.000	.00000	35.00	------	------
4	282.000	.00000	35.00	------	------
5	282.000	.00000	35.00	------	------
6	500.000	.00000	35.00	------	------

Notes:

(1) Cohesion = uniaxial compressive strength for rock materials.

(2) Values of E50 are reported for clay strata.
(3) Default values will be generated for E50 when input values are 0.
(4) RQD and k_rm are reported only for weak rock strata.

---

p-y Modification Factors

Distribution of p-y multipliers with depth defined using 2 points

Point No.	Depth X in	p-mult	y-mult
1	.000	.7834	1.0000
2	500.000	.7834	1.0000

Loading Type

Static loading criteria was used for computation of p-y curves.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Shear force at pile head = 16400.000 lbs
Bending moment at pile head = -357345.000 in-lbs
Axial load at pile head = 22675.000 lbs

Non-zero moment at pile head for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment) condition.

Computed Values of Load Distribution and Deflection for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Specified shear force at pile head = 16400.000 lbs
Specified moment at pile head = -357345.000 in-lbs
Specified axial load at pile head = 22675.000 lbs

Non-zero moment for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res. p lbs/in	Es*h F/L lbs/in
0.000	.117436	-357345.	16400.0000	-.0011051	313.4682	0.0000	0.0000
2.400	.114767	-317924.	16384.4639	-.0011189	284.4219	-12.9468	270.7430
4.800	.112066	-278578.	16338.5868	-.0011311	255.4302	-25.2841	541.4861
7.200	.109337	-239376.	16263.8423	-.0011417	226.5453	-37.0029	812.2291
9.600	.106585	-200387.	16161.7244	-.0011507	197.8170	-48.0954	1082.9722
12.000	.103814	-161675.	16033.7426	-.0011581	169.2925	-58.5561	1353.7152
14.400	.101027	-123299.	15881.4185	-.0011639	141.0163	-68.3806	1624.4582
16.800	.098227	-85317.1297	15706.2816	-.0011682	113.0301	-77.5668	1895.2013
19.200	.095419	-47781.7795	15509.8648	-.0011709	85.3729	-86.1138	2165.9443
21.600	.092607	-10742.3384	15293.7012	-.0011721	58.0812	-94.0225	2436.6874
24.000	.089793	25755.5566	15059.3195	-.0011718	69.1434	-101.2956	2707.4304
26.400	.086982	61669.9320	14808.2406	-.0011700	95.6061	-107.9369	2978.1734
28.800	.084177	96962.4536	14541.9736	-.0011668	121.6107	-113.9522	3248.9165
31.200	.081382	131598.	14262.0126	-.0011621	147.1315	-119.3486	3519.6595

