Resource International, Inc.

FRA-70-12.68 PROJECT 4R
FRA-70-1390C
RAMP C5 OVER I-70/71
PID NO. 105523
FRANKLIN COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT

Prepared For:
GPD GROUP
1801 Watermark Drive, Suite 210
Columbus, OH 43215

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

Rii Project No. W-13-045

July 2018

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

Planning
Engineering
Construction Management
Technology

August 19, 2016 (Revised July 10, 2018)

Mr. Christopher W. Luzier, P.E.
Project Manager
GPD GROUP
1801 Watermark Drive, Suite 210
Columbus, OH 43215

Re: Structure Foundation Exploration Report
FRA-70-12.68 Project 4R
FRA-70-1390C – Ramp C5 over I-70/71
PID No. 105523
Rii Project No. W-13-045

Mr. Luzier:

Resource International, Inc. (Rii) is pleased to submit this structure foundation exploration report for the above referenced project. Engineering logs have been prepared and are attached to this report along with the results of laboratory testing. This report includes recommendations for the design and construction of the proposed FRA-70-1390C bridge structure carrying Ramp C5 over I-70/71 as part of the FRA-70-12.68 Project 4R in Columbus, 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 Trenner

Brian R. Trenner, P.E.
Director – Geotechnical Programming

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Enclosure: Structure Foundation Exploration Report

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APPENDICIES

EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration for the design and construction of the proposed FRA-70-1390C bridge structure carrying the proposed Ramp C5 over I-70/71, as shown on the vicinity map and boring plan presented in Appendix I. The proposed Ramp C5 will be a two-lane to four-lane ramp that will collect and direct traffic from I-71 northbound and southbound as well as I-70 eastbound to exit in downtown at the intersection of Front Street and W. Fulton Avenue. Based on information provided by GPD GROUP, the proposed structure will consist of two single-span reinforced concrete deck structures supported transversely by simple span welded steel plate girders with reinforced concrete substructures. The proposed structure will have an approximate span length of approximately 92.5 feet where it will span over I-70 eastbound and 96.3 feet where it will span over I-70 westbound, as measured from the centerline of abutment bearings to the centerline of the pier. The east end of the bridge deck spanning over I-70 westbound will also be integrated with the FRA-70-1395 Front Street bridge deck at the northwest corner of that structure, where the ramp will be aligned with Fulton Street.

Exploration and Findings

Between August 6, 2013, and February 14, 2015, six (6) structural borings, designated as B-023-1-13, B-024-1-13, B-024-2-14, B-026-1-13, B-026-2-13 and B-026-3-13, were advanced to completion depths ranging from 48.1 to 90.0 feet below the existing ground surface. In addition to the borings performed by Rii as part of the current exploration, three (3) borings, designated as B-024-0-08, B-025-0-08 and B-026-0-08, were drilled to a completion depth of 111.5, 59.3 and 115.0 feet below the existing ground surface, respectively, by DLZ as part of the FRA-70-8.93 preliminary exploration (PID 77369). In addition to the project borings, four (4) borings, designated as B-001-C-59, B-002-F-59, B-003-A-59 and B-005-F-59, were drilled to completion depths ranging from 55.0 to 73.0 feet below the existing grade at the respective boring location at the time of the exploration by the Department of Highways as part of the FRA-40-12.89 project.

Borings B-023-1-13 and B-024-0-08 were performed along the south side of W. Fulton Street, and no discernable surface material was present at the ground surface. Borings B-024-1-13 and B-024-2-14 were drilled in the existing I-70 eastbound ramp to Front Street and encountered 14.0 and 5.0 inches of asphalt, respectively, overlying 6.0 inches of aggregate base in boring B-024-1-13 and 13.0 inches of concrete in boring B-024-2-14 at the ground surface. Borings B-025-0-08 and B-026-2-13 were drilled in the existing shoulders of I-70 eastbound and westbound and encountered 7.0 and 9.0 inches of asphalt overlying 7.0 and 6.0 inches of aggregate base, respectively. Boring B-026-0-08 was performed at the top of the slope along the north side of I-70/I-71 and encountered 4.0 inches of topsoil at the ground surface. Boring B-026-1-13 was performed in the existing pavement along S. Ludlow Street and encountered 4.0 inches of asphalt overlying 8.0 inches of aggregate base. Boring B-026-3-13 was performed within the existing sidewalk along the west side of S. Front

Street, at the intersection with W. Fulton Street on the north side of I-70/I-71 and encountered 6.0 inches of concrete overlying 6.0 inches of aggregate base.

Beneath the pavement materials in borings B-025-0-08, B-026-1-13 and B-026-2-13, material identified as existing fill or possible fill was encountered extending to depths ranging from 3.5 to 15.5 feet below exiting grade, which corresponds to elevations ranging from 731.3 to 736.9 feet msl. The fill material was described as medium dense to very dense, brown and gray gravel, gravel and sand, gravel with sand and silt (ODOT A-1-a, A-1-b, A-2-4), and hard, brown silt and clay (ODOT A-6a) and contained brick fragments throughout.

Underlying the surficial materials and existing fill, where encountered, natural soils were encountered consisting of both granular and cohesive material. The granular soils were generally described as loose to very dense brown, gray, brownish gray and dark gray gravel, gravel and sand, gravel with sand and silt, fine sand, coarse and fine sand, sandy silt and silt (ODOT A-1-a, A-1-b, A-2-4, A-3, A-3a, A-4a, A-4b). The cohesive materials were generally described as soft to hard, brown, brownish gray and dark gray sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6).

Cobbles and boulders were encountered in the majority of the borings at and below elevations ranging from 700 to 710 feet msl. At depths below this elevations range, drilling conditions were typically more challenging and high blow counts, including split spoon sampler refusal, were obtained throughout these deposits. Split spoon sampler refusal is defined as exceeding 50 blows from the hammer with less than 6.0 inches of penetration by the split spoon sampler. Additionally, heaving sands were encountered in the majority of the borings at elevations ranging from 685 to 700 feet msl. The height of sand heave within the augers was approximately 1.0 to 3.0 feet and was able to be controlled through the addition of water or mud to the boreholes during drilling.

Top of bedrock was encountered in borings B-024-0-08 and B-026-0-08 at a depth of 91.8 and 90.0 feet below existing grade, respectively, which corresponds to an elevation of 651.6 and 664.0 feet msl. The upper portion of the bedrock in boring B-026-0-08 consisted of brown, severely weathered claystone that extended to a depth of 97.8 feet (El. 656.2 feet msl) overlying blueish gray to dark gray, moderately to highly weathered shale.

In general, the historic borings, designated B-001-C-59, B-002-F-59, B-003-A-59 and B-005-F-59, encountered loose to very dense granular soils with intermittent seams of medium stiff to hard cohesive soils. The granular soils were generally described as brown and gray gravel, gravel and sand, gravel with sand and silt, coarse and fine sand and sandy silt (ODOT A-1-a, A-1-b, A-2-4, A-3a, A-4a), and the cohesive soils were generally described as brown, gray and brownish gray sandy silt, silt and silt and clay (ODOT A-4a, A-4b, A-6a). In general, the subsurface conditions encountered in the historic borings matched relatively closely with the subsurface conditions encountered in the preliminary engineering or current exploration borings

Analyses and Recommendations

Design details of the structure proposed were provided by GPD GROUP. Based on the information provided, it is understood that the proposed structure will consist of two single-span reinforced concrete deck structures supported transversely by simple span welded steel plate girders with reinforced concrete substructures supported on drilled shafts tied into footings or tangent drilled shafts. The proposed structure will have an approximate span length of approximately 92.5 feet where it will span over I-70 eastbound and 96.3 feet where it will span over I-70 westbound, as measured from the centerline of abutment bearings to the centerline of the pier. The east end of the bridge deck spanning over I-70 westbound will also be integrated with the FRA-70-1395 Front Street bridge deck at the northwest corner of that structure, where the ramp will be aligned with Fulton Street.

Consideration was given to a driven pile foundation, but given the dense, granular nature of the soil and the presence of cobbles and boulders that are common in the area, as well as the close proximity to existing underground utilities, this type of foundation system is not recommended due to the potential of damaging the pile elements or existing utilities during installation. Consideration was also given to supporting the structure on shallow foundations, but due to the close proximity to existing utilities at all of the substructure locations, this type of foundation system is not recommended due to the potential of damaging the utilities from the additional pressures from the foundation loading.

Drilled Shaft Recommendations

It is understood that a combination of drilled shafts tied into footings or tangent drilled shafts foundations are being utilized to support the substructure units. To achieve the most economical design, the drilled shafts should extend to bear in the dense to very dense gravel, gravel and sand, gravel with sand and silt, coarse and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a) or hard sandy silt, silt or silt and clay (ODOT A-4a, A-4b, A-6a) at or below elevation 705.0 feet msl in order to maximize the end bearing resistance. It is recommended that the drilled shafts be designed using the axial design parameters provided in the following tables.

Drilled Shaft Axial Design Parameters – Rear Abutment

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-023-1-13	728.6-724.4	0.0-4.2	A-7-6	19	1.51	0.40	0.45
	724.4-719.4	4.2-9.2	A-6a	15	1.03	0.40	0.45
	719.4-714.4	9.2-14.2	A-7-6	19	1.16	0.40	0.45
	714.4-710.4	14.2-18.2	A-1-b	39	1.73	0.50	0.55
	710.4-695.4	18.2-33.2	A-1-b	60	2.81	0.50	0.55
	695.4-690.4	33.2-38.2	A-6b	45	2.32	0.40	0.45
	690.4-684.4	38.2-44.2	A-1-a	60	4.76	0.50	0.55
B-024-0-08	728.6-715.4	0.0-13.2	A-4a	21	1.30	0.40	0.45
	715.4-711.4	13.2-17.2	A-4b	33	2.02	0.50	0.55
	711.4-706.4	17.2-22.2	A-1-a	44	1.93	0.50	0.55
	706.4-701.4	22.2-27.2	A-4a	72	3.60	0.40	0.45
	701.4-691.4	27.2-37.2	A-3a	60	2.29	0.50	0.55
	691.4-686.4	37.2-42.2	A-1-b	60	4.76	0.50	0.55
	686.4-681.4	42.2-47.2	A-4a	60	4.67	0.50	0.55
	681.4-651.6	47.2-77.0	A-1-a	60	5.36	0.50	0.55
B-024-1-13	728.6-720.9	0.0-7.7	A-4a	41	2.37	0.40	0.45
	720.9-714.4	7.7-14.2	A-6a	45	2.32	0.40	0.45
	714.4-694.4	14.2-34.2	A-1-a	60	4.41	0.50	0.55
	694.4-689.4	34.2-39.2	A-3a	52	2.05	0.50	0.55
	689.4-684.4	39.2-44.2	A-4a	72	3.60	0.40	0.45
	684.4-682.4	44.2-46.2	A-1-b	60	5.04	0.50	0.55
B-024-2-14	728.6-717.2	0.0-11.4	A-4a	29	1.82	0.40	0.45
	717.2-710.7	11.4-17.9	A-4b	25	1.66	0.50	0.55
	710.7-705.7	17.9-22.9	A-1-b	20	1.10	0.50	0.55
	705.7-700.7	22.9-27.9	A-1-b	60	2.54	0.50	0.55
	700.7-695.7	27.9-32.9	A-4a	58	2.92	0.40	0.45
	695.7-683.7	32.9-44.9	A-1-b	60	4.68	0.50	0.55
B-026-1-13	728.6-719.0	0.0-9.6	A-1-b	46	1.37	0.50	0.55
	719.0-714.0	9.6-14.6	A-1-b	60	2.19	0.50	0.55
	714.0-697.0	14.6-31.6	A-1-b	60	3.46	0.50	0.55

1. *Top of shaft elevation based on structure information provided by GPD Group.*
2. *Side resistance should be neglected for the upper 5.0 feet of the shaft length where cohesive soils (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6) are present below the top of shaft elevation if the shafts are not tied into an embedded pile cap.*

Drilled Shaft Axial Design Parameters – Pier

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-024-1-13	728.5-720.9	0.0-7.6	A-4a	43	2.37	0.40	0.45
	720.9-714.4	7.6-14.1	A-6a	45	2.32	0.40	0.45
	714.4-694.4	14.1-34.1	A-1-a	60	4.45	0.50	0.55
	694.4-689.4	34.1-39.1	A-3a	52	2.06	0.50	0.55
	689.4-684.4	39.1-44.1	A-4a	72	3.60	0.40	0.45
	684.4-682.4	44.1-46.1	A-1-b	60	5.07	0.50	0.55
B-024-2-14	729.5-717.2	0.0-12.3	A-4a	30	1.82	0.40	0.45
	717.2-710.7	12.3-18.8	A-4b	25	1.71	0.50	0.55
	710.7-705.7	18.8-23.8	A-1-b	20	1.13	0.50	0.55
	705.7-700.7	23.8-28.8	A-1-b	60	2.58	0.50	0.55
	700.7-695.7	28.8-33.8	A-4a	58	2.92	0.40	0.45
	695.7-683.7	33.8-45.8	A-1-b	60	4.74	0.50	0.55
B-025-0-08	728.5-715.4	0.0-13.1	A-4a	24	1.51	0.40	0.45
	715.4-711.9	13.1-16.6	A-6b	25	1.58	0.40	0.45
	711.9-701.9	16.6-26.6	A-1-b	60	3.64	0.50	0.55
	701.9-696.9	26.6-31.6	A-4a	72	3.60	0.40	0.45
	696.9-690.4	31.6-38.1	A-1-b	60	3.50	0.50	0.55
	690.4-683.4	38.1-45.1	A-6a	67	3.37	0.40	0.45
	683.4-681.4	45.1-47.1	A-3a	60	3.04	0.50	0.55
B-026-2-13	726.0-716.3	0.0-9.7	A-1-b	24	0.78	0.50	0.55
	716.3-695.3	9.7-30.7	A-1-b	60	3.61	0.50	0.55
	695.3-689.8	30.7-36.2	A-3a	16	1.15	0.50	0.55
	689.8-684.8	36.2-41.2	A-3a	60	2.09	0.50	0.55
	684.8-674.8	41.2-51.2	A-3a	60	2.52	0.50	0.55
	674.8-664.8	51.2-61.2	A-4a	72	3.60	0.40	0.45
	664.8-654.8	61.2-71.2	A-3a	60	3.01	0.50	0.55
	654.8-647.3	71.2-78.7	A-6b	72	3.60	0.40	0.45
B-002-F-59	724.5-712.1	0.0-12.4	A-1-b	60	2.81	0.50	0.55
	712.1-691.1	12.4-33.4	A-1-a	60	4.05	0.50	0.55
	691.1-681.1	33.4-43.4	A-3a	60	2.84	0.50	0.55

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-003-A-59	729.5-717.9	0.0-11.6	A-4a	20	1.23	0.40	0.45
	717.9-712.9	11.6-16.6	A-4b	39	2.08	0.50	0.55
	712.9-701.9	16.6-27.6	A-1-a	60	2.95	0.50	0.55
	701.9-696.9	27.6-32.6	A-3a	60	2.70	0.50	0.55
	696.9-691.9	32.6-37.6	A-4a	72	3.60	0.40	0.45
	691.9-686.9	37.6-42.6	A-2-4	60	3.53	0.50	0.55
	686.9-682.4	42.6-47.1	A-4b	69	3.48	0.40	0.45
	682.4-679.9	47.1-49.6	A-3a	60	3.04	0.50	0.55

1. *Top of shaft elevation based on structure information provided by GPD Group.*
2. *Side resistance should be neglected for the upper 5.0 feet of the shaft length where cohesive soils (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6) are present below the top of shaft elevation if the shafts are not tied into an embedded pile cap.*

Drilled Shaft Axial Design Parameters – Forward Abutment

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-025-0-08	732.0-715.4	0.0-16.6	A-4a	24	1.51	0.40	0.45
	715.4-711.9	16.6-20.1	A-6b	25	1.58	0.40	0.45
	711.9-701.9	20.1-30.1	A-1-b	60	3.84	0.50	0.55
	701.9-696.9	30.1-35.1	A-4a	72	3.60	0.40	0.45
	696.9-690.4	35.1-41.6	A-1-b	60	3.64	0.50	0.55
	690.4-683.4	41.6-48.6	A-6a	67	3.37	0.40	0.45
	683.4-681.4	48.6-50.6	A-3a	60	3.13	0.50	0.55
B-026-0-08	732.0-723.0	0.0-9.0	A-6a	20	1.37	0.40	0.45
	723.0-712.0	9.0-20.0	A-4a	23	1.44	0.40	0.45
	712.0-704.0	20.0-28.0	A-2-4	60	3.31	0.50	0.55
	704.0-697.0	28.0-35.0	A-6a	72	3.60	0.40	0.45
	697.0-687.0	35.0-45.0	A-1-b	60	4.41	0.50	0.55
	687.0-679.0	45.0-53.0	A-6a	50	2.53	0.40	0.45
	679.0-672.0	53.0-60.0	A-1-a	60	5.30	0.50	0.55
	672.0-664.0	60.0-68.0	A-4a	72	3.60	0.40	0.45

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-026-2-13	728.4-726.3	0.0-2.1	A-2-4	34	0.67	0.50	0.55
	726.3-716.3	2.1-12.1	A-1-b	24	0.91	0.50	0.55
	716.3-695.3	12.1-33.1	A-1-b	60	3.77	0.50	0.55
	695.3-689.8	33.1-38.6	A-3a	16	1.20	0.50	0.55
	689.8-684.8	38.6-43.6	A-3a	60	2.15	0.50	0.55
	684.8-674.8	43.6-53.6	A-3a	60	2.58	0.50	0.55
	674.8-664.8	53.6-63.6	A-4a	72	3.60	0.40	0.45
	664.8-654.8	63.6-73.6	A-3a	60	3.07	0.50	0.55
	654.8-647.3	73.6-81.1	A-6b	72	3.60	0.40	0.45
B-026-3-13	730.0-724.9	0.0-5.1	A-1-b	40	0.97	0.50	0.55
	724.9-719.9	5.1-10.1	A-4a	66	3.54	0.40	0.45
	719.9-704.9	10.1-25.1	A-1-b	60	3.21	0.50	0.55
	704.9-694.9	25.1-35.1	A-4a	72	3.60	0.40	0.45
	694.9-689.9	35.1-40.1	A-2-4	60	4.64	0.50	0.55
	689.9-669.9	40.1-60.1	A-1-b	60	4.07	0.50	0.55
	669.9-666.9	60.1-63.1	A-3a	60	3.23	0.50	0.55
B-001-C-59	730.0-723.4	0.0-6.6	A-2-4	60	1.65	0.50	0.55
	723.4-713.4	6.6-16.6	A-3a	60	1.95	0.50	0.55
	713.4-705.4	16.6-24.6	A-1-a	60	3.12	0.50	0.55
	705.4-694.4	24.6-35.6	A-1-b	60	4.43	0.50	0.55
	694.4-691.4	35.6-38.6	A-4a	60	5.45	0.50	0.55
B-005-F-59	730.0-720.7	0.0-9.3	A-4a	65	3.60	0.40	0.45
	720.7-709.7	9.3-20.3	A-1-a	60	3.89	0.50	0.55
	709.7-699.7	20.3-30.3	A-1-b	60	4.34	0.50	0.55
	699.7-691.7	30.3-38.3	A-6a	72	3.60	0.40	0.45

1. *Top of shaft elevation based on structure information provided by GPD Group.*
2. *Side resistance should be neglected for the upper 5.0 feet of the shaft length where cohesive soils (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6) are present below the top of shaft elevation if the shafts are not tied into an embedded pile cap.*

Drilled shaft lengths should measure a minimum of three (3) times the shaft diameter. Per Section 10.8.3.5.1b of the AASHTO LRFD BDS, side resistance should be neglected for the upper 5.0 feet of the shaft length where cohesive soils (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6) are present below the bottom of footing/top of shaft elevation. Total settlement of the drilled shafts is estimated to be less than 1.0 inch for shafts bearing at or below elevation 705.0 feet msl.