33.600	.078599	165547.	13969.8325	-.0011560	172.1455	-124.1347	3790.4026
36.000	.075833	198779.	13666.8861	-.0011486	196.6324	-128.3205	4061.1456
38.400	.073086	231273.	13354.6006	-.0011398	220.5744	-131.9174	4331.8886
40.800	.070362	263006.	13034.3741	-.0011297	243.9561	-134.9380	4602.6317
43.200	.067664	293961.	12707.5726	-.0011183	266.7647	-137.3965	4873.3747
45.600	.064994	324124.	12375.5274	-.0011057	288.9897	-139.3079	5144.1178
48.000	.062357	353483.	12039.5312	-.0010918	310.6229	-140.6888	5414.8608
50.400	.059754	382032.	11700.8365	-.0010768	331.6584	-141.5568	5685.6038
52.800	.057188	409765.	11360.6517	-.0010606	352.0925	-141.9305	5956.3469
55.200	.054663	436679.	11020.1395	-.0010433	371.9236	-141.8297	6227.0899
57.600	.052181	462775.	10680.4138	-.0010249	391.1520	-141.2751	6497.8330
60.000	.049743	488056.	10158.7983	-.0010055	409.7800	-293.4045	14156.0522
62.400	.047354	511647.	9378.2631	-.0009850	427.1621	-357.0415	18095.5100
64.800	.045015	533179.	8519.8010	-.0009637	443.0279	-358.3436	19105.1729
67.200	.042729	552647.	7660.9042	-.0009415	457.3720	-357.4037	20074.8146
69.600	.040496	570054.	6807.0651	-.0009185	470.1983	-354.1289	20987.4122
72.000	.038320	585420.	5963.9224	-.0008949	481.5208	-348.4900	21826.3091
74.400	.036201	598778.	5137.1562	-.0008707	491.3632	-340.4819	22573.0577
76.800	.034140	610174.	4332.4266	-.0008460	499.7596	-330.1260	23207.3330
79.200	.032140	619666.	3549.9005	-.0008209	506.7539	-321.9791	24043.4718
81.600	.030200	627302.	2787.8658	-.0007954	512.3806	-313.0498	24878.1354
84.000	.028322	633134.	2049.4046	-.0007696	516.6777	-302.3345	25619.9001
86.400	.026506	637223.	1338.6915	-.0007437	519.6906	-289.9263	26251.7213
88.800	.024752	639641.	659.6470	-.0007176	521.4720	-275.9441	26755.7348
91.200	.023062	640468.	15.8744	-.0006914	522.0812	-260.5330	27113.5192
93.600	.021434	639792.	-589.4031	-.0006652	521.5836	-243.8649	27306.4570
96.000	.019868	637711.	-1153.4062	-.0006391	520.0500	-226.1377	27316.2117
98.400	.018366	634326.	-1673.8613	-.0006131	517.5555	-207.5749	27125.3412
100.800	.016925	629743.	-2149.0593	-.0005873	514.1791	-188.4234	26718.0650
103.200	.015547	624074.	-2592.5528	-.0005617	510.0019	-181.1545	27965.1223
105.600	.014230	617360.	-3021.5145	-.0005363	505.0548	-176.3136	29737.6140
108.000	.012973	609629.	-3438.1344	-.0005112	499.3584	-170.8696	31611.4047
110.400	.011776	600913.	-3840.9889	-.0004865	492.9359	-164.8425	33596.2546
112.800	.010638	591245.	-4228.7054	-.0004621	485.8127	-158.2546	35704.0656
115.200	.009558	580665.	-4599.9670	-.0004381	478.0169	-151.1300	37949.5877
117.600	.008535	569213.	-4953.5164	-.0004146	469.5788	-143.4945	40351.4258
120.000	.007567	556933.	-5288.1590	-.0003916	460.5307	-135.3743	42933.5086
122.400	.006655	543873.	-5602.7637	-.0003691	450.9071	-126.7963	45727.2894
124.800	.005796	530080.	-5896.2624	-.0003472	440.7446	-117.7860	48775.1565
127.200	.004988	515608.	-6166.2562	-.0003258	430.0812	-107.2089	51578.8998