The axial resistance of a group of shafts may be less than the sum of the individual shaft resistance within a group of shafts. Per Section 10.8.3.6.3 of the AASHTO LRFD BDS, for soil profiles that consist of primarily granular soils, the individual nominal resistance of each drilled shaft shall be reduced by applying an adjustment factor, η, as defined in Table 10.8.3.6.1-1 of the AASHTO LRFD BDS. The following criteria are recommended for the group resistance of any shaft groups.

For a single row of drilled shafts:

- η = 0.9 for a center-to-center spacing of 2.0 diameters or less,
- η = 1.0 for a center-to-center spacing of 3.0 diameters or greater.

For multiple rows of drilled shafts:

- η = 0.67 for a center-to-center spacing of 2.5 diameters or less,
- η = 0.8 for a center-to-center spacing of 3.0 diameters,
- η = 1.0 for a center-to-center spacing of 4.0 diameters or greater.

For intermediate spacing under either scenario, the value of η may be determined by liner interpolation. Please note that the adjustment factor should be applied to the total individual nominal shaft resistance (including both end bearing side resistance along the shaft length).

Given that the drilled shafts at the abutments will be constructed tangent to each other, the shaft group capacity should also be checked using the block failure mechanism. Since the soil profile consists primarily of dense granular soils, the analysis should be performed considering the entire drilled shaft group as an equivalent strip footing with a length equal to the length of the tangent shaft wall and equivalent width equal to the total end area of the drilled shafts divided by the length of the drilled shaft wall. A resistance factor of φ_b = 0.45 should be utilized in calculating the factored bearing resistance for the this failure mode at the strength limit state.

The total group resistance shall be the lesser of the sum of the individual drilled shafts multiplied by the applicable group efficiency factor, η, or the resistance of the group in block failure mode.

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 FRA-70-12.68/13.11/14.05C (Project 4R/4H/4A) projects in Columbus, Ohio. The projects represent the central portion of FRA-70-8.93 (PID 77369) I-70/71 south innerbelt improvements project. The FRA-70-12.68 (Project 4R) phase will consist of all work associated with the construction of Ramp C5, starting at the bridge over Souder Avenue and extending east to Front Street. The proposed Ramp C5 will be a two-lane to four-lane ramp that will collect and direct traffic from I-71 northbound and SR-315 southbound as well as I-70 eastbound to exit in downtown at the intersection of Front Street and W. Fulton Avenue. This project includes the construction of six (6) new bridge structures for the proposed Ramp C5 alignment and replacement of three (3) bridge structures, two along I-70 and the Front Street Structure over I-70, as well as the construction of fourteen (14) new retaining walls and a culvert structure to accommodate the new configuration.

This report is a presentation of the structure foundation exploration performed for the design and construction of the proposed FRA-70-1390C bridge structure carrying the proposed Ramp C5 over I-70/71, as shown on the vicinity map and boring plan presented in Appendix I. Based on information provided by GPD GROUP, the proposed structure will consist of two single-span reinforced concrete deck structures supported transversely by simple span welded steel plate girders with reinforced concrete substructures. The proposed structure will have an approximate span length of approximately 92.5 feet where it will span over I-70 eastbound and 96.3 feet where it will span over I-70 westbound, as measured from the centerline of abutment bearings to the centerline of the pier. The east end of the bridge deck spanning over I-70 westbound will also be integrated with the FRA-70-1395 Front Street bridge deck at the northwest corner of that structure, where the ramp will be aligned with Fulton Street.

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 based on geological age, depositional process and geomorphic occurrence (physical features or landforms). The project area lies within the Columbus Lowland District of the Till Plains Section. This area is characterized by flat to gently rolling ground moraine deposits from the Late Wisconsinan age. The site topography exhibits moderate to high relief. The ground moraine deposits are composed primarily of silty loam till (Darby, Bellefontaine, Centerburg, Grand Lake, Arcanum, Knightstown Tills), with smaller alluvium and outwash deposits bordering the Scioto River, its tributaries and floodplain areas. A ground moraine is the sheet of debris left after the steady retreat of glacial ice. The debris left behind ranges in composition from clay size particles to boulders (including silt, sand, and gravel). 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.

According to the bedrock geology and topography maps obtained from the Ohio Department of Natural Resources (ODNR), the underlying bedrock consists predominantly of the Middle to Lower Devonian-aged Columbus Limestone Formation. This formation is further subdivided into two members in the central portion of the state, known as the Delhi and Bellepoint Members. The Delhi Member consists of light gray, finely to coarsely crystalline, irregularly bedded, fossiliferous limestone. The Bellepoint Member consists of variable brown, finely crystalline, massively bedded limy dolomite. Both of these members contain chert nodules. Just east of Scioto River, the Upper Devonian Ohio Shale Formation overlies the Columbus Limestone Formation. The Ohio Shale formation consists of brownish black to greenish gray, thinly bedded, fissile, carbonaceous shale. Regionally, the bedrock surface forms a broad valley aligned roughly north-to-south beneath the Scioto River. According to bedrock topography mapping, the elevation of the bedrock surface ranges from approximately 600 feet mean sea level (msl) in the valley to approximately 625 feet msl near the project limits. However, shale bedrock was encountered in two of the borings performed for this structure at elevations ranging from 651.6 to 664.0 feet msl.

2.2 Existing Conditions

The proposed FRA-70-1390C structure is located just west of the existing S. Front Street over I-70/71 overpass, approximately 0.7 miles east of the Scioto River. The existing I-70/I-71 in the vicinity of the structure is a six-lane, bi-directional, composite asphalt and concrete paved roadway that is generally east-west aligned through downtown Columbus, Ohio. The existing S. Front Street crossing is a three-lane, asphalt paved roadway with northbound parking lane against the eastern curb. The existing I-70 profile grades down from west to east into the downtown area, and is generally lower in elevation with respect to the surrounding terrain, as the existing corridor was cut approximately 20 to 25 below the existing grade of S. Front Street and the surrounding downtown area. Portions of the proposed rear abutment substructure will be located within the grass area between W. Fulton Avenue and an apartment complex, and will also cross a portion of the parking at the southeast corner of W. Fulton Avenue and S. 2nd Street. The traffic volume along the project alignment is very high, and the alignment traverses primarily commercial and government properties. The surrounding terrain across grades down gently to the west out of the downtown area.

3.0 EXPLORATION

Between August 6, 2013, and February 14, 2015, six (6) structural borings, designated as B-023-1-13, B-024-1-13, B-024-2-14, B-026-1-13, B-026-2-13 and B-026-3-13, were advanced to completion depths ranging from 48.1 to 90.0 feet below the existing ground surface. In addition to the borings performed by Rii as part of the current exploration, three (3) borings, designated as B-024-0-08, B-025-0-08 and B-026-0-08, were performed DLZ in the vicinity of the bridge structure as part of the FRA-70-8.93 preliminary exploration (PID 77369), and their findings were published in a report dated September 24, 2009. The borings were advanced to a completion depth of 111.5, 59.3 and 115.0 feet below the existing ground surface, respectively. The current project boring locations are shown on the boring plan provided in Appendix I of this report and summarized in Table 1 below.

Table 1. Test Boring Summary

Boring Number	Reference Alignment	Station	Offset	Latitude	Longitude	Ground Elevation (feet msl)	Boring Depth (feet)
B-023-1-13	BL Ramp C5	5084+74.16	15.0' Rt.	39.952844807	-83.003019835	732.4	48.1
B-024-0-08	BL Ramp C5	5085+90.21	3.1' Lt.	39.952928381	-83.002605586	743.4	111.5
B-024-1-13	BL Ramp C5	5087+81.22	64.3' Rt.	39.952930262	-83.001880690	746.4	64.3
B-024-2-14	BL Ramp C5	5086+86.08	34.9' Lt.	39.953082824	-83.002320685	742.7	59.2
B-025-0-08	BL Ramp C5	5088+53.62	76.0' Lt.	39.953359121	-83.001796370	740.4	59.3
B-026-0-08	BL Ramp C5	5088+59.96	128.9' Lt.	39.953503747	-83.001825833	754.0	115.0
B-026-1-13	BL I-70 EB	184+88.08	111.1' Rt.	39.952673289	-83.001473185	747.0	50.0
B-026-2-13	BL Ramp C5	5089+73.78	16.5' Rt.	39.953112248	-83.001308349	736.8	89.5
B-026-3-13	BL Ramp C5	5091+04.93	11.5' Lt.	39.953296762	-83.000848553	756.9	90.0

The locations for the current exploration borings performed by Rii were determined and located in the field by Rii representatives. Rii utilized a handheld GPS unit to obtain geographic latitude and longitude coordinates of the boring locations. Ground surface elevations at the boring locations were interpolated using topographic mapping information provided by GPD Group.

The borings performed by Rii for the current exploration were drilled using a truck or an all-terrain vehicle (ATV) mounted rotary drilling machine, utilizing either a 3.25 or 4.25-inch inside diameter, hollow stem auger to advance the holes. The borings performed by DLZ were drilled using a truck or an all-terrain vehicle (ATV) mounted rotary drilling machine, utilizing either a 3.25-inch inside diameter, hollow stem auger or a 4.0-inch flush joint casing to advance the holes. In general, standard penetration test

(SPT) and split spoon sampling were performed in the borings at 2.5-foot increments of depth to 20.0 or 30.0 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 using a 140-pound hammer falling 30.0 inches to drive a 2.0-inch outside diameter split spoon sampler 18.0 inches. Rii utilized a calibrated automatic drop hammer to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of blows per 6.0-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). Standard penetration blow counts aid in determining soil properties applicable in foundation system design. Measured blow count (N) values are corrected to an equivalent (60%) energy ratio, N_{60}, by the following equation. Both values are represented on boring logs in Appendix III.

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

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

The hammers for the Mobile B-53 and CME 750 drill rigs operated by Rii were calibrated on April 26, 2013, and have drill rod energy ratios of 77.7 and 82.6 percent, respectively. The hammer for the CME 55 drill rig operated by Rii was calibrated on October 20, 2014, and has a drill rod energy ratio of 92.0 percent. The hammers for the CME 75 and CME 750X drill rigs operated by DLZ have drill rod energy ratios of 61.2 and 63.1 percent, respectively. No calibration date is available for the DLZ rig calibrations.

During drilling for the borings performed by Rii, field logs were prepared by Rii personnel 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	113
Plastic and Liquid Limits	AASHTO T89, T90	38
Gradation – Sieve/Hydrometer	AASHTO T88	38
One-Dimensional Consolidation	ASTM D2435	1
Unconfined Compressive Strength of Cohesive Soil	ASTM D2166	1

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

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.

Where borings that were performed by DLZ were extended into the underlying bedrock, an NXM or NQ double-tube diamond bit core barrel (utilizing wire line equipment) was used to core the bedrock. Coring produced 1.85 inch diameter cores from which the type of rock and its geological characteristics were determined.

Rock cores were analyzed to identify the type of rock, color, mineral content, bedding planes and other geological and mechanical features of interest in this project. The Rock Quality Designation (RQD) for each rock core run was calculated according to the following equation:

$$RQD = \frac{\sum segments\ equal\ to\ or\ longer\ than\ 4.0\ inches}{core\ run\ length} x100$$

In addition to the borings performed as part of the preliminary engineering and current explorations, historic borings performed in 1959 by the Department of Highways as part of the original FRA-40-12.82 project were also obtained from the construction documents on record. Two (2) borings, designated as B-002-F-59 and B-005-F-59, were obtained at the rear and forward abutment of the existing adjacent Front Street bridge structure over I-70/I-71 (FRA-40-1300). One (1) boring, designated as B-001-C-59, was obtained along the alignment of the existing retaining wall on the north side of I-70 westbound between the Front Street and High Street bridge structures (Retaining Wall C). One (1) boring, designated as B-003-A-59, was obtained along the alignment of the existing retaining wall between I-70 eastbound and W. Fulton Avenue (Retaining Wall A). Based on the elevations provided on the boring logs, it is anticipated that the borings for the Front Street bridge structure and Retaining Walls C were performed from the then-existing ground surface and that the profile for the then-proposed US 40 (existing I-70/71) was lowered to provide sufficient clearance for the bridge to be constructed at the then-existing ground surface. The borings were extended to depths ranging from 55.0 to 73.0 feet below the ground surface at the time the borings were obtained. Please note that the elevations provided on the historic boring logs were referenced to the North American Datum (NAD) 27. The current design survey is referenced to NAD 83. The NAD 27 datum is 0.6 feet lower than the NAD 83 datum. **Therefore, all elevations noted in this report with respect to the historic borings are adjusted to the current NAD 83 datum.** The historic boring locations are shown on the boring plan provided in Appendix I of this report and the historic boring logs are provided in Appendix IV.

4.0 FINDINGS

Interpreted engineering logs have been prepared based on the field logs, visual examination of samples and laboratory test results. Classification follows the respective version of the ODOT Specifications for Geotechnical Explorations (SGE) at the time the exploration borings were performed. The following is a summary of what was found in the test borings performed as part of the preliminary engineering phase and current exploration and what is represented on the boring logs.

4.1 Surface Materials

Borings B-023-1-13 and B-024-0-08 were performed along the south side of W. Fulton Street, and no discernable surface material was present at the ground surface. Borings B-024-1-13 and B-024-2-14 were drilled in the existing I-70 eastbound ramp to Front Street and encountered 14.0 and 5.0 inches of asphalt, respectively, overlying 6.0 inches of aggregate base in boring B-024-1-13 and 13.0 inches of concrete in boring B-024-2-14 at the ground surface. Borings B-025-0-08 and B-026-2-13 were drilled in the existing shoulders of I-70 eastbound and westbound and encountered 7.0 and 9.0 inches of asphalt overlying 7.0 and 6.0 inches of aggregate base, respectively. Boring B-026-0-08 was performed at the top of the slope along the north side of I-70/I-71 and encountered 4.0 inches of topsoil at the ground surface. Boring B-026-1-13 was performed in the existing pavement along S. Ludlow Street and encountered 4.0 inches of asphalt overlying 8.0 inches of aggregate base. Boring B-026-3-13 was performed within the existing sidewalk along the west side of S. Front Street, at the intersection with W. Fulton Street on the north side of I-70/I-71 and encountered 6.0 inches of concrete overlying 6.0 inches of aggregate base.

4.2 Subsurface Soils

Beneath the pavement materials in borings B-025-0-08, B-026-1-13 and B-026-2-13, material identified as existing fill or possible fill was encountered extending to depths ranging from 3.5 to 15.5 feet below exiting grade, which corresponds to elevations ranging from 731.3 to 736.9 feet msl. The fill material was described as medium dense to very dense, brown and gray gravel, gravel and sand, gravel with sand and silt (ODOT A-1-a, A-1-b, A-2-4), and hard, brown silt and clay (ODOT A-6a) and contained brick fragments throughout.

Underlying the surficial materials and existing fill, where encountered, natural soils were encountered consisting of both granular and cohesive material. The granular soils were generally described as loose to very dense brown, gray, brownish gray and dark gray gravel, gravel and sand, gravel with sand and silt, fine sand, coarse and fine sand, sandy silt and silt (ODOT A-1-a, A-1-b, A-2-4, A-3, A-3a, A-4a, A-4b). The cohesive materials were generally described as soft to hard, brown, brownish gray and dark gray sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6).

Cobbles and boulders were encountered in the majority of the borings at and below elevations ranging from 700 to 710 feet msl. At depths below this elevations range, drilling conditions were typically more challenging and high blow counts, including split spoon sampler refusal, were obtained throughout these deposits. Split spoon sampler refusal is defined as exceeding 50 blows from the hammer with less than 6.0 inches of penetration by the split spoon sampler. Additionally, heaving sands were encountered in the majority of the borings at elevations ranging from 685 to 700 feet msl. The height of sand heave within the augers was approximately 1.0 to 3.0 feet and was able to be controlled through the addition of water or mud to the boreholes during drilling.