129.600	.004232	500518.	-6406.1931	-.0003050	418.9620	-92.7385	52594.1862
132.000	.003524	484892.	-6611.9489	-.0002849	407.4484	-78.7248	53609.4726
134.400	.002864	468811.	-6784.6529	-.0002654	395.5998	-65.1952	54624.7590
136.800	.002250	452354.	-6925.4955	-.0002466	383.4738	-52.1736	55640.0454
139.200	.001681	435596.	-7035.7200	-.0002284	371.1256	-39.6802	56655.3318
141.600	.001154	418608.	-7116.6142	-.0002110	358.6084	-27.7317	57670.6182
144.000	.000668	401459.	-7169.5025	-.0001942	345.9727	-16.3418	58685.9046
146.400	.000222	384215.	-7195.7374	-.0001781	333.2670	-5.5206	59701.1910
148.800	-.000187	366939.	-7196.6926	-.0001628	320.5372	4.7246	60716.4774
151.200	-.000559	349689.	-7173.7556	-.0001481	307.8269	14.3896	61731.7638
153.600	-.000898	332521.	-7128.3204	-.0001342	295.1771	23.4730	62747.0502
156.000	-.001204	315488.	-7061.7815	-.0001209	282.6264	31.9760	63762.3366
158.400	-.001478	298638.	-6975.5275	-.0001084	270.2108	39.9023	64777.6230
160.800	-.001724	282017.	-6870.9353	-9.6529E-05	257.9642	47.2579	65792.9094
163.200	-.001942	265668.	-6749.3647	-8.5335E-05	245.9176	54.0510	66808.1958
165.600	-.002133	249629.	-6612.1533	-7.4803E-05	234.1000	60.2918	67823.4822
168.000	-.002301	233937.	-6460.6121	-6.4919E-05	222.5379	65.9925	68838.7686
170.400	-.002445	218625.	-6296.0211	-5.5669E-05	211.2554	71.1667	69854.0550
172.800	-.002568	203723.	-6119.6256	-4.7037E-05	200.2747	75.8296	70869.3414
175.200	-.002671	189256.	-5932.6327	-3.9005E-05	189.6154	79.9978	71884.6278
177.600	-.002755	175250.	-5736.2083	-3.1554E-05	179.2954	83.6892	72899.9142
180.000	-.002822	161726.	-5531.4746	-2.4667E-05	169.3302	86.9223	73915.2006
182.400	-.002874	148702.	-5319.5076	-1.8322E-05	159.7338	89.7169	74930.4870
184.800	-.002910	136194.	-5101.3355	-1.2499E-05	150.5178	92.0932	75945.7734
187.200	-.002934	124217.	-4877.9373	-7.1765E-06	141.6925	94.0720	76961.0598
189.600	-.002945	112781.	-4650.2413	-2.3325E-06	133.2662	95.6747	77976.3462
192.000	-.002945	101896.	-4419.1246	2.0553E-06	125.2458	96.9226	78991.6326
194.400	-.002935	91568.8591	-4185.4128	6.0095E-06	117.6365	97.8372	80006.9190
196.800	-.002916	81805.2107	-3949.8798	9.5532E-06	110.4424	98.4403	81022.2054
199.200	-.002889	72608.3962	-3713.2480	1.2709E-05	103.6659	98.7529	82037.4918
201.600	-.002855	63980.2370	-3476.1890	1.5501E-05	97.3084	98.7963	83052.7782
204.000	-.002815	55921.0021	-3239.3243	1.7952E-05	91.3702	98.5910	84068.0646
206.400	-.002769	48429.5267	-3003.2267	2.0084E-05	85.8502	98.1570	85083.3510
208.800	-.002718	41503.3279	-2768.4217	2.1923E-05	80.7468	97.5138	86098.6374
211.200	-.002664	35138.7163	-2535.3891	2.3489E-05	76.0572	96.6801	87113.9238
213.600	-.002605	29330.9036	-2304.5649	2.4807E-05	71.7778	95.6735	88129.2102
216.000	-.002544	24074.1049	-2076.3438	2.5898E-05	67.9044	94.5108	89144.4966
218.400	-.002481	19361.6348	-1851.0813	2.6786E-05	64.4321	93.2079	90159.7830
220.800	-.002416	15185.9990	-1629.0969	2.7492E-05	61.3554	91.7792	91175.0694

223.200	-.002349	11538.9775	-1410.6762	2.8039E-05	58.6682	90.2380	92190.3558
225.600	-.002281	8411.7014	-1196.0748	2.8446E-05	56.3639	88.5965	93205.6422
228.000	-.002213	5794.7224	-985.5208	2.8737E-05	54.4356	86.8651	94220.9286
230.400	-.002143	3678.0737	-779.2189	2.8930E-05	52.8760	85.0531	95236.2150
232.800	-.002074	2051.3228	-577.3536	2.9047E-05	51.6774	83.1680	96251.5014
235.200	-.002004	903.6151	-380.0929	2.9108E-05	50.8317	81.2159	97266.7878
237.600	-.001934	223.7088	-187.5926	2.9131E-05	50.3308	79.2010	98282.0742
240.000	-.001864	0.0000	0.0000	2.9135E-05	50.1659	77.1261	49648.6803

Output Verification:

Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =      .11743638 in
Computed slope at pile head      =     -.00110512
Maximum bending moment           =   640467.68935 lbs-in
Maximum shear force              =    16400.00000 lbs
Depth of maximum bending moment  =    91.20000000 in
Depth of maximum shear force     =        0.00000 in
Number of iterations             =             10
Number of zero deflection points =              1
```

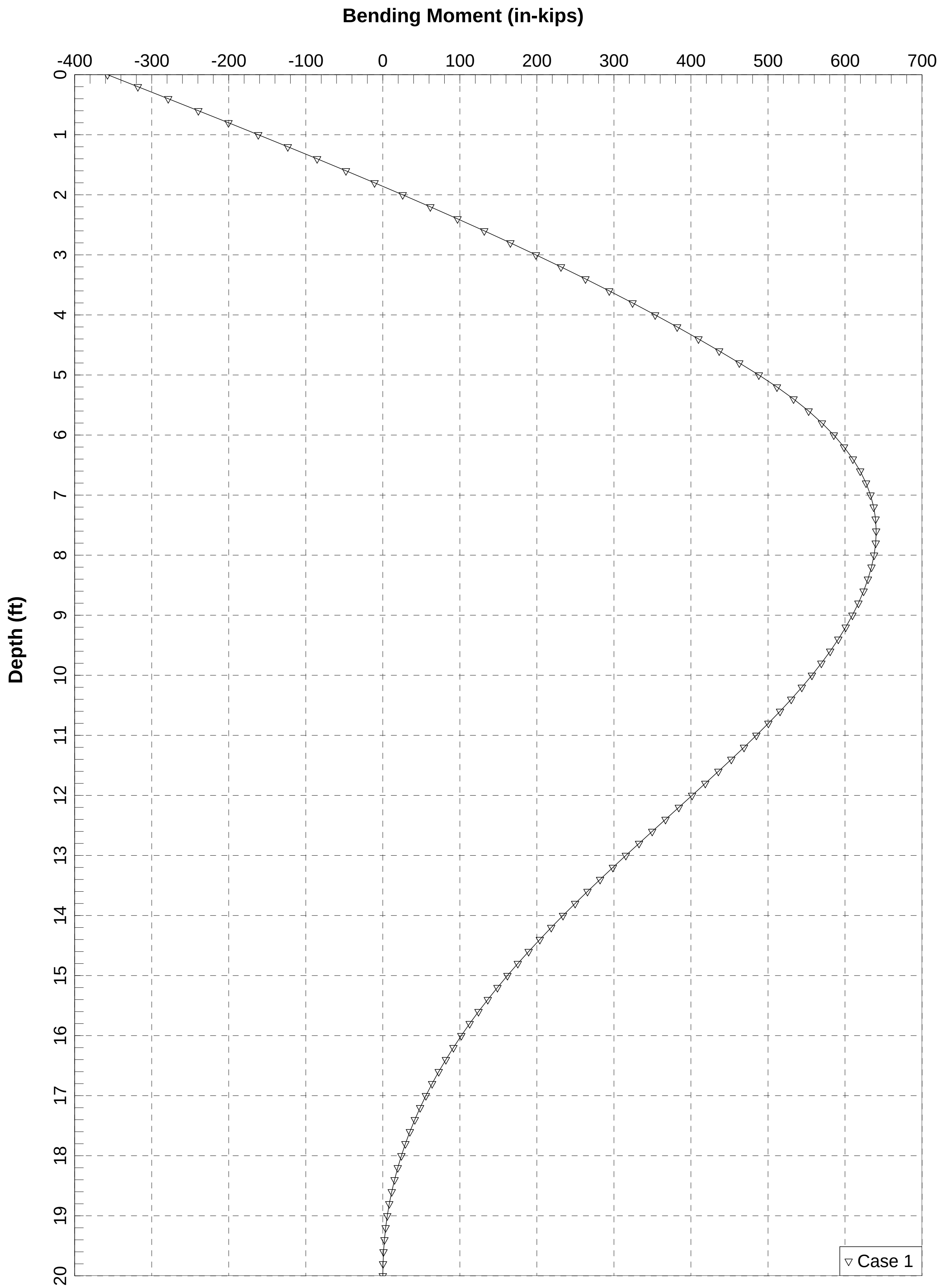
Summary of Pile Response(s)

Definition of Symbols for Pile-Head Loading Conditions:

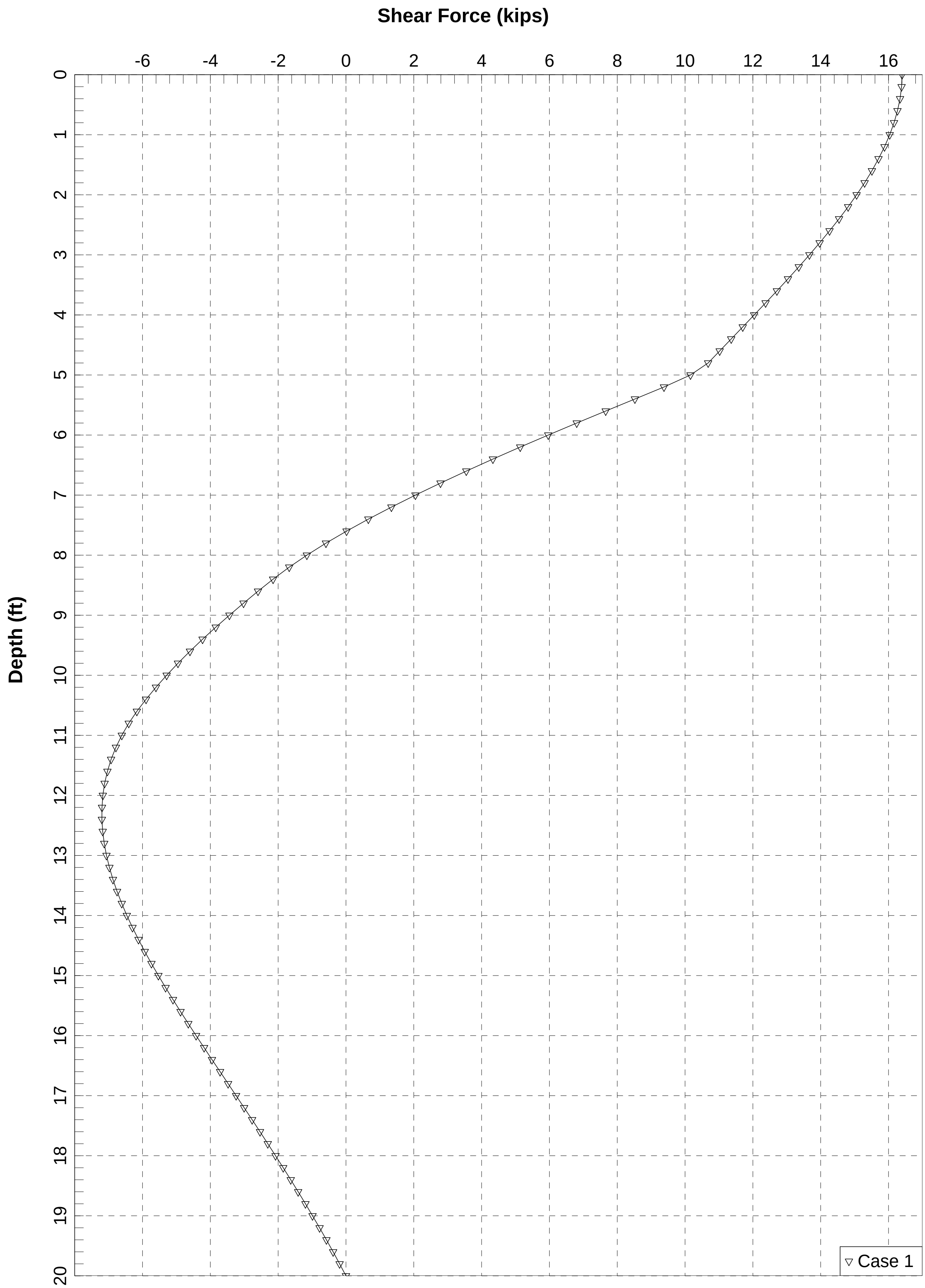
```
Type 1 = Shear and Moment,          y = pile-head displacment in
Type 2 = Shear and Slope,           M = Pile-head Moment lbs-in
Type 3 = Shear and Rot. Stiffness,  V = Pile-head Shear Force lbs
Type 4 = Deflection and Moment,     S = Pile-head Slope, radians
Type 5 = Deflection and Slope,      R = Rot. Stiffness of Pile-head in-lbs/rad
```

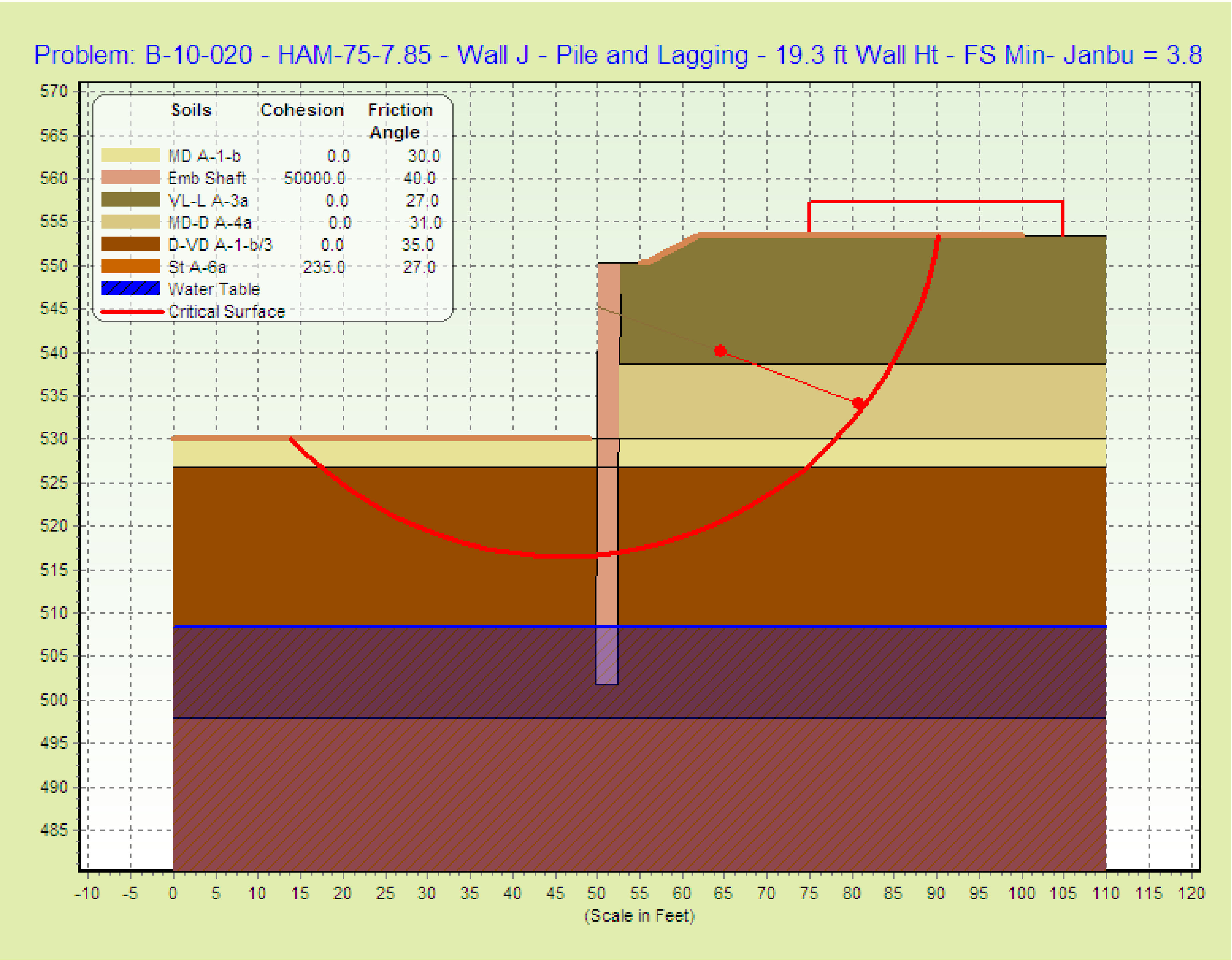