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 loose ($5 \leq N_{60} < 10$ blows per foot [bpf]) to very dense ($N_{60} > 50$ bpf). Overall blow counts recorded from the SPT sampling ranged from 6 bpf to split spoon sampler refusal. The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soil encountered ranged from soft ($0.25 < HP \leq 0.5$ tsf) to hard ($HP > 4.0$ tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 0.5 to over 4.5 tsf (limit of instrument).

Natural moisture contents of the soil samples tested ranged from 3 to 30 percent. The natural moisture content of the cohesive soil samples tested for plasticity index ranged from 7 percent below to 5 percent above their corresponding plastic limits. In general, the soil exhibited natural moisture contents considered to be moderately below to moderately above optimum moisture levels.

4.3 Bedrock

Bedrock was encountered in borings B-024-0-08 and B-026-0-08 as presented in Table 3.

Table 3. Top of Bedrock Elevations

Boring Number	Ground Surface Elevation (feet msl)	Top of Bedrock		Top of Bedrock Core	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-024-0-08	743.4	91.8	651.6	90.0	653.4
B-026-0-08	754.0	90.0	664.0	90.0	664.0

Top of bedrock was encountered in borings B-024-0-08 and B-026-0-08 at a depth of 91.8 and 90.0 feet below existing grade, respectively, which corresponds to an elevation of 651.6 and 664.0 feet msl. The upper portion of the bedrock in boring B-026-0-08 consisted of brown, severely weathered claystone that extended to a depth of 97.8 feet (El. 656.2 feet msl) overlying blueish gray to dark gray, moderately to highly weathered shale. The shale is described as blueish gray to dark gray, moderately to highly weathered, weak, laminated to thinly laminated, calcareous, pyritic, fissile, friable, jointed and moderately to highly fractured with tight, slightly rough apertures. The shale bedrock contains thin seams of interbedded limestone throughout.

The percent recovery, RQD values and unconfined compressive strengths of the bedrock core runs are summarized in Table 4.

Table 4. Rock Core Summary

Boring	Core No.	Depth (feet)	Elevation (feet msl)	Recovery (%)	RQD (%)	Unconfined Compressive Strength
B-024-0-08	R-1	90.0 to 91.5	653.4 to 651.9	0	0	N/A
	R-2	91.5 to 101.5	651.9 to 641.9	97	81	q_u @ 97.7' = 1,650 psi
	R-3	101.5 to 111.5	641.9 to 631.9	63	48	N/A
B-026-0-08	R-1	90.0 to 95.0	664.0 to 659.0	8	0	N/A
	R-2	95.0 to 100.0	659.0 to 654.0	100	80	N/A
	R-3	100.0 to 105.0	654.0 to 649.0	100	85	q_u @ 100.5' = 2,391 psi
	R-4	105.0 to 110.0	649.0 to 644.0	100	90	N/A
	R-5	110.0 to 115.0	644.0 to 639.0	100	83	N/A

It should be noted that bedrock can experience mechanical breaks during the drilling and coring processes. It is anticipated that DLZ attempted to account for fresh, manmade breaks during tabulation of the RQD analysis, per ODOT SGE specifications. The quality of the weathered claystone bedrock, according to the RQD values, was very poor (RQD ≤ 25%), and the quality of the shale bedrock ranged from poor (25 < RQD ≤ 50%) to good (75 < RQD ≤ 90%). High angle factures were noted in the shale bedrock in boring B-026-0-08 at depths ranging from 110.2 to 114.2 feet below existing grade.

4.4 Groundwater

Groundwater was encountered in the borings as presented in Table 5.

Table 5. Groundwater Levels

Boring Number	Ground Surface Elevation (feet msl)	Initial Groundwater		Upon Completion	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-023-1-13	732.4	32.0	700.4	18.0	714.4
B-024-0-08	743.4	28.0	715.4	16.5 [1]	726.9
B-024-1-13	746.4	34.0	712.4	N/A [2]	N/A
B-024-2-14	742.7	26.0	716.7	N/A [2]	N/A
B-025-0-08	740.4	26.0	714.4	39.0	701.4
B-026-0-08	754.0	41.0	713.0	29.1 [1]	724.9
B-026-1-13	747.0	28.5	718.5	N/A [2]	N/A
B-026-2-13	736.8	18.5	718.3	N/A [2]	N/A
B-026-3-13	756.9	36.0	720.9	N/A [2]	N/A

1. *The groundwater level at completion was measured prior to introduction of water as a circulating fluid for the rock coring process.*
2. *The groundwater level at completion could not be obtained due to the addition of water or mud as a drilling fluid.*

Groundwater was encountered initially during the drilling process in all of the borings performed as part of the current or preliminary explorations at depths ranging from 18.5 to 41.0 feet below existing grade, which corresponds to elevations ranging from 700.4 to 720.9 feet msl. The groundwater level at the completion of drilling in borings B-023-1-13, B-024-0-08, B-026-0-08 and B-026-0-08 ranged from 18.0 to 39.0 feet below existing grade, which corresponds to elevations ranging from 701.4 to 726.9 feet msl. The groundwater levels at the completion of drilling could not be measured in the remainder of the borings due to the addition of mud or water to counteract heaving sands.

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

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

4.5 Historic Borings

In general, the historic borings, designated B-001-C-59, B-002-F-59, B-003-A-59 and B-005-F-59, encountered loose to very dense granular soils with intermittent seams of medium stiff to hard cohesive soils. The granular soils were generally described as brown and gray gravel, gravel and sand, gravel with sand and silt, coarse and fine sand and sandy silt (ODOT A-1-a, A-1-b, A-2-4, A-3a, A-4a), and the cohesive soils were generally described as brown, gray and brownish gray sandy silt, silt and silt and clay (ODOT A-4a, A-4b, A-6a). A boulder zone was encountered in boring B-001-C-59 beginning at elevation 753.2 feet msl and extending to the boring termination depth at elevation 692.0 feet msl. Boulders were also encountered in boring B-003-A-59 beginning at elevation 713.0 feet msl and extending to the boring termination depth at 680.5 feet msl. Boulders were not noted on the log for borings B-002-F-59 or B-005-F-59; however, high blow counts were encountered for the majority of the boring depths, which is typically an indication of large aggregate, cobbles or boulders being present in the soil. Bedrock was not encountered in the historic borings prior to the termination depths. Groundwater levels were not noted in the borings performed during the 1959 exploration. In general, the subsurface conditions encountered in the historic borings matched relatively closely with the subsurface conditions encountered in the preliminary engineering or current exploration borings.

5.0 ANALYSES AND RECOMMENDATIONS

Data obtained from the historical and current subsurface explorations 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 bridge, as well as the construction specifications related to the placement of foundation systems and general earthwork recommendations, which are discussed in the following paragraphs.

Design details of the structure proposed were provided by GPD GROUP. Based on the information provided, it is understood that the proposed structure will consist of two single-span reinforced concrete deck structures supported transversely by simple span welded steel plate girders with reinforced concrete substructures supported on drilled shafts tied into footings or tangent drilled shafts. The proposed structure will have an approximate span length of approximately 95.8 feet where it will span over I-70 eastbound and 99.0 feet where it will span over I-70 westbound, as measured from the centerline of abutment bearings to the centerline of the pier. The east end of the bridge deck spanning over I-70 westbound will also be integrated with the FRA-70-1395 Front Street bridge deck at the northwest corner of that structure, where the ramp will be aligned with Fulton Street. Proposed structural data was obtained from design details provided by GPD GROUP and are included in Table 6.

Table 6. Structure and Bridge Design Elevations

Substructure Unit	Structure Component [1]	Elevation [1,2] (feet msl)	Design Maximum Factored Load [1]
Rear Abutment	Top of Shaft	728.6	1,483 kips/shaft
Pier	Top of Shaft	729.5 / 724.5	878 kips/shaft
Forward Abutment	Top of Shaft [3]	728.4 / 732.0	703 / 728 kips/shaft

1. *Proposed foundation elevations and structural loading based on structure information provided by GPD GROUP.*
2. *Multiple values indicate the maximum and minimum top of shaft elevation along the substructure unit.*
3. *For the tangent shaft section of the forward abutment, the elevation of the bottom of the cantilever section of the drilled shafts is included in the elevation range.*

Consideration was given to a driven pile foundation, but given the dense, granular nature of the soil and the presence of cobbles and boulders that are common in the area, as well as the close proximity to existing underground utilities, this type of foundation system is not recommended due to the potential of damaging the pile elements or existing utilities during installation. Consideration was also given to supporting the structure on shallow foundations, but due to the close proximity to existing utilities at all of the substructure locations, this type of foundation system is not recommended due to the potential of damaging the utilities from the additional pressures from the foundation loading.

5.1 Drilled Shaft Recommendations

It is understood that a combination of drilled shafts tied into footings or tangent drilled shafts foundations are being utilized to support the substructure units. To achieve the most economical design, the drilled shafts should extend to bear in the dense to very dense gravel, gravel and sand, gravel with sand and silt, coarse and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-3a) or hard sandy silt, silt or silt and clay (ODOT A-4a, A-4b, A-6a) at or below elevation 705.0 feet msl in order to maximize the end bearing resistance. It is recommended that the drilled shafts be designed using the axial design parameters provided in Table 7 through Table 9.

Table 7. Drilled Shaft Axial Design Parameters – Rear Abutment

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-023-1-13	728.6-724.4	0.0-4.2	A-7-6	19	1.51	0.40	0.45
	724.4-719.4	4.2-9.2	A-6a	15	1.03	0.40	0.45
	719.4-714.4	9.2-14.2	A-7-6	19	1.16	0.40	0.45
	714.4-710.4	14.2-18.2	A-1-b	39	1.73	0.50	0.55
	710.4-695.4	18.2-33.2	A-1-b	60	2.81	0.50	0.55
	695.4-690.4	33.2-38.2	A-6b	45	2.32	0.40	0.45
	690.4-684.4	38.2-44.2	A-1-a	60	4.76	0.50	0.55
B-024-0-08	728.6-715.4	0.0-13.2	A-4a	21	1.30	0.40	0.45
	715.4-711.4	13.2-17.2	A-4b	33	2.02	0.50	0.55
	711.4-706.4	17.2-22.2	A-1-a	44	1.93	0.50	0.55
	706.4-701.4	22.2-27.2	A-4a	72	3.60	0.40	0.45
	701.4-691.4	27.2-37.2	A-3a	60	2.29	0.50	0.55
	691.4-686.4	37.2-42.2	A-1-b	60	4.76	0.50	0.55
	686.4-681.4	42.2-47.2	A-4a	60	4.67	0.50	0.55
	681.4-651.6	47.2-77.0	A-1-a	60	5.36	0.50	0.55
B-024-1-13	728.6-720.9	0.0-7.7	A-4a	41	2.37	0.40	0.45
	720.9-714.4	7.7-14.2	A-6a	45	2.32	0.40	0.45
	714.4-694.4	14.2-34.2	A-1-a	60	4.41	0.50	0.55
	694.4-689.4	34.2-39.2	A-3a	52	2.05	0.50	0.55
	689.4-684.4	39.2-44.2	A-4a	72	3.60	0.40	0.45
	684.4-682.4	44.2-46.2	A-1-b	60	5.04	0.50	0.55
B-024-2-14	728.6-717.2	0.0-11.4	A-4a	29	1.82	0.40	0.45
	717.2-710.7	11.4-17.9	A-4b	25	1.66	0.50	0.55
	710.7-705.7	17.9-22.9	A-1-b	20	1.10	0.50	0.55
	705.7-700.7	22.9-27.9	A-1-b	60	2.54	0.50	0.55
	700.7-695.7	27.9-32.9	A-4a	58	2.92	0.40	0.45
	695.7-683.7	32.9-44.9	A-1-b	60	4.68	0.50	0.55
B-026-1-13	728.6-719.0	0.0-9.6	A-1-b	46	1.37	0.50	0.55
	719.0-714.0	9.6-14.6	A-1-b	60	2.19	0.50	0.55
	714.0-697.0	14.6-31.6	A-1-b	60	3.46	0.50	0.55

1. *Top of shaft elevation based on structure information provided by GPD Group.*
2. *Side resistance should be neglected for the upper 5.0 feet of the shaft length where cohesive soils (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6) are present below the top of shaft elevation if the shafts are not tied into an embedded pile cap.*

Table 8. Drilled Shaft Axial Design Parameters – Pier

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-024-1-13	728.5-720.9	0.0-7.6	A-4a	43	2.37	0.40	0.45
	720.9-714.4	7.6-14.1	A-6a	45	2.32	0.40	0.45
	714.4-694.4	14.1-34.1	A-1-a	60	4.45	0.50	0.55
	694.4-689.4	34.1-39.1	A-3a	52	2.06	0.50	0.55
	689.4-684.4	39.1-44.1	A-4a	72	3.60	0.40	0.45
	684.4-682.4	44.1-46.1	A-1-b	60	5.07	0.50	0.55
B-024-2-14	729.5-717.2	0.0-12.3	A-4a	30	1.82	0.40	0.45
	717.2-710.7	12.3-18.8	A-4b	25	1.71	0.50	0.55
	710.7-705.7	18.8-23.8	A-1-b	20	1.13	0.50	0.55
	705.7-700.7	23.8-28.8	A-1-b	60	2.58	0.50	0.55
	700.7-695.7	28.8-33.8	A-4a	58	2.92	0.40	0.45
	695.7-683.7	33.8-45.8	A-1-b	60	4.74	0.50	0.55
B-025-0-08	728.5-715.4	0.0-13.1	A-4a	24	1.51	0.40	0.45
	715.4-711.9	13.1-16.6	A-6b	25	1.58	0.40	0.45
	711.9-701.9	16.6-26.6	A-1-b	60	3.64	0.50	0.55
	701.9-696.9	26.6-31.6	A-4a	72	3.60	0.40	0.45
	696.9-690.4	31.6-38.1	A-1-b	60	3.50	0.50	0.55
	690.4-683.4	38.1-45.1	A-6a	67	3.37	0.40	0.45
	683.4-681.4	45.1-47.1	A-3a	60	3.04	0.50	0.55
B-026-2-13	726.0-716.3	0.0-9.7	A-1-b	24	0.78	0.50	0.55
	716.3-695.3	9.7-30.7	A-1-b	60	3.61	0.50	0.55
	695.3-689.8	30.7-36.2	A-3a	16	1.15	0.50	0.55
	689.8-684.8	36.2-41.2	A-3a	60	2.09	0.50	0.55
	684.8-674.8	41.2-51.2	A-3a	60	2.52	0.50	0.55
	674.8-664.8	51.2-61.2	A-4a	72	3.60	0.40	0.45
	664.8-654.8	61.2-71.2	A-3a	60	3.01	0.50	0.55
	654.8-647.3	71.2-78.7	A-6b	72	3.60	0.40	0.45
B-002-F-59	724.5-712.1	0.0-12.4	A-1-b	60	2.81	0.50	0.55
	712.1-691.1	12.4-33.4	A-1-a	60	4.05	0.50	0.55
	691.1-681.1	33.4-43.4	A-3a	60	2.84	0.50	0.55

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-003-A-59	729.5-717.9	0.0-11.6	A-4a	20	1.23	0.40	0.45
	717.9-712.9	11.6-16.6	A-4b	39	2.08	0.50	0.55
	712.9-701.9	16.6-27.6	A-1-a	60	2.95	0.50	0.55
	701.9-696.9	27.6-32.6	A-3a	60	2.70	0.50	0.55
	696.9-691.9	32.6-37.6	A-4a	72	3.60	0.40	0.45
	691.9-686.9	37.6-42.6	A-2-4	60	3.53	0.50	0.55
	686.9-682.4	42.6-47.1	A-4b	69	3.48	0.40	0.45
	682.4-679.9	47.1-49.6	A-3a	60	3.04	0.50	0.55

1. *Top of shaft elevation based on structure information provided by GPD Group.*
2. *Side resistance should be neglected for the upper 5.0 feet of the shaft length where cohesive soils (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6) are present below the top of shaft elevation if the shafts are not tied into an embedded pile cap.*

Table 9. Drilled Shaft Axial Design Parameters – Forward Abutment

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-025-0-08	732.0-715.4	0.0-16.6	A-4a	24	1.51	0.40	0.45
	715.4-711.9	16.6-20.1	A-6b	25	1.58	0.40	0.45
	711.9-701.9	20.1-30.1	A-1-b	60	3.84	0.50	0.55
	701.9-696.9	30.1-35.1	A-4a	72	3.60	0.40	0.45
	696.9-690.4	35.1-41.6	A-1-b	60	3.64	0.50	0.55
	690.4-683.4	41.6-48.6	A-6a	67	3.37	0.40	0.45
	683.4-681.4	48.6-50.6	A-3a	60	3.13	0.50	0.55
B-026-0-08	732.0-723.0	0.0-9.0	A-6a	20	1.37	0.40	0.45
	723.0-712.0	9.0-20.0	A-4a	23	1.44	0.40	0.45
	712.0-704.0	20.0-28.0	A-2-4	60	3.31	0.50	0.55
	704.0-697.0	28.0-35.0	A-6a	72	3.60	0.40	0.45
	697.0-687.0	35.0-45.0	A-1-b	60	4.41	0.50	0.55
	687.0-679.0	45.0-53.0	A-6a	50	2.53	0.40	0.45
	679.0-672.0	53.0-60.0	A-1-a	60	5.30	0.50	0.55
	672.0-664.0	60.0-68.0	A-4a	72	3.60	0.40	0.45