Load Type	Pile-Head Condition 1	Pile-Head Condition 2	Axial Load lbs	Pile-Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
1	V= 16400.	M= -3.57E+05	22675.0000	.1174364	640468.	16400.0000

The analysis ended normally.



Bending Moment (in-kips)
-400 -300 -200 -100 0 100 200 300 400 500 600 700
Depth (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Case 1


Shear Force (kips)
-6
-4
-2
0
2
4
6
8
10
12
14
16
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Case 1



Problem: B-10-020 - HAM-75-7.85 - Wall J - Pile and Lagging - 19.3 ft Wall Ht - FS Min- Janbu = 3.8
Soils
Cohesion
Friction Angle
MD A-1-b 0.0 30.0
Emb Shaft 50000.0 40.0
VL-L A-3a 0.0 27.0
MD-D A-4a 0.0 31.0
D-VD A-1-b/3 0.0 35.0
St A-6a 235.0 27.0
Water Table
Critical Surface
570
565
560
555
550
545
540
535
530
525
520
515
510
505
500
495
490
485
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
(Scale in Feet)

** STABL for WINDOWS **
by
Geotechnical Software Solutions

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: U.S.C.
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION B-10-020 - HAM-75-7.85 - Wall J - Pile and Lagging - 19.3 ft Wall Ht

BOUNDARY COORDINATES

6 Top Boundaries
20 Total Boundaries

**** ERROR - PF06 **** Boundaries 9 and 10

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	530.00	50.00	530.00	3
2	50.00	530.00	50.10	550.30	6
3	50.10	550.30	52.70	550.30	6
4	52.70	550.30	55.70	550.30	1
5	55.70	550.30	61.70	553.50	1
6	61.70	553.50	110.00	553.50	1
7	50.00	530.00	52.50	530.00	6
8	52.50	530.00	52.60	536.80	2
9	52.60	536.80	52.70	546.80	1
10	52.60	538.60	110.00	538.60	2
11	52.50	530.00	110.00	530.00	3
12	0.00	526.80	49.90	526.80	4
13	49.90	526.80	50.00	530.00	6
14	49.90	526.80	52.40	526.80	6
15	52.40	526.80	52.50	530.00	3
16	52.40	526.80	110.00	526.80	4
17	49.80	501.80	49.90	526.80	6
18	49.80	501.80	52.30	501.80	4
19	52.30	501.80	52.40	526.80	4
20	0.00	497.90	110.00	497.90	5

1

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	125.0	0.0	27.0	0.00	0.0	1
2	125.0	130.0	0.0	31.0	0.00	0.0	1
3	125.0	130.0	0.0	30.0	0.00	0.0	1
4	135.0	140.0	0.0	35.0	0.00	0.0	1
5	120.0	130.0	235.0	27.0	0.00	0.0	1
6	140.0	140.0	50000.0	40.0	0.00	0.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	508.40
2	110.00	508.40

1

BOUNDARY LOAD(S)

1 Load(s) Specified

Load No.	X-Left (ft)	X-Right (ft)	Intensity (psf)	Deflection (deg)
1	75.00	105.00	240.0	0.0

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

1

TIEBACK LOAD(S)

1 Tieback Load(s) Specified

Tieback No.	X-Pos (ft)	Y-Pos (ft)	Load (lbs)	Spacing (ft)	Inclination (deg)	Length (ft) free	Length (ft) fixed
1	50.08	545.30	62298.0	4.0	20.00	15.3	17.4

NOTE - An Equivalent Line Load Is Calculated For Each Row Of Tiebacks
Assuming A Uniform Distribution Of Load Horizontally Between
Individual Tiebacks.

1

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

750 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 75 Points Equally Spaced
Along The Ground Surface Between X = 0.00 ft.
and X = 49.00 ft.

Each Surface Terminates Between X = 55.00 ft.
and X = 100.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =450.00 ft.

3.00 ft. Line Segments Define Each Trial Failure Surface.

1