Boring Number	Elevation [1] (feet msl)	Shaft Length (feet)	Soil Type	Nominal Resistance (ksf)		Resistance Factor	
				End	Side	End	Side
B-026-2-13	728.4-726.3	0.0-2.1	A-2-4	34	0.67	0.50	0.55
	726.3-716.3	2.1-12.1	A-1-b	24	0.91	0.50	0.55
	716.3-695.3	12.1-33.1	A-1-b	60	3.77	0.50	0.55
	695.3-689.8	33.1-38.6	A-3a	16	1.20	0.50	0.55
	689.8-684.8	38.6-43.6	A-3a	60	2.15	0.50	0.55
	684.8-674.8	43.6-53.6	A-3a	60	2.58	0.50	0.55
	674.8-664.8	53.6-63.6	A-4a	72	3.60	0.40	0.45
	664.8-654.8	63.6-73.6	A-3a	60	3.07	0.50	0.55
	654.8-647.3	73.6-81.1	A-6b	72	3.60	0.40	0.45
B-026-3-13	730.0-724.9	0.0-5.1	A-1-b	40	0.97	0.50	0.55
	724.9-719.9	5.1-10.1	A-4a	66	3.54	0.40	0.45
	719.9-704.9	10.1-25.1	A-1-b	60	3.21	0.50	0.55
	704.9-694.9	25.1-35.1	A-4a	72	3.60	0.40	0.45
	694.9-689.9	35.1-40.1	A-2-4	60	4.64	0.50	0.55
	689.9-669.9	40.1-60.1	A-1-b	60	4.07	0.50	0.55
	669.9-666.9	60.1-63.1	A-3a	60	3.23	0.50	0.55
B-001-C-59	730.0-723.4	0.0-6.6	A-2-4	60	1.65	0.50	0.55
	723.4-713.4	6.6-16.6	A-3a	60	1.95	0.50	0.55
	713.4-705.4	16.6-24.6	A-1-a	60	3.12	0.50	0.55
	705.4-694.4	24.6-35.6	A-1-b	60	4.43	0.50	0.55
	694.4-691.4	35.6-38.6	A-4a	60	5.45	0.50	0.55
B-005-F-59	730.0-720.7	0.0-9.3	A-4a	65	3.60	0.40	0.45
	720.7-709.7	9.3-20.3	A-1-a	60	3.89	0.50	0.55
	709.7-699.7	20.3-30.3	A-1-b	60	4.34	0.50	0.55
	699.7-691.7	30.3-38.3	A-6a	72	3.60	0.40	0.45

1. *Top of shaft elevation based on structure information provided by GPD Group.*
2. *Side resistance should be neglected for the upper 5.0 feet of the shaft length where cohesive soils (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6) are present below the top of shaft elevation if the shafts are not tied into an embedded pile cap.*

Drilled shaft lengths should measure a minimum of three (3) times the shaft diameter. Per Section 10.8.3.5.1b of the AASHTO LRFD BDS, side resistance should be neglected for the upper 5.0 feet of the shaft length where cohesive soils (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6) are present below the top of shaft elevation if the shafts are not tied into an embedded pile cap. Total settlement of the drilled shafts is estimated to be less than 1.0 inch for shafts bearing at or below elevation 705.0 feet msl.

Per Section 10.8.3.5.3 of the AASHTO LRFD BDS, where drilled shafts are extended to end bear in a strong soil layer overlying a weaker soil layer, the end bearing resistance shall be reduced if the tip elevation is within 1.5 times the diameter of the drilled shaft above the top of the weaker soil layer. A weighted average that varies linearly from the full end bearing resistance in the overlying strong soil layer at a distance of 1.5 times the diameter of the drilled shaft above the top of the weak soil layer to the end bearing resistance of the weak soil layer at the top of the weak soil layer should be used to determine the end bearing resistance utilized in the design. Therefore, the end bearing resistance utilized in the design will need to be adjusted accordingly if the tip elevation of the drilled shafts will be within 1.5 times the diameter of the drilled shaft above the underlying weaker soil layer. Drilled shaft calculations are provided in Appendix VI.

5.1.1 Group Efficiency

The axial resistance of a group of shafts may be less than the sum of the individual shaft resistance within a group of shafts. Per Section 10.8.3.6.3 of the AASHTO LRFD BDS, for soil profiles that consist of primarily granular soils, the individual nominal resistance of each drilled shaft shall be reduced by applying an adjustment factor, η, as defined in Table 10.8.3.6.1-1 of the AASHTO LRFD BDS. The following criteria are recommended for the group resistance of any shaft groups.

For a single row of drilled shafts:

- η = 0.9 for a center-to-center spacing of 2.0 diameters or less,
- η = 1.0 for a center-to-center spacing of 3.0 diameters or greater.

For multiple rows of drilled shafts:

- η = 0.67 for a center-to-center spacing of 2.5 diameters or less,
- η = 0.8 for a center-to-center spacing of 3.0 diameters,
- η = 1.0 for a center-to-center spacing of 4.0 diameters or greater.

For intermediate spacing under either scenario, the value of η may be determined by liner interpolation. Please note that the adjustment factor should be applied to the total individual nominal shaft resistance (including both end bearing side resistance along the shaft length).

Given that the drilled shafts at the abutments will be constructed tangent to each other, the shaft group capacity should also be checked using the block failure mechanism. Since the soil profile consists primarily of dense granular soils, the analysis should be performed considering the entire drilled shaft group as an equivalent strip footing with a length equal to the length of the tangent shaft wall and equivalent width equal to the total end area of the drilled shafts divided by the length of the drilled shaft wall. A resistance factor of φ_b = 0.45 should be utilized in calculating the factored bearing resistance for the this failure mode at the strength limit state.

The total group resistance shall be the lesser of the sum of the individual drilled shafts multiplied by the applicable group efficiency factor, η, or the resistance of the group in block failure mode.

5.1.2 Lateral Design

If lateral load or moments are expected to be applied on the foundation elements, they should be analyzed to verify the shaft has enough lateral and bending resistance against these loads. A boring-by-boring tabulation of parameters that should be used for lateral loading design is provided in Appendix VII. In order to evaluate the lateral capacity, it is recommended that a derivation of COM624, such as LPILE, be utilized to determine the proper embedment depth and cross section required to resist the lateral load for a given end condition and deflection. Table 10 lists the eleven different soil types internal to the LPILE program. These strata were utilized to define the soil strata in the soil profile for each boring provided in Appendix VII.

Table 10. Subsurface Strata Description

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

For the case of closely spaced drilled shafts, a pile group reduction factor will need to be applied to the p-y curves that are internally generated by the lateral analysis software. Reese, Isenhower, and Wang published an equation for the pile group p-reduction factor, otherwise known as p-multiplier (β_a), for a single row of piles placed side by side in the publication "Analysis and Design of Shallow and Deep Foundations" (2006), as follows:

$$\beta_a = 0.64(S/D)^{0.34}$$

In which:

$$1 \leq S/D < 3.75 \text{ and } 0.5 \leq \beta_a \leq 1.0$$

Where:
S = center to center spacing of the drilled shafts
D = diameter of drilled shafts

5.1.3 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.
- When the bearing material has been encountered and identified and/or the design tip elevation has been reached, the shaft walls and base should be observed for anomalies, unexpected soft soil conditions, obstructions or caving.
- Concrete placed freefall should not be allowed to hit the sidewalls of the excavation or the rebar cage and should not pass through any water.
- Structural stability of the rebar cage should be maintained during the concrete pour to prevent buckling.
- The volume of concrete should be checked to ensure voids did not result during extraction of the casing (if utilized).
- 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).
- 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).
- 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).

The use of casing for drilled shafts is recommended under any of the following conditions:

- Caving material is encountered at any time during the drilling of the shaft.
- Groundwater is encountered at any time during the drilling of the shaft, or groundwater seepage occurs in the drilled shaft.
- Down hole inspection is planned (casing is required for this instance).

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

It is anticipated that conventional drilled shaft equipment (with a standard soil bit) will be able to penetrate the surficial soils to the required tip elevation. Although not encountered in any of the borings performed for this structure, boulders were encountered in several of the borings performed in the area of this structure and should be anticipated to be encountered during installation of the drilled shafts. If boulders are encountered during installation of the drilled shafts, specialized drilling/coring equipment may be required to advance the drilled shaft excavation beyond the obstruction.

5.2 Lateral Earth Pressure

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

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

Soil Type	γ (pcf) [1]	c (psf)	φ	k_a	k_o	k_p
Soft to Stiff Cohesive Soil	115	1,500	0°	N/A	N/A	N/A
Very Stiff to Hard Cohesive Soil	125	3,000	0°	N/A	N/A	N/A
Loose Granular Soil	120	0	28°	0.32	0.53	5.07
Medium Dense Granular Soil	125	0	32°	0.27	0.47	6.82
Dense to Very Dense Granular Soil	130	0	36°	0.23	0.41	9.09
Compacted Cohesive Engineered Fill	120	2,000	0°	N/A	N/A	N/A
Compacted Granular Engineered Fill	130	0	33°	0.26	0.46	7.41

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

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

Soil Type	γ (pcf) [1]	c (psf)	φ'	k_a	k_o	k_p
Soft to Stiff Cohesive Soil	115	0	26°	0.35	0.56	4.53
Very Stiff to Hard Cohesive Soil	125	50	28°	0.32	0.53	5.07
Loose Granular Soil	120	0	28°	0.32	0.53	5.07
Medium Dense Granular Soil	125	0	32°	0.27	0.47	6.82
Dense to Very Dense Granular Soil	130	0	36°	0.23	0.41	9.09
Compacted Cohesive Engineered Fill	120	0	30°	0.30	0.50	5.58
Compacted Granular Engineered Fill	130	0	33°	0.26	0.46	7.41

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

These parameters are considered appropriate for the design of all subsurface structures and any excavation support systems. Subsurface structures (where the top of the structure is restrained from movement) should be designed based on at-rest conditions (k_o). For proposed temporary retaining structures (where the top of the structure is allowed to move), earth pressure distributions should be based on active (k_a) and passive (k_p) conditions. The values in this table have been estimated from correlation charts based on minimum standards specified for compacted engineered fill materials. These recommendations do not take into consideration the effect of any surcharge loading or a sloped ground surface (a flat surface is considered). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage.

5.3 Construction Considerations

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

5.3.1 Excavation Considerations

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

Table 13. Excavation Back Slopes

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

5.3.2 Groundwater Considerations

Based on the groundwater observations made during drilling, groundwater is anticipated during construction of the drilled shafts. Where 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 using a rigid tremie pipe. Any seepage or groundwater encountered at this site should be able to be controlled by pumping from temporary sumps. Additional measures may be required depending on seasonal fluctuations of the groundwater level. Note that determining and maintaining actual groundwater levels during construction is the responsibility of the contractor.

6.0 LIMITATIONS OF STUDY

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

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

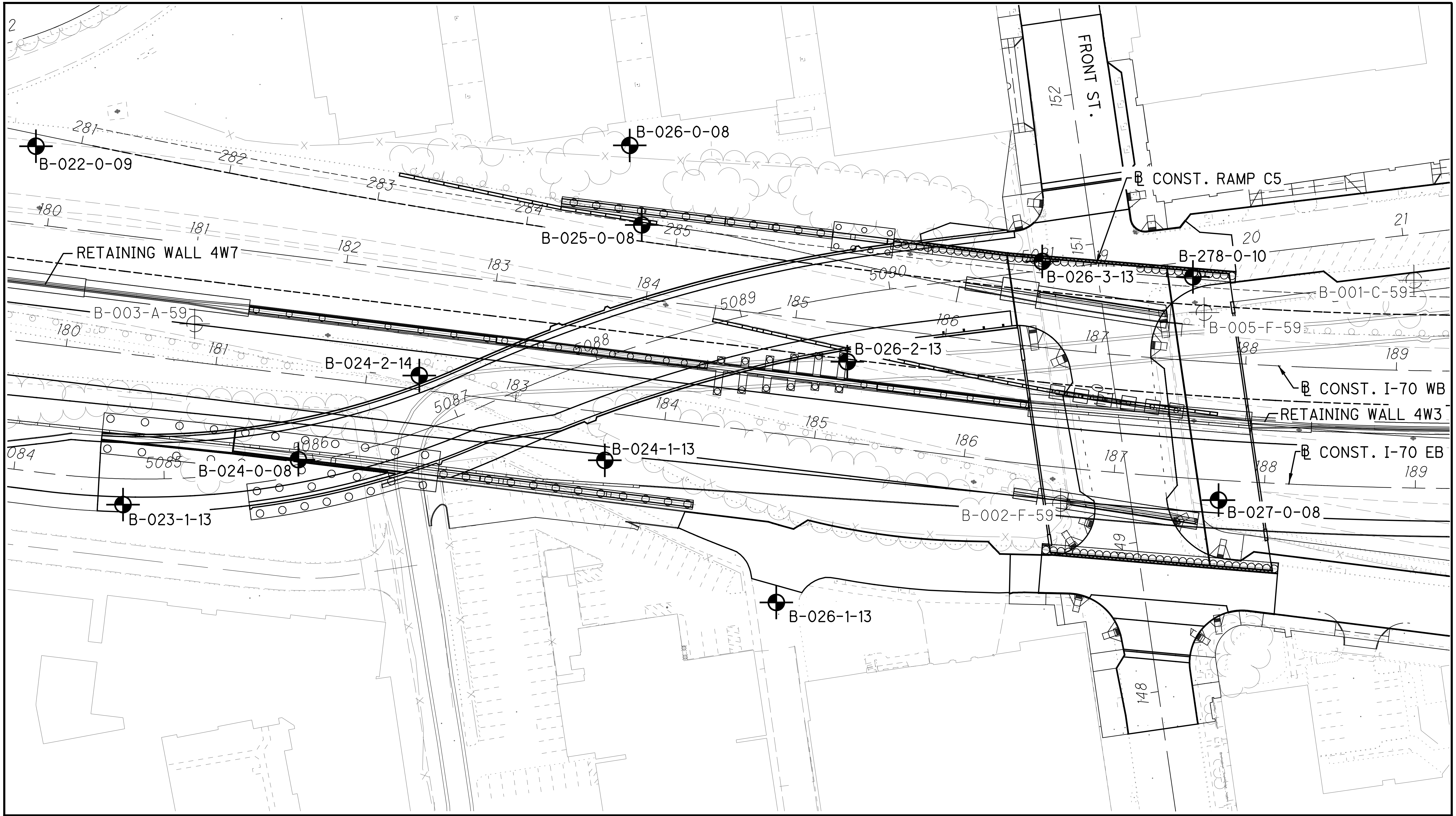
The conclusions and recommendations herein have been based upon the available soil and bedrock information and the design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be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

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

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

APPENDIX I

VICINITY MAP AND BORING PLAN



BORING PLAN

FRA-70-1390C

FRANKLIN COUNTY, OHIO

RII PROJECT NO.
W-13-045

SCALE: 1"=60'
0 30 60

DRAWN
RRM

REVIEWED
BRT

DATE
7-5-18

RESOURCE
INTERNATIONAL, INC.

APPENDIX II

DESCRIPTION OF SOIL TERMS

DESCRIPTION OF SOIL TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CLASSIFICATION OF SOILS

Ohio Department of Transportation

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

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

MATERIAL CLASSIFIED BY VISUAL INSPECTION

▧	Sod and Topsoil
☒	Pavement or Base
⋰	Uncontrolled Fill (Describe)
▦	Bouldery Zone
P	Peat

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

DESCRIPTION OF ROCK TERMS

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

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

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

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

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

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

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

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

Degree of Fracturing

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

Aperture Width

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

Surface Roughness

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

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

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

APPENDIX III

PROJECT BORING LOGS:

B-023-1-13 through B-026-3-13

BORING LOGS

Definitions of Abbreviations

AS = Auger sample

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

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

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

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

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

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

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

RC = Rock core sample

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

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

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

S = Sulfate content (parts per million)

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

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

SS = Split spoon sample

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

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

TR = Top of rock

W = Initial water level measured during drilling

▼ = Water level measured at completion of drilling

Classification Test Data

Gradation (as defined on Description of Soil Terms):

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

Atterberg Limits:

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

WC = Water content (%)

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / S.M.	DRILL RIG: CME-750 (SN 98048)	STATION / OFFSET: 5084+74.16 / 15.0' RT	**EXPLORATION ID** **B-023-1-13**
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / K.R.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL RAMP C5	
PID: 77372 BR ID: N/A	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 732.4 (MSL) EOB: 48.1 ft.	PAGE 1 OF 2
START: 8/6/13 END: 8/6/13	SAMPLING METHOD: SPT	ENERGY RATIO (%): 82.6	LAT / LONG: 39.952844807, -83.003019835	

MATERIAL DESCRIPTION AND NOTES	ELEV. 732.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
VERY STIFF TO HARD, BROWN **CLAY**, "AND" SILT, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.		1																
		2	5 7 13	28	53	SS-1	4.5+	-	-	-	-	-	-	-	-	14	A-7-6 (V)	
		3																
		4	4 4 6	14	58	SS-2	3.50	10	5	11	37	37	42	21	21	16	A-7-6 (13)	
		5																
		6																
		7	6 8 10	25	53	SS-3	4.5+	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
VERY STIFF TO HARD, BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST. -COBBLES PRESENT @ 9.0' -QU @ 8.3' = 2.95 TSF -CONSOLIDATION TEST PERFORMED @ 8.9'	724.4	8																
		9			60	ST-4	4.5+	16	11	15	34	24	29	18	11	22	A-6a (5)	
		10																
		11																
		12	4 5 6	15	78	SS-5	3.00	-	-	-	-	-	-	-	-	18	A-6a (V)	
STIFF TO VERY STIFF, BROWN **CLAY**, SOME SILT, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, DAMP TO MOIST.	719.4	13																
		14	4 6 6	17	81	SS-6	2.00	25	13	12	25	25	48	19	29	16	A-7-6 (10)	
		15																
		16																
		17			98	ST-7	3.00	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
DENSE TO VERY DENSE, BROWN TO GRAY **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST TO WET. -COBBLES PRESENT THROUGHOUT	714.4	▼ W 18																
		19	4 8 16	33	100	SS-8	-	-	-	-	-	-	-	-	-	18	A-1-b (V)	
		20																
		21																
		22																
		23																
		24	4 17 20	51	100	SS-9	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
		25																
		26																
		27																
		28																
		29	22 50/5"	-	0	SS-10	-	-	-	-	-	-	-	-	-	-		
			45	-	100	3S-10A	-	54	18	10	14	4	25	22	3	12	A-1-b (0)	