```
           Y           A     X     I     S            F     T

           0.00    129.54    259.09    388.63    518.17    647.71

X      0.00 +---------+---------+---------+-------*W+*--------+
            -
            -                                      * **
            -                                         **/1
            -                                        t
            -                                     *W ***1/
     129.54 +
            -
            -
            -
            -
            -
A    259.09 +
            -
            -
            -
            -
            -
X    388.63 +
            -
            -
            -
            -
            -
I    518.17 +
            -
            -
            -
            -
            -
S    647.71 +
            -
            -
            -
            -
            -
     777.26 +
            -
            -
            -
            -
            -
F    906.80 +
            -
            -
            -
            -
            -
T   1036.34 +

******************************************
******  EXECUTION OF STABL ABORTED  ******
******************************************
```

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 34 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	13.91	530.00

2	16.08	527.93
3	18.38	526.01
4	20.81	524.25
5	23.35	522.65
6	25.99	521.22
7	28.72	519.98
8	31.52	518.92
9	34.40	518.05
10	37.32	517.37
11	40.28	516.89
12	43.27	516.61
13	46.26	516.53
14	49.26	516.64
15	52.25	516.96
16	55.20	517.48
17	58.12	518.19
18	60.98	519.09
19	63.77	520.19
20	66.48	521.46
21	69.11	522.92
22	71.63	524.54
23	74.03	526.34
24	76.32	528.28
25	78.46	530.38
26	80.46	532.61
27	82.31	534.98
28	84.00	537.46
29	85.52	540.05
30	86.86	542.73
31	88.02	545.50
32	88.99	548.33
33	89.77	551.23
34	90.23	553.50

*** 3.800 ***

Individual data on the 49 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Force Norm (lbs)	Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	2.2	280.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.4	446.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.9	430.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.4	1519.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	2.5	2165.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	2.6	2789.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	2.7	3375.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	2.8	3907.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	2.9	4371.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	2.9	4755.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	3.0	5049.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	3.0	5247.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	3.0	5342.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	3.0	5333.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.6	1055.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	72.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.1	183.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.1	327.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	2.1	10048.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.1	537.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	182.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	458.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.1	451.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.1	436.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	2.5	10421.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.5	2061.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	2.4	10044.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	2.9	12090.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.7	3086.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	2.1	8713.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	2.7	11047.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	2.6	10192.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0

33	2.5	9268.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	2.4	8293.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.5	1790.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	0.4	1367.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	1.3	4142.4	0.0	0.0	0.0	0.0	0.0	0.0	315.8
38	1.8	5220.8	0.0	0.0	0.0	0.0	0.0	0.0	421.8
39	0.4	1104.2	0.0	0.0	0.0	0.0	0.0	0.0	93.3
40	2.0	5357.3	0.0	0.0	0.0	0.0	0.0	0.0	480.5
41	1.8	4415.5	0.0	0.0	0.0	0.0	0.0	0.0	443.7
42	1.7	3518.6	0.0	0.0	0.0	0.0	0.0	0.0	404.9
43	0.7	1245.8	0.0	0.0	0.0	0.0	0.0	0.0	160.8
44	0.8	1442.1	0.0	0.0	0.0	0.0	0.0	0.0	203.4
45	1.3	1950.3	0.0	0.0	0.0	0.0	0.0	0.0	322.0
46	1.2	1306.6	0.0	0.0	0.0	0.0	0.0	0.0	278.3
47	1.0	768.7	0.0	0.0	0.0	0.0	0.0	0.0	233.4
48	0.8	348.6	0.0	0.0	0.0	0.0	0.0	0.0	187.5
49	0.5	61.6	0.0	0.0	0.0	0.0	0.0	0.0	108.6

Individual data on the 1 ties

No	Bnd	Slice	Head Coordinates (ft)		End Coordinates (ft)		T (lbs)	Length(ft) free	Length(ft) fixed
1	2	0	50.1	545.3	80.8	534.1	271.7	15.3	17.4

Failure Surface Specified By 33 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	18.54	530.00
2	20.67	527.89
3	22.95	525.93
4	25.36	524.15
5	27.90	522.56
6	30.55	521.15
7	33.30	519.94
8	36.13	518.94
9	39.02	518.15
10	41.96	517.57
11	44.94	517.22
12	47.94	517.08
13	50.94	517.16
14	53.92	517.46
15	56.88	517.98
16	59.78	518.72
17	62.63	519.67
18	65.40	520.83
19	68.07	522.18
20	70.64	523.73
21	73.09	525.47
22	75.40	527.38
23	77.57	529.45
24	79.58	531.68
25	81.42	534.05
26	83.08	536.55
27	84.55	539.17
28	85.83	541.88
29	86.90	544.68
30	87.76	547.56
31	88.41	550.48
32	88.84	553.45
33	88.85	553.50

*** 3.802 ***

1

Failure Surface Specified By 32 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)

1	19.20	530.00
2	21.32	527.88
3	23.60	525.92
4	26.01	524.14
5	28.55	522.54
6	31.20	521.13
7	33.95	519.93
8	36.78	518.93
9	39.67	518.15
10	42.62	517.59
11	45.60	517.24
12	48.60	517.12