PID: 77372	BR ID: N/A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5084+74.16 / 15.0 RT	START: 8/6/13	END: 8/6/13	PG 2 OF 2	B-023-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 702.4	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 TO GRAY **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST TO WET. *(same as above)* -HEAVING SAND ENCOUNTERED @ 32.0' -COBBLES PRESENT THROUGHOUT	695.4	31 W 32 33 34 35 36 37	17 18 22	55	100	SS-11	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
VERY STIFF, DARK GRAY **SILTY CLAY**, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.	690.4	38 39 40 41 42	9 6 23	40	100	SS-12	3.50	4	8	20	46	22	36	16	20	11	A-6b (11)	
VERY DENSE, GRAY **GRAVEL**, LITTLE COARSE TO FINE SAND, TRACE SILT, DAMP. -COBBLES PRESENT @ 46.0'	684.3	43 44 45 46 47	12 30 36	91	78	SS-13	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
	EOB	48	50/1"	-	0	SS-14	-	-	-	-	-	-	-	-	-	-		

NOTES: SEEPAGE ENCOUNTERED @ 18.5'; GROUNDWATER ENCOUNTERED INITIALLY @ 32.0' AND AT COMPLETION @ 18.0'

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

PROJECT: FRA-70-12.68 - PHASE 4A
TYPE: STRUCTURE
PID: 77372 BR ID: FRA-70-1390
START: 2/11/15 END: 2/14/15

DRILLING FIRM / OPERATOR: RII / J.K.
SAMPLING FIRM / LOGGER: RII / C.D.
DRILLING METHOD: 4.25" HSA
SAMPLING METHOD: SPT

DRILL RIG: CME 55 (SN 386345)
HAMMER: CME AUTOMATIC
CALIBRATION DATE: 10/20/14
ENERGY RATIO (%): 92

STATION / OFFSET: 5087+81.22 / 64.3' RT
ALIGNMENT: BL RAMP C5
ELEVATION: 746.4 (MSL) EOB: 64.3 ft.
LAT / LONG: 39.952930262, -83.001880690

EXPLORATION ID
B-024-1-13

PAGE
1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 746.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
1.2' - ASPHALT (14.0")	745.2	1																
0.5' - AGGREGATE BASE (6.0")	744.7	2																
VERY STIFF TO HARD, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE TO LITTLE FINE GRAVEL, DAMP.		3	8 6 5	17	33	SS-1	4.50	-	-	-	-	-	-	-	-	12	A-6a (V)	
	740.9	4 5	2 6 7	20	100	SS-2	3.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
VERY DENSE, GRAY **GRAVEL**, TRACE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.	738.4	6 7 8	9 19 20	60	33	SS-3	-	83	7	3	5	2	NP	NP	NP	3	A-1-a (0)	
HARD, GRAY **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP.	735.9	9 10	12 17 13	46	89	SS-4	4.5+	23	13	14	31	19	23	13	10	8	A-4a (3)	
DENSE, GRAY **GRAVEL**, TRACE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.	733.4	11 12 13	19 16 13	44	39	SS-5	-	-	-	-	-	-	-	-	-	3	A-1-a (V)	
HARD, GRAY TO DARK GRAY **SANDY SILT**, LITTLE CLAY, LITTLE FINE GRAVEL, DRY TO DAMP. -SS-6: SULFATE CONCENTRATION = 1,447 PPM		14 15	9 10 13	35	100	SS-6	4.5+	-	-	-	-	-	-	-	-	5	A-4a (V)	
		16 17 18	16 22 18	61	39	SS-7	-	-	-	-	-	-	-	-	-	7	A-4a (V)	
		19 20	6 13 11	37	67	SS-8	4.5+	18	14	17	32	19	22	13	9	9	A-4a (3)	
	723.4	21 22	9 8 10	28	100	SS-9	4.50	-	-	-	-	-	-	-	-	10	A-4a (V)	
VERY DENSE, DARK GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DAMP.	720.9	23 24 25	14 30 19	75	100	SS-10	-	31	28	27	9	5	NP	NP	NP	5	A-1-b (0)	
HARD, GRAY **SILT AND CLAY**, TRACE FINE SAND, MOIST.		26 27 28	7 10 18	43	100	SS-11	4.5+	-	-	-	-	-	-	-	-	18	A-6a (V)	
		29	6 10 15	38	100	SS-12	4.5+	0	0	3	49	48	30	15	15	18	A-6a (10)	

PID: 77372	BR ID: FRA-70-1390	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5087+81.22 / 64.3 RT	START: 2/11/15	END: 2/14/15	PG 2 OF 3	B-024-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 716.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
HARD, GRAY **SILT AND CLAY**, TRACE FINE SAND, MOIST. *(same as above)*	714.4	31																
VERY DENSE, DARK GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		W 32 33 34 35	21 30 24	83	89	SS-13	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
		36 37 38 39 40	4 15 50/4"	-	81	SS-14	-	72	16	5	4	3	17	13	4	8	A-1-a (0)	
		41 42 43 44 45	14 50/3"	-	44	SS-15	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
	694.4	46 47 48 49 50 51 52	50/3"	-	100	SS-16	-	-	-	-	-	-	-	-	-	5	A-1-a (V)	
DENSE, GRAY **COARSE AND FINE SAND**, SOME FINE GRAVEL, TRACE SILT, TRACE CLAY, MOIST. -HEAVING SANDS ENCOUNTERED @ 53.5' -INTRODUCED WATER @ 53.5' -PETROLEUM ODOR PRESENT IN SS-17	689.4	53 54 55 56 57	12 14 15	44	89	SS-17	-	-	-	-	-	-	-	-	-	13	A-3a (V)	
HARD, GRAY **SILT AND CLAY**, SOME FINE GRAVEL, SOME COARSE TO FINE SAND, DAMP.	684.4	58 59 60 61	50/5"	-	80	SS-18	4.5+	34	14	13	25	14	23	13	10	6	A-4a (1)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/28/15 22:00 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1390	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5087+81.22 / 64.3 RT	START: 2/11/15	END: 2/14/15	PG 3 OF 3	B-024-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 684.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST. *(same as above)*		63																
	682.1	EOB 64	47 50/3"	-	100	SS-19	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 34.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 188 LBS CEMENT / 50 LABS BENTONITE POWDER / 40 GAL WATER

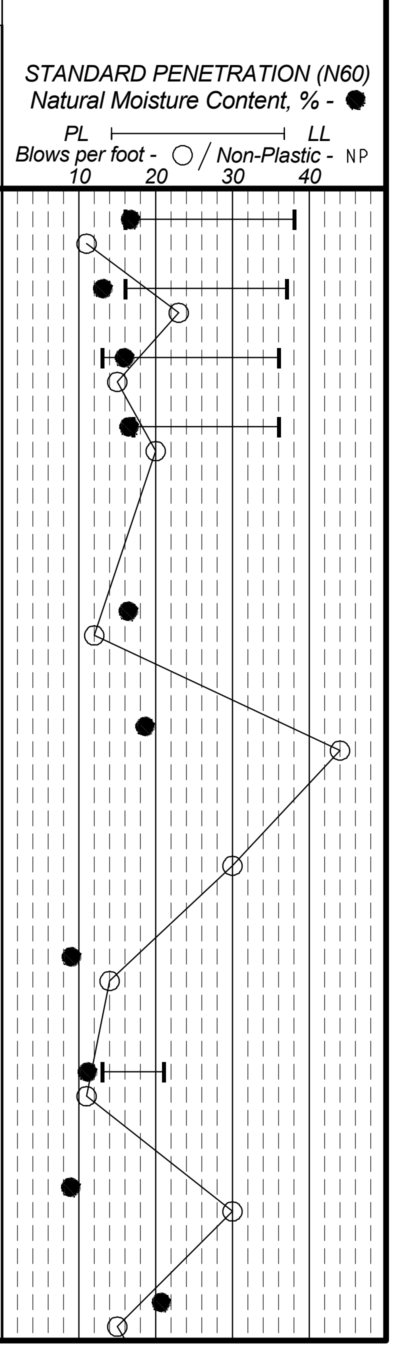
Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-024-0-08 | *Location:* Sta. 5085+90.21, 3.1' LT., BL RAMP C5 | *Date Drilled:* 7/1/2008 to 7/2/2008

WATER OBSERVATIONS:
Water seepage at: *28.5'-80.0'*
Water level at completion: *16.5' (prior to coring)*
10.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 3.25" diameter hollowstem augers.

Depth (ft)	*Elev. (ft)*	*Blows per 6"*	*Recovery*	*Sample No. Drive*	*Sample No. Press / Core*	*Hand Penetrometer (tsf)*	*DESCRIPTION*	*Graphic Log*	*% Aggregate*	*% C. Sand*	*% M. Sand*	*% F. Sand*	*% Silt*	*% Clay*
	743.4													
		3 4 7	11	1		--	Stiff to very stiff brown SILTY CLAY (A-6b), trace to little fine to coarse sand, little gravel; damp to moist. @ 0.0 - 3.0', contains roots.		11	9	---	11	32	37
		7 12 11	12	2		4.5+	@ 1.5', hard.		15	8	---	10	32	35
		5 7 8	16	3		4.0	@ 3.0', very stiff to hard.		11	8	---	12	33	36
5		4 6 14	13	4		3.75			12	10	---	13	31	34
10		4 4 8	15	5		4.5								
		14 21 22	9	6		--	@ 11.0', encountered rock fragments.							
15		17 14 15	1	7		--								
15.5	727.9						Very stiff brownish gray SANDY SILT (A-4a), little to some fine to coarse sand, trace gravel; damp to moist.							
		4 7 7	18	8		3.5								
20		2 4 7	18	9		3.0			9	15	---	19	35	22
		7 13 16	12	10		--	@ 21.5', encountered possible large rock fragments, cobbles.							
25	718.4	3 7 8	18	11		3.25								



Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

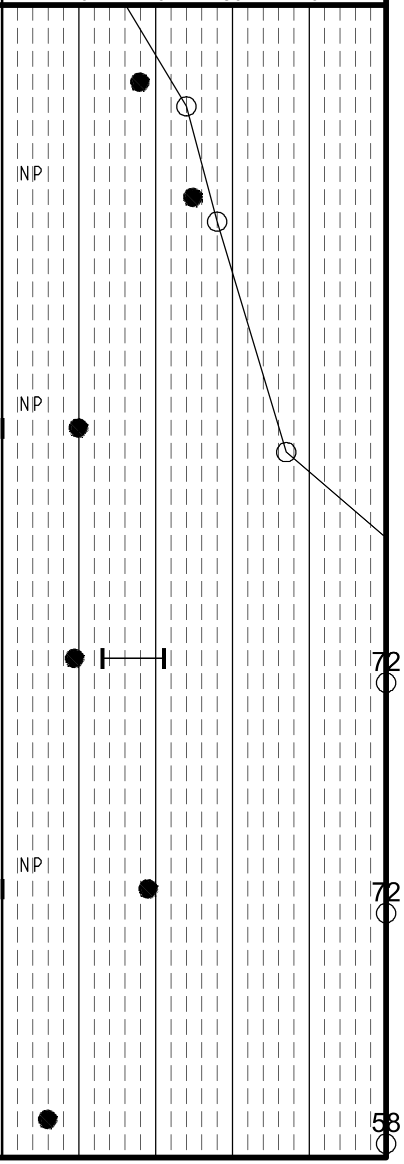
LOG OF: Boring B-024-0-08 | *Location:* Sta. 5085+90.21, 3.1' LT., BL RAMP C5 | *Date Drilled:* 7/1/2008 to 7/2/2008

WATER OBSERVATIONS:
Water seepage at: *28.5'-80.0'*
Water level at completion: *16.5' (prior to coring)*
10.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 3.25" diameter hollowstem augers.

Depth (ft)	Elev. (ft) 718.4	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
28.0	715.4	8 10 14	18	12		--	Very stiff brownish gray SANDY SILT (A-4a), little to some fine to coarse sand, trace gravel; damp to moist.						
30 32.0	711.4	3 12 15	16	13			Medium dense brownish gray SILT (A-4b), little fine sand; wet.	0	0	---	17	--83--	
35 37.0	706.4	7 18 18	11	14			Dense brown GRAVEL (A-1-a), some fine to coarse sand, trace to little silty clay; wet.	60	22	---	8	--10--	
40 42.0	701.4	13 26 45	15	15		--	Hard brownish gray SANDY SILT (A-4a), little gravel, trace clay; damp.	12	14	---	27	33	14
45 47.0	696.4	17 26 45	18	16			Very dense brownish gray COARSE AND FINE SAND (A-3a), little silty clay, little gravel; wet. @ 43.5', 2.0 feet sand heave.	16	25	---	47	--12--	
50	693.4	26 30 27	13	17			Very dense brownish gray SANDY SILT (A-4a), little gravel; wet.						

STANDARD PENETRATION (N60)
Natural Moisture Content, % - ●
PL ⊢—⊣ LL
Blows per foot - ○ / Non-Plastic - NP



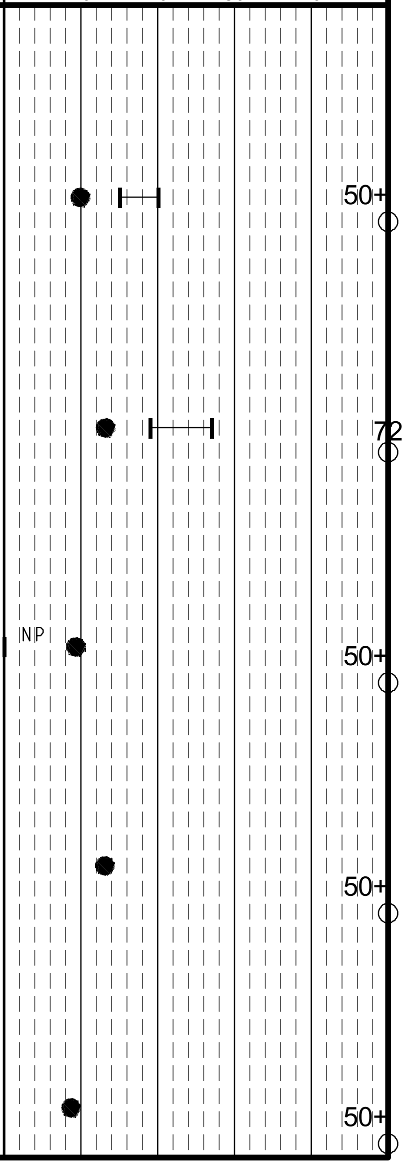
Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-024-0-08 | *Location:* Sta. 5085+90.21, 3.1' LT., BL RAMP C5 | *Date Drilled:* 7/1/2008 to 7/2/2008

WATER OBSERVATIONS:
Water seepage at: 28.5'-80.0'
Water level at completion: 16.5' (prior to coring)
10.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 3.25" diameter hollowstem augers.

Depth (ft)	Elev. (ft) 693.4	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N60)
							Very dense brownish gray GRAVEL WITH SAND (A-1-b), some silty clay; wet.							
55		15 40 50/4	13	18			@ 50.0'-60.0', difficulty advancing boring due to obstruction inside augers blocking rods; possible boulder zone.	30	31	---	16	15	8	50+
57.0	686.4						Very dense brownish gray SANDY SILT (A-4a), some gravel, some fine to coarse sand; damp.							
60		37 21 50	13	19				30	19	---	10	28	13	72
62.0	681.4						Very dense brown and gray GRAVEL (A-1-a), some fine to coarse sand, trace silt; wet.							
65		11 50/4	10	20			@ 63.5', one foot sand heave; encountered black shale fragments.	73	17	---	5	--5--		NP 50+
70		50/3	0	21			@ 68.5', possible cobbles or boulders.							50+
75	668.4	50 50/3	6	22			@ 73.5', 6.0 feet sand heave; washed out with tricone.							50+



Client: ms consultants	*Project:* FRA-70-8.93	*Job No.* 0221-1004.01
LOG OF: Boring B-024-0-08	*Location:* Sta. 5085+90.21, 3.1' LT., BL RAMP C5	*Date Drilled:* 7/1/2008 to 7/2/2008

WATER OBSERVATIONS:
Water seepage at: 28.5'-80.0'
Water level at completion: 16.5' (prior to coring)
10.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 3.25" diameter hollowstem augers.

Depth (ft)	Elev. (ft) 668.4	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N60) / Natural Moisture Content, % - ● / PL ⊢⊣ LL / Blows per foot - ○ / Non-Plastic - NP
							Very dense brown and gray GRAVEL (A-1-a), some fine to coarse sand, trace silt; wet.							
		39 50/3	9	23			@ 78.5', 3.0 feet sand heave.	55	36	---	5	--4--		NP ● 50+
80														
							@ 80.0'-90.0', difficult drilling; possible cobbles.							
		50/0	0	24										50+
85														
		50/0	0	25			@ 88.5', 1.0 foot sand heave. @ 90.0' - 91.5', core loss.							50+
90														
		Core 18"	Rec 0"	RQD 0%	R1		@ 91.5' - 91.8', encountered igneous-plutonic cobble/boulder; likely peridotite or gabbro.							
91.8	651.6						Interbedded Shale (90%) and Limestone (10%) RQD 60%, LOSS 26%; Shale, blue-gray, highly weathered, weak, laminated, slightly calcareous, contains abundant pyritic inclusions, moderately to highly fractured; Limestone, light gray, moderately weathered, moderately strong to strong, fractured.							
95														
		Core 120"	Rec 116"	RQD 81%	R2		@ 97.7' - 98.1', qu = 1650 psi							
100	643.4													

Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-024-0-08 | *Location:* Sta. 5085+90.21, 3.1' LT., BL RAMP C5 | *Date Drilled:* 7/1/2008 to 7/2/2008

WATER OBSERVATIONS:
Water seepage at: 28.5'-80.0'
Water level at completion: 16.5' (prior to coring)
10.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 3.25" diameter hollowstem augers.

Depth (ft)	Elev. (ft) 643.4	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	Graphic Log	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N60) Natural Moisture Content, % - ● PL ⊢—⊣ LL Blows per foot - ○ / Non-Plastic - NP 10 20 30 40
105 110 111.5	631.9	Core 120"	Rec 76"	RQD 48%	R3		Interbedded Shale (90%) and Limestone (10%) RQD 60%, LOSS 26%; Shale, blue-gray, highly weathered, weak, laminated, slightly calcareous, contains abundant pyritic inclusions, moderately to highly fractured; Limestone, light gray, moderately weathered, moderately strong to strong, fractured. @ 101.2', dark gray (shale). @ 107.8' - 111.5', core loss due to pyritic inclusion lodged in core barrel.								
115 120 125							Bottom of Boring - 111.5'								

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 5086+86.08 / 34.9' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / N.A.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C5
PID: 77372 BR ID: FRA-70-1390	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 742.7 (MSL) EOB: 59.2 ft.
START: 2/11/15 END: 2/13/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.953082824, -83.002320685

EXPLORATION ID
B-024-2-14

PAGE
1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 742.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
0.4' - ASPHALT (5.0")	742.3																	
1.1' - CONCRETE (13.0")	741.2																	
VERY STIFF TO HARD, BROWN TO GRAY **SANDY SILT**, SOME CLAY, LITTLE FINE GRAVEL, DAMP.			8 12 13	32	78	SS-1	4.00	-	-	-	-	-	-	-	-	12	A-4a (V)	
			5 6 7	17	100	SS-2	4.5+	-	-	-	-	-	-	-	-	10	A-4a (V)	
			3 7 9	21	100	SS-3	2.75	16	17	17	30	20	22	13	9	11	A-4a (3)	
			3 5 8	17	100	SS-4	4.5+	-	-	-	-	-	-	-	-	10	A-4a (V)	
			5 5 5	13	100	SS-5	4.5+	-	-	-	-	-	-	-	-	10	A-4a (V)	
			5 9 12	27	100	SS-6	4.5+	14	15	18	30	23	21	13	8	9	A-4a (4)	
	724.7		8 12 14	34	100	SS-7	4.5+	-	-	-	-	-	-	-	-	9	A-4a (V)	
MEDIUM DENSE, GRAY **SANDY SILT**, TRACE CLAY, MOIST.	722.2		9 10 10	26	100	SS-8	-	0	0	47	48	5	NP	NP	NP	20	A-4a (4)	
VERY STIFF, DARK GRAY **SANDY SILT**, SOME CLAY, MOIST.			5 10 11	27	100	SS-9	4.00	-	-	-	-	-	-	-	-	17	A-4a (V)	
	717.2		5 9 9	23	100	SS-10	3.00	0	0	18	48	34	22	14	8	19	A-4a (8)	
MEDIUM DENSE, GRAY **SILT**, LITTLE FINE SAND, LITTLE CLAY, TRACE FINE GRAVEL, WET.		W	2 5 6	14	100	SS-11	-	-	-	-	-	-	-	-	-	30	A-4b (V)	
			9 10 11	27	100	SS-12	-	1	0	17	67	15	NP	NP	NP	22	A-4b (8)	

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

PID: 77372 | BR ID: FRA-70-1390 | PROJECT: FRA-70-12.68 - PHASE 4A | STATION / OFFSET: 5086+86.08 / 34.9 LT | START: 2/11/15 | END: 2/13/15 | PG 2 OF 2 | B-024-2-14

MATERIAL DESCRIPTION AND NOTES	ELEV. 712.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)
								GR	CS	FS	SI	CL	LL	PL	PI		
MEDIUM DENSE, GRAY **SILT**, LITTLE FINE SAND, LITTLE CLAY, TRACE FINE GRAVEL, WET. *(same as above)*	710.7	31 32															
MEDIUM DENSE TO VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST TO WET.		33															
		34 35	3 4 9	17	100	SS-13	-	-	-	-	-	-	-	-	-	19	A-1-b (V)
		36 37 38															
		39 40	12 18 21	51	100	SS-14	-	40	23	27	6	4	NP	NP	NP	11	A-1-b (0)
	700.7	41															
HARD, GRAY **SANDY SILT**, TRACE CLAY, TRACE FINE GRAVEL, DAMP.		42 43															
		44 45	15 19 21	52	100	SS-15	4.5+	-	-	-	-	-	-	-	-	11	A-4a (V)
	695.7	46															
VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST.		47 48															
-HEAVING SANDS ENCOUNTERED @ 48.5'		49 50	25 32 41	95	100	SS-16	-	-	-	-	-	-	-	-	-	12	A-1-b (V)
		51 52 53															
		54	50/5"	-	0	SS-17	-	-	-	-	-	-	-	-	-	-	
-NO RECOVERY IN SS-17 AND SS-18. SOIL TYPE DETERMINED BASED ON VISUAL DESCRIPTION OF SOIL CUTTINGS ON FIELD LOG.		55 56 57 58															
	683.5	EOB 59	50 50/2"	-	0	SS-18	-	-	-	-	-	-	-	-	-	-	

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 26.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 188 LBS CEMENT / 50 LBS BENTONITE CHIPS / 40 GAL WATER

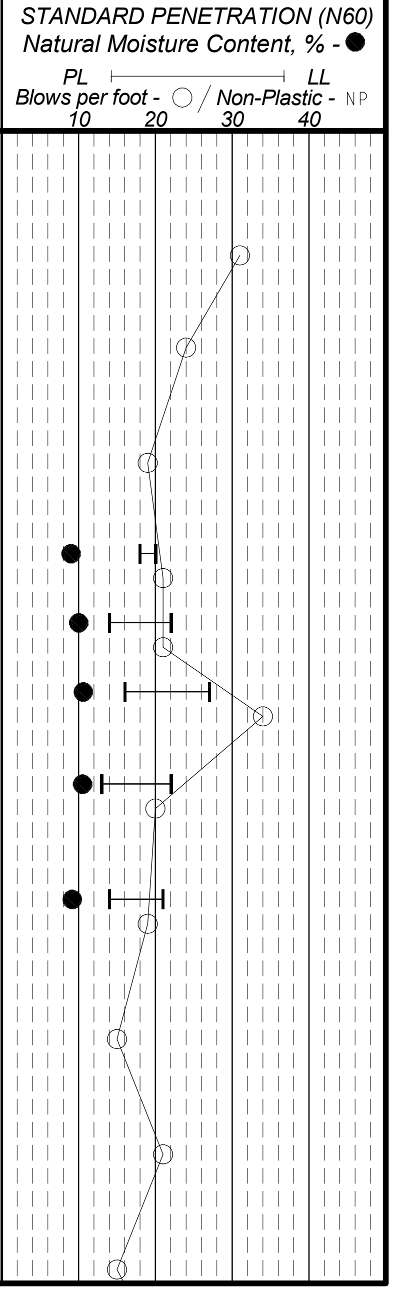
Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-025-0-08 | *Location:* Sta. 5088+53.62, 76.0' LT., BL RAMP C5 | *Date Drilled:* 7/24/2008

WATER OBSERVATIONS:
Water seepage at: 26.0'
Water level at completion: 39.0'

FIELD NOTES:
Advanced boring using 3.25" diameter hollowstem augers.

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
	740.4						Asphalt Concrete - 7" Aggregate Base - 7"						
1.2	739.2												
		14 13 17	15	1		4.5+	FILL: Hard brown SILT AND CLAY (A-6a), some fine to coarse sand, trace gravel; contains few brick fragments; damp.						
3.5	736.9												
5		11 10 14	14	2		4.5+	Hard gray SANDY SILT (A-4a), some to "and" fine to coarse sand, trace to little gravel; damp.						
		6 8 11	14	3		4.5+							
10		7 10 11	18	4		4.5+		18	12	---	16	32	22
		6 10 11	18	5		4.5+		8	15	---	20	36	21
11.5	728.9												
		14 16 17	4	6		4.5+	Hard gray SILT AND CLAY (A-6a), some fine to coarse sand, trace gravel; damp to moist.	12	16	---	18	34	20
13.5	726.9												
15		5 8 12	18	7		4.5+	Very stiff to hard gray SANDY SILT (A-4a), some to "and" fine to coarse sand, trace to little gravel; damp.						
		5 7 12	18	8		4.5+		15	14	---	19	31	21
20		4 6 9	18	9		2.75							
		5 9 12	18	10		4.5							
25	715.4	5 6 9	18	11		2.5							



Client: ms consultants

Project: FRA-70-8.93

Job No. 0221-1004.01

LOG OF: Boring B-025-0-08

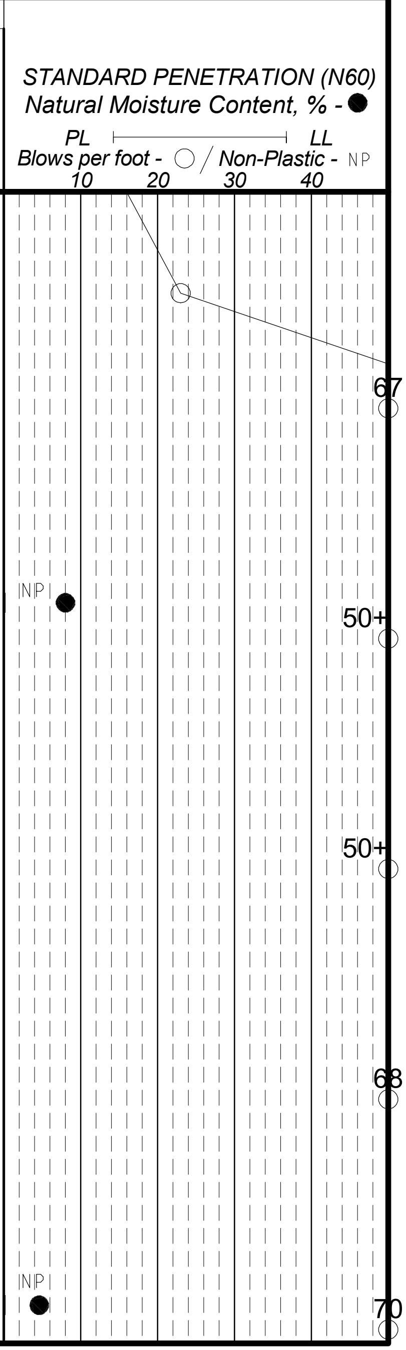
Location: Sta. 5088+53.62, 76.0' LT., BL RAMP C5

Date Drilled: 7/24/2008

WATER OBSERVATIONS:
Water seepage at: 26.0'
Water level at completion: 39.0'

FIELD NOTES:
Advanced boring using 3.25" diameter hollowstem augers.

Depth (ft)	Elev. (ft) 715.4	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
		3 6 17	13	12		3.5	Very stiff gray SILTY CLAY (A-6b), little fine sand; moist.						
28.5	711.9	17 29 37	10	13			Very dense brown GRAVEL WITH SAND (A-1-b), some fine to coarse sand, little silty clay; wet. @ 30.0'-38.5', encountered cobbles while augering.						
30													
		29 50/5	6	14				50	21	---	10	14	5
35													
38.5	701.9	23 50/6	10	15		4.5+	Hard gray SANDY SILT (A-4a), some fine to coarse sand, trace gravel; damp.						
40													
43.5	696.9	9 30 37	12	16			Very dense gray GRAVEL WITH SAND (A-1-b), "and" fine to coarse sand, little silt; wet.						
45													
50	690.4	22 39 30	15	17				39	26	---	22	--13--	



Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-025-0-08 | *Location:* Sta. 5088+53.62, 76.0' LT., BL RAMP C5 | *Date Drilled:* 7/24/2008

WATER OBSERVATIONS:
Water seepage at: 26.0'
Water level at completion: 39.0'

FIELD NOTES:
Advanced boring using 3.25" diameter hollowstem augers.

Depth (ft)	Elev. (ft) 690.4	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	Graphic Log	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N60) Natural Moisture Content, % - ● PL ⊢⊣ LL Blows per foot - ○ / Non-Plastic - NP 10 20 30 40
							Very stiff gray SILT AND CLAY (A-6a), some fine to coarse sand, trace gravel; moist.	▨							
55		22 33 26	13	18		2.5		▨							60 ○
57.0	683.4						Very dense brown COARSE AND FINE SAND (A-3a), some silt, little gravel; wet.	∴							
59.3	681.1	48 50/3	9	19				∴							50+ ○
60							Bottom of Boring - 59.3'								
65															
70															
75															

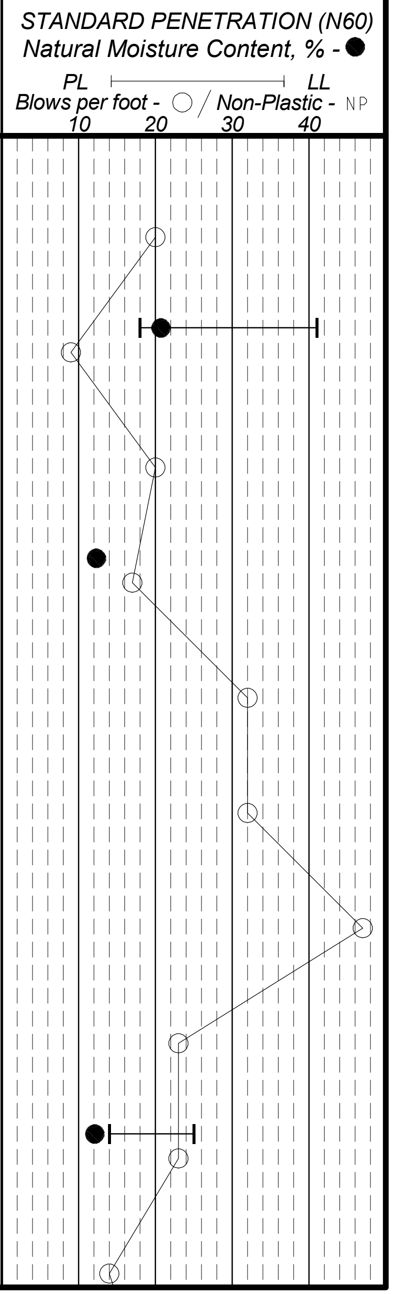
Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-026-0-08 | *Location:* Sta. 5088+59.96, 128.9' LT., BL RAMP C5 | *Date Drilled:* 8/1/2008 to 8/6/2008

WATER OBSERVATIONS:
Water seepage at: 41.0', 58.0', 77.0'
Water level at completion: 29.1' (beginning of shift, 8/5/08)
30.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 4.0" diameter flush joint casing.

Depth (ft)	Elev. (ft) 754.0	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0.3	753.7						Topsoil - 4"						
2.0	752.0	8 11 8	18	1A 1B		1.5 0.5	Stiff brown SILT AND CLAY (A-6a), some fine to coarse sand, trace gravel; moist.						
3.5	750.5						Soft brown SANDY SILT (A-4a), some fine to coarse sand, little gravel; wet.						
5		5 4 5	18	2		2.75	Very stiff to hard brown CLAY (A-7-6), little to some fine to coarse sand, trace to little gravel; moist.	5	6	---	13	37	39
		5 8 11	18	3		4.25							
10		11 8 8	18	4		0.5	@ 8.5'-10.0', soft, wet.						
		8 10 20	4	5		2.5							
15		5 10 20	2	6		1.5	@ 13.5', becomes gray. @ 13.5'-15.0', stiff.						
		19 23 22	0	7		--							
18.5	735.5												
20		11 8 14	18	8		3.0	Very stiff to hard gray SILT AND CLAY (A-6a), some fine to coarse sand, trace gravel; damp to moist.						
		11 12 10	18	9		2.5		9	14	---	16	35	26
25	729.0	7 5 8	18	10		4.5+							



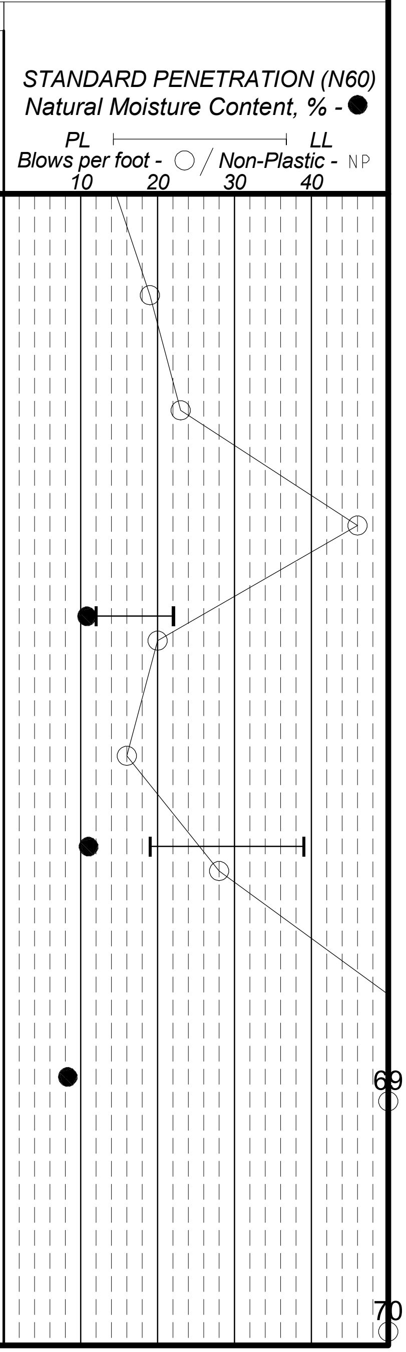
Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-026-0-08 | *Location:* Sta. 5088+59.96, 128.9' LT., BL RAMP C5 | *Date Drilled:* 8/1/2008 to 8/6/2008

WATER OBSERVATIONS:
Water seepage at: *41.0', 58.0', 77.0'*
Water level at completion: *29.1' (beginning of shift, 8/5/08)*
30.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 4.0" diameter flush joint casing.