13	51.60	517.22
14	54.58	517.54
15	57.53	518.09
16	60.43	518.85
17	63.27	519.83
18	66.02	521.01
19	68.68	522.40
20	71.23	523.98
21	73.66	525.75
22	75.94	527.69
23	78.08	529.80
24	80.05	532.06
25	81.85	534.46
26	83.47	536.98
27	84.89	539.62
28	86.12	542.36
29	87.13	545.19
30	87.94	548.08
31	88.52	551.02
32	88.83	553.50

*** 3.809 ***

Failure Surface Specified By 33 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	15.23	530.00
2	17.39	527.92
3	19.69	525.99
4	22.12	524.23
5	24.67	522.65
6	27.32	521.25
7	30.07	520.04
8	32.89	519.03
9	35.78	518.22
10	38.72	517.61
11	41.69	517.22
12	44.69	517.04
13	47.69	517.06
14	50.68	517.30
15	53.64	517.75
16	56.57	518.41
17	59.44	519.28
18	62.25	520.34
19	64.97	521.60
20	67.60	523.05
21	70.11	524.68
22	72.51	526.48
23	74.77	528.45
24	76.89	530.58
25	78.86	532.84
26	80.66	535.24
27	82.28	537.77
28	83.72	540.40
29	84.98	543.12
30	86.03	545.93
31	86.89	548.81
32	87.54	551.73
33	87.80	553.50

*** 3.815 ***

1

Failure Surface Specified By 33 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	18.54	530.00
2	20.70	527.92
3	23.00	525.99
4	25.43	524.23
5	27.98	522.65
6	30.64	521.26
7	33.38	520.05
8	36.21	519.05
9	39.10	518.24
10	42.04	517.65
11	45.02	517.26
12	48.01	517.09
13	51.01	517.13
14	54.00	517.39
15	56.96	517.85
16	59.89	518.53
17	62.75	519.41
18	65.55	520.49
19	68.27	521.77
20	70.88	523.23
21	73.39	524.88
22	75.77	526.71
23	78.02	528.70
24	80.12	530.84
25	82.06	533.12
26	83.84	535.54
27	85.44	538.08
28	86.85	540.73
29	88.07	543.47
30	89.10	546.28
31	89.92	549.17
32	90.54	552.11
33	90.73	553.50

*** 3.818 ***

Failure Surface Specified By 33 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	15.89	530.00
2	18.10	527.97
3	20.44	526.09
4	22.91	524.39
5	25.49	522.86
6	28.17	521.52
7	30.94	520.36
8	33.79	519.40
9	36.69	518.65
10	39.64	518.10
11	42.62	517.75
12	45.61	517.62
13	48.61	517.69
14	51.60	517.97
15	54.56	518.47
16	57.48	519.16
17	60.34	520.06
18	63.13	521.16
19	65.84	522.45

20	68.45	523.92
21	70.96	525.58
22	73.34	527.40
23	75.58	529.39
24	77.69	531.53
25	79.64	533.81
26	81.42	536.22
27	83.03	538.75
28	84.46	541.39
29	85.71	544.12
30	86.75	546.93
31	87.60	549.81
32	88.25	552.74
33	88.37	553.50

*** 3.818 ***

1

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	20.53	530.00
2	22.65	527.88
3	24.93	525.94
4	27.36	524.17
5	29.92	522.61
6	32.59	521.24
7	35.37	520.10
8	38.22	519.17
9	41.13	518.46
10	44.10	517.99
11	47.09	517.75
12	50.09	517.74
13	53.08	517.97
14	56.04	518.43
15	58.96	519.12
16	61.82	520.04
17	64.59	521.18
18	67.27	522.53
19	69.84	524.08
20	72.27	525.84
21	74.56	527.77
22	76.70	529.88
23	78.66	532.15
24	80.44	534.57
25	82.02	537.11
26	83.40	539.78
27	84.57	542.54
28	85.52	545.39
29	86.24	548.30
30	86.74	551.26
31	86.93	553.50

*** 3.820 ***

Failure Surface Specified By 33 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	19.20	530.00
2	21.37	527.93
3	23.68	526.02
4	26.13	524.27
5	28.69	522.71
6	31.35	521.34
7	34.11	520.16

8	36.95	519.18
9	39.85	518.40
10	42.79	517.84
11	45.77	517.49
12	48.77	517.35
13	51.77	517.43
14	54.75	517.72
15	57.71	518.23
16	60.62	518.94
17	63.48	519.87
18	66.26	520.99
19	68.95	522.32
20	71.54	523.83
21	74.02	525.52
22	76.37	527.39
23	78.58	529.42
24	80.64	531.60
25	82.53	533.92
26	84.26	536.38
27	85.80	538.95
28	87.16	541.63
29	88.32	544.39
30	89.28	547.23
31	90.03	550.14
32	90.58	553.09
33	90.62	553.50

*** 3.821 ***

1

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	21.85	530.00
2	23.97	527.88
3	26.26	525.93
4	28.69	524.18
5	31.25	522.62
6	33.93	521.27
7	36.71	520.13
8	39.57	519.22
9	42.49	518.54
10	45.45	518.09
11	48.45	517.88
12	51.45	517.90
13	54.43	518.17
14	57.39	518.67
15	60.30	519.40
16	63.14	520.36
17	65.90	521.54
18	68.55	522.94
19	71.09	524.54
20	73.49	526.34
21	75.74	528.33
22	77.83	530.48
23	79.73	532.80
24	81.45	535.26
25	82.97	537.85
26	84.28	540.55
27	85.37	543.34
28	86.23	546.21
29	86.87	549.14
30	87.27	552.12
31	87.35	553.50

*** 3.832 ***

Failure Surface Specified By 32 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	21.19	530.00
2	23.32	527.89
3	25.61	525.94
4	28.03	524.18
5	30.58	522.60
6	33.24	521.22
7	36.00	520.04
8	38.84	519.07
9	41.75	518.32
10	44.70	517.79
11	47.68	517.49
12	50.68	517.41
13	53.68	517.56
14	56.66	517.93
15	59.60	518.52
16	62.48	519.34
17	65.30	520.37
18	68.03	521.61
19	70.66	523.05
20	73.18	524.69
21	75.56	526.51
22	77.80	528.51
23	79.88	530.67
24	81.80	532.98
25	83.53	535.43
26	85.08	538.00
27	86.42	540.68
28	87.56	543.45
29	88.49	546.31
30	89.20	549.22
31	89.69	552.18
32	89.81	553.50

*** 3.838 ***

1

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               Y          A     X     I     S          F     T

               0.00    129.54    259.09    388.63    518.17    647.71

 X      0.00 +---------+---------+---------+-------*W.*--------+
             -                                       11
             -                                      *1**
             -                                       11**/1
             -                                       .t11
             -                                     *W ***1/
      129.54 +
             -
             -
             -
             -
             -
 A    259.09 +
             -
             -
             -
             -
             -
 X    388.63 +
             -
             -
             -
             -
             -
 I    518.17 +
             -
             -
             -
             -
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               -
S     647.71 +
               -
               -
               -
               -
               -
      777.26 +
               -
               -
               -
               -
               -
F     906.80 +
               -
               -
               -
               -
               -
T    1036.34 +
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