Depth (ft)	Elev. (ft) 729.0	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
							Very stiff gray SILT AND CLAY (A-6a), little to some fine to coarse sand, trace gravel; moist.						
		9 10 8	18	11		3.5							
30		8 12 10	10	12		2.25							
31.0	723.0												
		21 21 23	18	13		1.5	Stiff to very stiff gray SANDY SILT (A-4a), little to some fine to coarse sand, trace to little gravel; damp to moist.						
35		4 8 11	18	14		3.0		10	13	---	18	36	23
		12 8 7	18	15		3.25							
38.5	715.5												
40		6 9 18	16	16		1.75	Stiff gray SILTY CLAY (A-6b), trace fine sand; damp.	0	0	---	1	39	60
42.0	712.0												
							Very dense gray GRAVEL WITH SAND AND SILT (A-2-4), some fine to coarse sand, some silty clay; wet.						
45		29 34 32	18	17									
50	704.0	19 35 32	18	18									



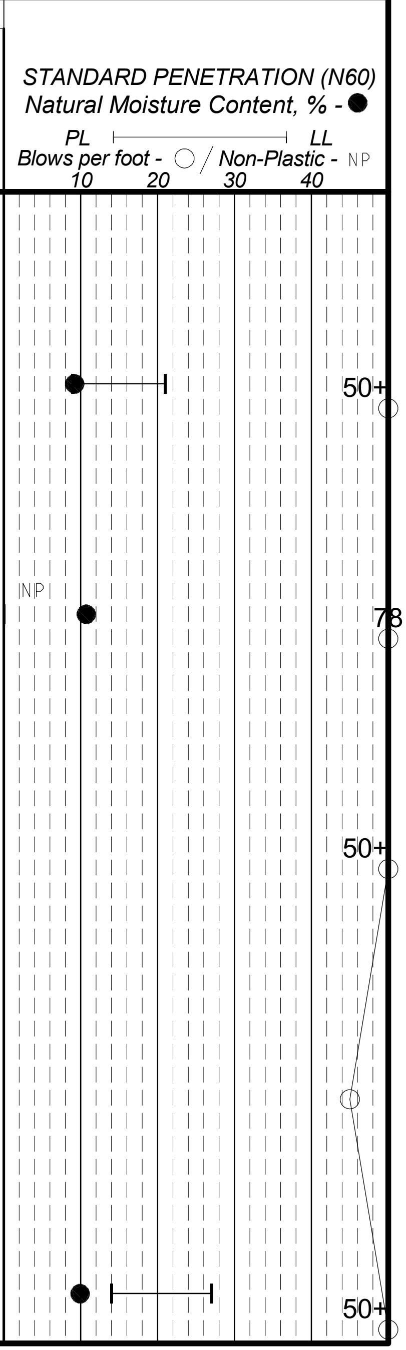
Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-026-0-08 | *Location:* Sta. 5088+59.96, 128.9' LT., BL RAMP C5 | *Date Drilled:* 8/1/2008 to 8/6/2008

WATER OBSERVATIONS:
Water seepage at: 41.0', 58.0', 77.0'
Water level at completion: 29.1' (beginning of shift, 8/5/08)
30.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 4.0" diameter flush joint casing.

Depth (ft)	Elev. (ft) 704.0	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	Graphic Log	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
							Hard gray SILT AND CLAY (A-6a), some fine to coarse sand, trace to little gravel; contains sand seams; damp.							
55		21 23 50/5	17	19		4.5+			10	13	---	22	35	20
57.0	697.0						Very dense gray GRAVEL WITH SAND (A-1-b), trace to little silt; wet.							
60		19 30 44	18	20					30	41	---	21	--8--	
65		29 50/4	2	21										
67.0	687.0						Hard gray SILT AND CLAY (A-6a), some fine to coarse sand, trace to little gravel; damp to moist.							
70		8 20 23	2	22		4.5								
75	679.0	13 50/5	10	23		4.5+			9	10	---	19	40	22



Client: ms consultants

Project: FRA-70-8.93

Job No. 0221-1004.01

LOG OF: Boring B-026-0-08

Location: Sta. 5088+59.96, 128.9' LT., BL RAMP C5

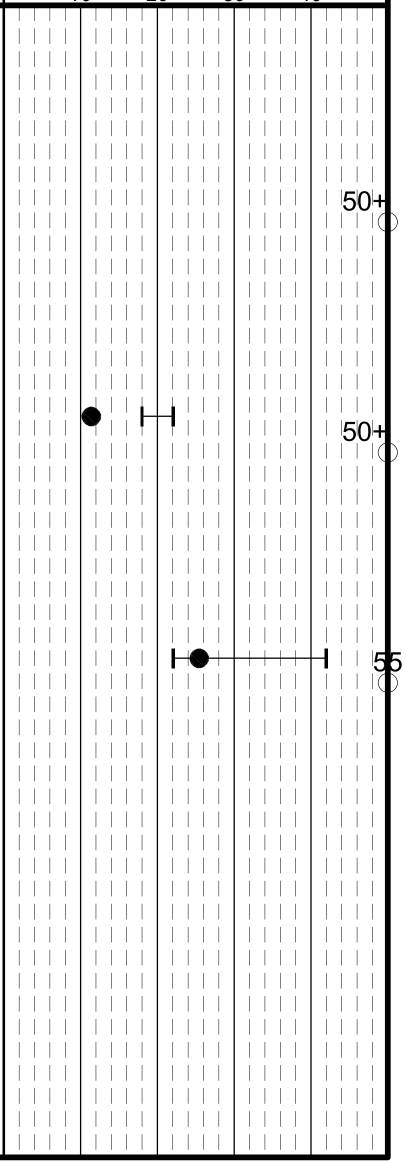
Date Drilled: 8/1/2008 to 8/6/2008

WATER OBSERVATIONS:
Water seepage at: *41.0', 58.0', 77.0'*
Water level at completion: *29.1' (beginning of shift, 8/5/08)*
30.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 4.0" diameter flush joint casing.

Depth (ft)	Elev. (ft) 679.0	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
		50/5	2	24			Very dense gray GRAVEL (A-1-a); possible cobbles and boulders; wet.						
82.0	672.0	35 50/5	7	25		1.75	Stiff gray SANDY SILT (A-4a), "and" fine to coarse sand, trace gravel; damp.	9	13	---	27	33	18
87.0	667.0	13 19 33	7	26		1.5	Stiff gray CLAY (A-7-6), trace fine to coarse sand, trace gravel; moist.	6	3	---	2	30	59
90.0	664.0						Claystone, brown, severely weathered, very weak, fractured, RQD 14%, Loss 67%. @ 90.0'-97.8' lost recovery.						
97.8	656.2						Shale, blue-gray, highly weathered, weak, laminated, friable, fissile, jointed, fractured to moderately fractured, tight, slightly rough, RQD 87%, Loss 0%.						
100	654.0												

STANDARD PENETRATION (N60)
Natural Moisture Content, % - ●
PL ⊢—⊣ LL
Blows per foot - ○ / Non-Plastic - NP



Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-026-0-08 | *Location:* Sta. 5088+59.96, 128.9' LT., BL RAMP C5 | *Date Drilled:* 8/1/2008 to 8/6/2008

WATER OBSERVATIONS:
Water seepage at: 41.0', 58.0', 77.0'
Water level at completion: 29.1' (beginning of shift, 8/5/08)
30.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 4.0" diameter flush joint casing.

Depth (ft)	Elev. (ft) 679.0	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N60)
		50/5	2	24			Very dense gray GRAVEL (A-1-a); possible cobbles and boulders; wet.							50+
82.0	672.0	35 50/5	7	25		1.75	Stiff gray SANDY SILT (A-4a), "and" fine to coarse sand, trace gravel; damp.	9	13	---	27	33	18	50+
87.0	667.0	13 19 33	7	26		1.5	Stiff gray CLAY (A-7-6), trace fine to coarse sand, trace gravel; moist.	6	3	---	2	30	59	55
90.0	664.0	Core 60"	Rec 5"	RQD 0%	R1		Claystone, brown, severely weathered, very weak, fractured, RQD 14%, Loss 67%. @ 90.0'-97.8' lost recovery.							
		Core 60"	Rec 60"	RQD 80%	R2									
97.8	656.2						Shale, blue-gray, highly weathered, weak, laminated, friable, fissile, jointed, fractured to moderately fractured, tight, slightly rough, RQD 87%, Loss 0%.							
100	654.0													

Depth scale: 80, 85, 90, 95, 100

STANDARD PENETRATION (N60)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○ / Non-Plastic - NP
10 20 30 40

Client: ms consultants

Project: FRA-70-8.93

Job No. 0221-1004.01

LOG OF: Boring B-026-0-08

Location: Sta. 5088+59.96, 128.9' LT., BL RAMP C5

Date Drilled: 8/1/2008 to 8/6/2008

WATER OBSERVATIONS:
Water seepage at: *41.0', 58.0', 77.0'*
Water level at completion: *29.1' (beginning of shift, 8/5/08)*
30.7' (includes drilling water)

FIELD NOTES:
Advanced boring using 4.0" diameter flush joint casing.

Depth (ft)	Elev. (ft) 654.0	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetro-meter (tsf)	DESCRIPTION	Graphic Log	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N60) Natural Moisture Content, % - ● PL ⊢⊣ LL Blows per foot - ○ / Non-Plastic - NP 10 20 30 40
105		Core 60"	Rec 60"	RQD 85%	R3		Shale, blue-gray, highly weathered, weak, laminated, friable, fissile, jointed, fractured to moderately fractured, tight, slightly rough, RQD 87%, Loss 0%. Contains dark gray, well cemented shale zones [thin, dark bands]. Dark shale zones are typically 1-2 inches thick, spaced at intervals of 12 to 18 inches. @ 100.5' - 101.0', qu = 2391 psi								
		Core 60"	Rec 60"	RQD 90%	R4										
108.9 110	645.1	Core 60"	Rec 60"	RQD 83%	R5		Interbedded Shale (90%) and Limestone (10%), RQD 88%, Loss 0%; Shale, dark gray, moderately weathered, weak, thinly laminated, calcareous, fissile, pyritic, jointed, moderately fractured, tight, slightly rough; Limestone, light gray, slightly weathered, strong, thinly bedded, pyritic. @ 110.2'-110.5', 113.9'-114.2', high angle fractures.								
115.0 115	639.0						Bottom of Boring - 115.0'								
120															
125															

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 184+88.08 / 111.1' RT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / S.M.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-70 EB
PID: 77372 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 747.0 (MSL) EOB: 50.0 ft.
START: 9/19/13 END: 9/19/13	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.952673289, -83.001473185

EXPLORATION ID
B-026-1-13

PAGE
1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 747.0	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
0.3' - ASPHALT (4.0")	746.7																	
0.7' - AGGREGATE BASE (8.0")	746.0																	
FILL: MEDIUM DENSE TO VERY DENSE, GRAY TO BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP.		1 2 3	23 14 7	27	50	SS-1	-	-	-	-	-	-	-	-	-	9	A-2-4 (V)	
		4 5 6 7 8	4 9 9	23	50	SS-2	-	17	34	14	26	9	27	22	5	10	A-2-4 (0)	
	735.0	9 10 11 12	12 27 27	70	61	SS-3	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
FILL: DENSE, GRAY AND BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.	731.5	13 14 15	12 17 19	47	33	SS-4	-	63	16	6	10	5	22	18	4	4	A-1-a (0)	
MEDIUM DENSE TO DENSE, BROWN TO GRAY **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST.		16 17 18	11 14 20	44	50	SS-5	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
		19 20	9 12 12	31	44	SS-6	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
		21 22 23	7 9 14	30	56	SS-7	-	31	32	14	19	4	21	18	3	7	A-1-b (0)	
		24 25	13 15 17	41	61	SS-8	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
	719.0	26 27	9 16 17	43	50	SS-9	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST.		W 28 29	15 17 25	54	33	SS-10	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	

PID: 77372	BR ID: N/A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 184+88.08 / 111.1 RT	START: 9/19/13	END: 9/19/13	PG 2 OF 2	B-026-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 717.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST. *(same as above)*		31 32	16 16 23	51	33	SS-11	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
		33 34 35	30 32 33	84	39	SS-12	-	70	10	0	18	2	20	16	4	6	A-1-b (0)	
		36 37 38 39 40	27 29 33	80	50	SS-13	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
		41 42 43 44 45	27 25 32	74	67	SS-14	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
	697.0	46 47 48 49 EOB 50	25 26 27	69	72	SS-15	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 28.5'

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

PROJECT: FRA-70-12.68 - PHASE 4A
TYPE: STRUCTURE
PID: 77372 BR ID: FRA-70-1390
START: 8/8/13 END: 8/14/13

DRILLING FIRM / OPERATOR: RII / J.B.
SAMPLING FIRM / LOGGER: RII / S.B.
DRILLING METHOD: 4.25" HSA
SAMPLING METHOD: SPT

DRILL RIG: MOBILE B-53 (SN 624400)
HAMMER: AUTOMATIC
CALIBRATION DATE: 4/26/13
ENERGY RATIO (%): 77.7

STATION / OFFSET: 5089+73.78 / 16.5' RT
ALIGNMENT: BL RAMP C5
ELEVATION: 736.8 (MSL) EOB: 89.5 ft.
LAT / LONG: 39.953112248, -83.001308349

EXPLORATION ID
B-026-2-13

PAGE
1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 736.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
0.8' - ASPHALT (9.0")	736.0																	
0.5' - AGGREGATE BASE (6.0")	735.5	1																
POSSIBLE FILL: MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP. -STONE FRAGMENTS PRESENT IN SS-1		2 3	5 6 8	18	50	SS-1	-	40	28	11	15	6	20	16	4	7	A-1-b (0)	
	731.3	4 5	2 12 14	34	72	SS-2	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP. -COBBLES PRESENT THROUGHOUT		6 7 8	3 4 8	16	67	SS-3	-	40	24	11	18	7	26	17	9	10	A-2-4 (0)	
	726.3	9 10	7 10 23	43	33	SS-4	-	-	-	-	-	-	-	-	-	6	A-2-4 (V)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST.		11 12 13	14 18 7	32	44	SS-5	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
	721.3	14 15 W	6 5 4	12	50	SS-6	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, LITTLE FINE GRAVEL, TRACE SILT, MOIST.	718.8	16 17 18 W	8 6 4	13	33	SS-7	-	-	-	-	-	-	-	-	-	16	A-3a (V)	
MEDIUM DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST. -INTRODUCED MUD @ 20.0'	716.3	19 20	6 8 11	25	83	SS-8	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
DENSE TO VERY DENSE, GRAY **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST TO WET.		21 22 23	20 50 50/5"	-	82	SS-9	-	51	19	12	14	4	18	16	2	8	A-1-b (0)	
		24 25	20 42 50/4"	-	81	SS-10	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
		26 27 28	10 20 33	69	56	SS-11	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
		29	3 13 23	47	56	SS-12	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	

PID: 77372	BR ID: FRA-70-1390	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5089+73.78 / 16.5 RT	START: 8/8/13	END: 8/14/13	PG 2 OF 3	B-026-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 706.8	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
DENSE TO VERY DENSE, GRAY **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST TO WET. *(same as above)*	702.6	31 32 33 34	11 20 50/2"	-	79	SS-13	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
HARD, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DRY.	699.8	35 36 37					4.50	-	-	-	-	-	-	-	-	9	A-6a (V)	
VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, MOIST. -ENCOUNTERED LIMESTONE BOULDER @ 40.0'. SWITCHED TO ROCK CORING TECHNIQUES TO CORE BOULDER		38 39	50/2"	-	100	SS-14	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
	695.3	40 41	0		94	RC-1											CORE	
VERY DENSE, GRAY **FINE SAND**, TRACE FINE GRAVEL, TRACE SILT, TRACE CLAY, DAMP. -HEAVING SAND ENCOUNTERED @ 41.5'	693.8	42 43	24 40 48	114	100	SS-15	-	-	-	-	-	-	-	-	-	10	A-3 (V)	
MEDIUM DENSE, GRAY **COARSE AND FINE SAND**, SOME FINE GRAVEL, LITTLE SILT, TRACE CLAY, MOIST.		44 45	4 3 8	14	50	SS-16	-	24	24	29	17	6	15	11	4	17	A-3a (0)	
	689.8	46																
VERY DENSE, GRAY **COARSE AND FINE SAND**, LITTLE SILT, LITTLE FINE GRAVEL, TRACE CLAY, MOIST.		47 48																
		49 50	5 16 23	51	33	SS-17	-	-	-	-	-	-	-	-	-	18	A-3a (V)	
		51 52 53																
		54 55	9 12 38	65	100	SS-18	-	16	29	33	18	4	15	13	2	11	A-3a (V)	
		56 57 58																
		59 60	17 20 37	74	100	SS-19	-	-	-	-	-	-	-	-	-	13	A-3a (V)	
	674.8	61																

PID: 77372	BR ID: FRA-70-1390	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5089+73.78 / 16.5 RT	START: 8/8/13	END: 8/14/13	PG 3 OF 3	B-026-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 674.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
VERY STIFF, GRAY **SANDY SILT**, LITTLE FINE GRAVEL, TRACE CLAY, MOIST. *(same as above)*		63																
		64	42 42 38	104	89	SS-20	2.00	-	-	-	-	-	-	-	-	14	A-4a (V)	
		65																
		66																
		67																
		68																
		69	12 18 37	71	100	SS-21	3.00	13	23	21	33	10	18	14	4	17	A-4a (2)	
		70																
		71																
	664.8	72																
VERY DENSE, GRAY **COARSE AND FINE SAND**, TRACE SILT, TRACE CLAY, TRACE FINE GRAVEL, MOIST.		73																
		74	15 22 30	67	83	SS-22	-	-	-	-	-	-	-	-	-	13	A-3a (V)	
		75																
		76																
		77																
		78																
		79	15 25 50/5"	-	100	SS-23	-	8	28	50	7	7	NP	NP	NP	17	A-3a (0)	
		80																
		81																
	654.8	82																
HARD, BROWNISH GRAY **SILTY CLAY**, TRACE TO LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.		83																
		84	18 22 40	80	89	SS-24	4.5+	-	-	-	-	-	-	-	-	17	A-6b (V)	
		85																
		86																
		87																
		88																
	647.4	EOB 89	30 50/5"	-	100	SS-25	4.50	7	5	5	42	41	39	20	19	17	A-6b (12)	

NOTES: SEEPAGE ENCOUNTERED @ 61.0'; GROUNDWATER INITIALLY ENCOUNTERED @ 18.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 150 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A
TYPE: STRUCTURE
PID: 77372 BR ID: FRA-70-1390
START: 8/21/13 END: 8/22/13

DRILLING FIRM / OPERATOR: RII / S.M.
SAMPLING FIRM / LOGGER: RII / K.S.
DRILLING METHOD: 3.25" HSA
SAMPLING METHOD: SPT

DRILL RIG: CME-750 (SN 98048)
HAMMER: CME AUTOMATIC
CALIBRATION DATE: 4/26/13
ENERGY RATIO (%): 82.6

STATION / OFFSET: 5091+04.93 / 11.5' LT
ALIGNMENT: BL RAMP C5
ELEVATION: 756.9 (MSL) EOB: 90.0 ft.
LAT / LONG: 39.953296762, -83.000848553

EXPLORATION ID
B-026-3-13

PAGE
1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 756.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
0.5' - CONCRETE (6.0")	756.4																	
0.5' - AGGREGATE BASE (6.0")	755.9																	
LOOSE, GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, DAMP.	753.9	1 2 3	3 2 2	6	33	SS-1	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
STIFF, BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP. -COBBLES PRESENT @ 5.0'	751.4	4 5	4 9 8	23	39	SS-2	1.50	-	-	-	-	-	-	-	-	12	A-6a (V)	
LOOSE, GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, MOIST.	748.9	6 7 8	5 3 3	8	33	SS-3	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
SOFT, BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.	746.4	9 10	WOH 7 7	19	72	SS-4	0.50	8	7	10	46	29	36	19	17	23	A-6b (11)	
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST.		11 12 13	5 7 8	21	67	SS-5	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
		14 15	8 16 15	43	61	SS-6	-	32	39	11	15	3	19	17	2	7	A-1-b (0)	
		16 17 18	8 17 20	51	61	SS-7	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
		19 20	18 16 13	40	72	SS-8	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
		21 22 23	18 12 14	36	83	SS-9	-	42	30	10	13	5	NP	NP	NP	8	A-1-b (0)	
		24 25	6 10 13	32	72	SS-10	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
		26 27 28	5 10 12	30	78	SS-11	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
-STONE FRAGMENTS PRESENT THROUGHOUT		29	8 11 16	37	67	SS-12	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/14/15 17:35 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1390	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5091+04.93 / 11.5 LT	START: 8/21/13	END: 8/22/13	PG 2 OF 3	B-026-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 726.9	DEPTHS		SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
									GR	CS	FS	SI	CL	LL	PL	PI			
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST. *(same as above)*	724.9		31 32																
HARD, GRAY **SANDY SILT**, LITTLE CLAY, LITTLE FINE GRAVEL, DAMP.			33																
			34 35	10 22 24	63	83	SS-13	4.5+	15	11	17	38	19	21	14	7	9	A-4a (4)	
		W	36																
	719.9		37																
VERY DENSE, BROWN TO BROWNISH GRAY **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST.			38																
			39 40	11 26 26	72	83	SS-14	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
			41 42 43																
			44 45	8 29 50	109	83	SS-15	-	52	14	17	14	3	17	14	3	11	A-1-b (0)	
			46 47 48																
			49 50	10 20 28	66	56	SS-16	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
	704.9		51 52																
HARD, GRAY **SANDY SILT**, LITTLE CLAY, LITTLE FINE GRAVEL, DAMP.			53																
			54 55	3 22 28	69	78	SS-17	4.5+	12	11	19	40	18	24	14	10	10	A-4a (5)	
			56 57 58																
			59 60	10 44 50/5"	-	88	SS-18	4.5+	-	-	-	-	-	-	-	-	8	A-4a (V)	
	694.9		61																

PID: 77372	BR ID: FRA-70-1390	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5091+04.93 / 11.5 LT	START: 8/21/13	END: 8/22/13	PG 3 OF 3	B-026-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 694.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
VERY DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, WET. *(same as above)*	689.9	64	WOH 45 50/3"	-	40	SS-19	-	-	-	-	-	-	-	-	-	20	A-2-4 (V)	
VERY DENSE, GRAY TO DARK GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST.		69	8 22 28	69	44	SS-20	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
		74	12 23 28	70	67	SS-21	-	38	28	23	10	1	13	10	3	13	A-1-b (0)	
		79	37 50/3"	-	33	SS-22	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
	669.9	84	10 19 28	65	56	SS-23	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
VERY DENSE, GRAY **COARSE AND FINE SAND**, LITTLE FINE GRAVEL, LITTLE SILT, TRACE CLAY, WET.	666.9	89	12 28 50	107	67	SS-24	-	11	30	39	18	2	NP	NP	NP	10	A-3a (0)	
		EOB 90																

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 36.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 376 LBS PORTLAND CEMENT / 100 LBS BENTONITE POWDER / 100 GAL WATER

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/14/15 17:35 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

APPENDIX IV

HISTORIC BORING LOGS:

B-001-C-59, B-002-F-59, B-003-A-59 and B-005-F-59

B-001-C-59

STATE OF OHIO
DEPARTMENT OF HIGHWAYS
TESTING LABORATORY

LOG OF BORING

CO., RT. NO., SEC. FRA-40-12.82 RETAINING WALL C BRIDGE NO. RETAINING WALL C

LOCATION: T.H. 1B STA. 62+75 OFFSET 102'LT FED. NO.

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
763.0	0			
	2			
	4			
758.0	6	3/4	29107	Brown Sandy Gravelly Clay
	8			
753.0	10	26/32	29108	Brown Silty Sandy Gravel
	12			
	14			
748.0	16	-----		Brown Silty Sandy Gravel
	18			
743.0	20			
	22	96/90	29109	Brown Silty Sandy Gravel
	24			
738.0	26	33/47	29110	Gray Gravel
735.5	28			
		24/16		
733.0	30	37/36	29111	Brown Silty Sandy Gravel
	32			
	34			
728.0	36	27/18	29112	Brown Sandy Gravel

Glacial Boulders (igneous and limestone)

BM
8-24-59

B-001-C-59

LOG OF BORING (CONTINUED)

SHEET 4

BRIDGE NO. RETAINING WALL C T.H. 1B

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
725.5	38	34/34	29113	Brown Sandy Gravel
723.0	40	21/22	29114	Gray Silty Sand
	42			
720.5	44	40/76	29115	Gray Silty Sand
718.0	46	28/42	29116	Gray Silty Gravelly Sand
716.5	48	72/*	29117	Gray Silty Sand
713.0	50	59/36	29118	Gray Silty Sandy Gravel
711.5	52	24/39	29119	Gray Sandy Gravel
	54			
708.0	56	27/29	29120	Gray Sand
706.5	58	100*	29121	Brown Silty Sandy Gravel
703.0	60	43/53	-----	Gray Silty Sandy Gravel
	62			
	64			
698.0	66	33/*	29122	Gray Silty Gravelly Sand
	68			
693.0	70			
692.0		------	29123	Gray Sandy Gravelly Silt
	72			BOTTOM OF BORING
	74			*Refusal
	76			
	78			
	80			
	82			

Glacial Boulders (igneous and limestone)

STATE OF OHIO
DEPARTMENT OF HIGHWAYS
TESTING LABORATORY

LOG OF BORING

CO., RT. NO., SEC. FRA-40-12.82 BRIDGE NO. FRA-40-1300
REAR ABUTMENT SOUTH INNERBELT UNDER FRONT STREET

LOCATION: T.H. 2B STA. 49+33 OFFSET 46'LT FED. NO.

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
754.7	0			
	2			
	4			
749.7	6	3/5	19858	Brown Silty Sandy Gravel
	8			
744.7	10			
	12	15/14	19859	Brown Silty Sandy Gravel
	14			
739.7	16	19/25	19860	Brown Silty Sandy Gravel
	18			
734.7	20			
	22	15/26	19861	Brown Silty Sandy Gravel
732.2	24	100/*	19862	Brown Sandy Gravel
729.7	26	18/21	19863	Brown Silty Sandy Gravel
727.2	28	38/59	19864	Brown Silty Sandy Gravel
724.7	30			
	32	34/31	19865	Brown Silty Sandy Gravel
722.2	34	42/*	19866	Brown Silty Sandy Gravel
719.7	36	21/57	19867	Gray Silty Sandy Gravel

*Refusal

BM
6.26.59

B-002-F-59

LOG OF BORING (CONTINUED)

SHEET 5

BRIDGE NO. FRA-40-1300 T.H. 2 B

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
717.2	38			
		35/62	19868	Gray Sandy Gravel
714.7	40			
		60/128	19869	Gray Silty Sandy Gravel
	42			
712.2				
	44	47/70	19870	Gray Silty Sandy Gravel
709.7				
	46	45/52	19871	Gray Silty Sandy Gravel
	48			
704.7	50			
		75/108	19872	Gray Sandy Gravel
	52			
	54			
699.7	56	77/150	------	Gray Silty Sandy Gravel
	58			
694.7	60			
		138/*	19873	Gray Silty Sandy Gravel
	62			
	64			
689.7	66	62/109	19874	Gray Silty Gravelly Sand
	68			
684.7	70			
		138/*	-----	Gray Silty Gravelly Sand
	72			
682.2 681.7		70/*	19875	Gray Silty Sandy Gravel
	74			BOTTOM OF BORING
	76			
	78			*Refusal
	80			
	82			

B-003-A-59

STATE OF OHIO
DEPARTMENT OF HIGHWAYS
TESTING LABORATORY

SHEET 6

LOG OF BORING

CO., RT. NO., SEC. FRA-40-12.82 BRIDGE NO.
RETAINING WALL-A SOUTH-EAST INNERBELT

LOCATION: T.H. 3-A STA. 54+68 OFFSET 60'RT FED. NO.

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
735.5	0			
	2			
	4			
730.5				
	6	19/14	19701	Gray Silty Sandy Gravel
728.0				
	8	8/9	19702	Gray Sandy Gravelly Silt
725.5	10			
		9/9	19703	Gray Gravelly Sandy Silt
723.0	12			
	14	7/10	19704	Gray Silt and Clay
720.5				
	16	9/10	19705	Gray Silt
718.0	18			
		13/15	19706	Gray Silty Sand
715.5	20			
		16/22	19707	Gray Sandy Silt
713.0	22			
	24	42/36	19708	Gray Silty Sandy Gravel W/Boulders
710.5				
	26	25/25	19709	Gray Gravel W/Boulders
708.0	28			
		20/46	19710	Brown Sandy Gravel W/Boulders
705.5	30			
		40/75	19711	Brown Sandy Gravel W/Boulders
	32			
	34			
700.5				
	36	75/*	19712	Gray Silty Sand W/Boulders

*Refusal

MB
8.26.59

SHEET 7

LOG OF BORING (CONTINUED)

BRIDGE NO. ____________ T.H. 3-A B

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
	38			
695.5	40			
		38/34	19713	Gray Sandy Silt
	42			
	44			
690.5				
	46	27/42	19714	Gray Silty Sandy Gravel
	48			
685.5	50			
		25/37	19715	Gray Silt W/Boulders
	52			
683.0				
	54	75/*	-----	Bouldery Gray Sand
680.5				
	56			BOTTOM OF BORING
	58			
				*Refusal
	60			
	62			
	64			
	66			
	68			
	70			
	72			
	74			
	76			
	78			
	80			
	82			

B-005-F-59

SHEET 6

STATE OF OHIO
DEPARTMENT OF HIGHWAYS
TESTING LABORATORY

LOG OF BORING

CO., RT. NO., SEC. FRA-40-12.82 BRIDGE NO. FRA-40-1300
FORWARD ABUTMENT SOUTH INNERBELT UNDER FRONT STREET

LOCATION: T.H. 5B STA. 50+44 OFFSET 67' RT FED. NO.

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
758.3	0			
	2			
	4			
753.3				
	6	4/6	20608	Brown Sandy Silt
	8			
748.3	10	7/10	20609	Brown Silty Sandy Gravel
	12			
	14			
743.3				
	16	54/83	20610	Brown Sandy Gravel
	18			
738.3	20			
		58/46	20611	Brown Silty Sandy Gravel
	22			
	24			
733.3				
	26	44/58	20612	Brown and Gray Silty Sandy Gravel
	28			
728.3	30			
		48/40	20613	Gray Gravelly Sandy Silt
725.8	32			
	34	21/36	20614	Gray Sandy Silt
723.3				
	36	38/57	20615	Gray Sandy Silt

RM
6-26-59

B-005-F-59

SHEET 7

LOG OF BORING (CONTINUED)

BRIDGE NO. FRA-40-1300 T.H. 5 B

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
720.8	38			
		91/*	20616	Gray Silty Gravelly Sand
718.3	40			
		59/94	20617	Gray Sandy Gravel
715.8	42			
	44	100/*	20618	Gray Sandy Gravel
713.3				
	46	100/*	-----	Bouldery Gray Sandy Gravel
	48			
708.3	50			
		64/142	20619	Brown Silty Sandy Gravel
706.3	52			
		100/138	20620	Brown Silty Sandy Gravel
	54			
703.3				
	56	49/78	20621	Brown Silty Gravelly Sand
	58			
698.3	60			
		52/104	20622	Brownish-Gray Sandy Clay
	62			
	64			
693.3				
692.3	66	100/*	20623	Brown Gravelly Sandy Silt
				BOTTOM OF BORING
	68			
	70			
				*Refusal
	72			
	74			
	76			
	78			
	80			
	82			

APPENDIX V

LABORATORY TEST RESULTS

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

UNCONFINED COMPRESSION

ASTM D -2166

PROJECT FRA-70-12.68
JOB No. W-13-045

BORING B-023-1-13
STATION / OFFSET 5084+74.16 / 15.0' Rt.
SAMPLE No. / DEPTH ST-4 / 8.3 ft
DATE OF TESTING 8/14/2013
TESTED BY JJH

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

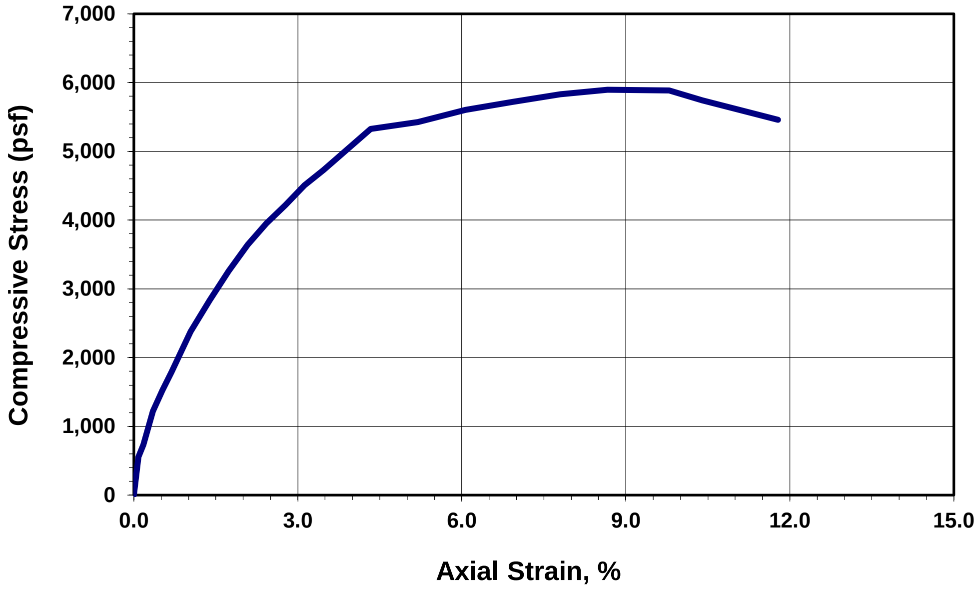
Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	29	18	11	16	11	15	34	24

DIAMETER, D_0	2.87 in	72.898 mm	STRAIN RATE	1.00	%/min
AREA, A_0	6.47 in^2	41.7 cm^2	WET SOIL + PAN MASS	1384.2	g
HEIGHT, L_0	5.77 in	146.58 mm	PAN MASS	90.2	g
VOLUME, V_0	37.33 in^3	611.8 cm^3	DRY SOIL + PAN MASS	1197.9	g
MACH. RATE	0.577	in/min	WET DENSITY	132.04	lb/ft^3
WATER CONT.	16.82	%	DRY DENSITY	113.03	lb/ft^3

UNCONFINED COMPRESSION STRESS, q_u **5,896** **psf** 2.95 tsf
AXIAL STRAIN @ FAILURE 8.66 %
HAND PENETROMETER 4.5+ tsf

Failure Sketch

Unconfined Compression Test



One-Dimensional Consolidation Test Report (ASTM D2435)

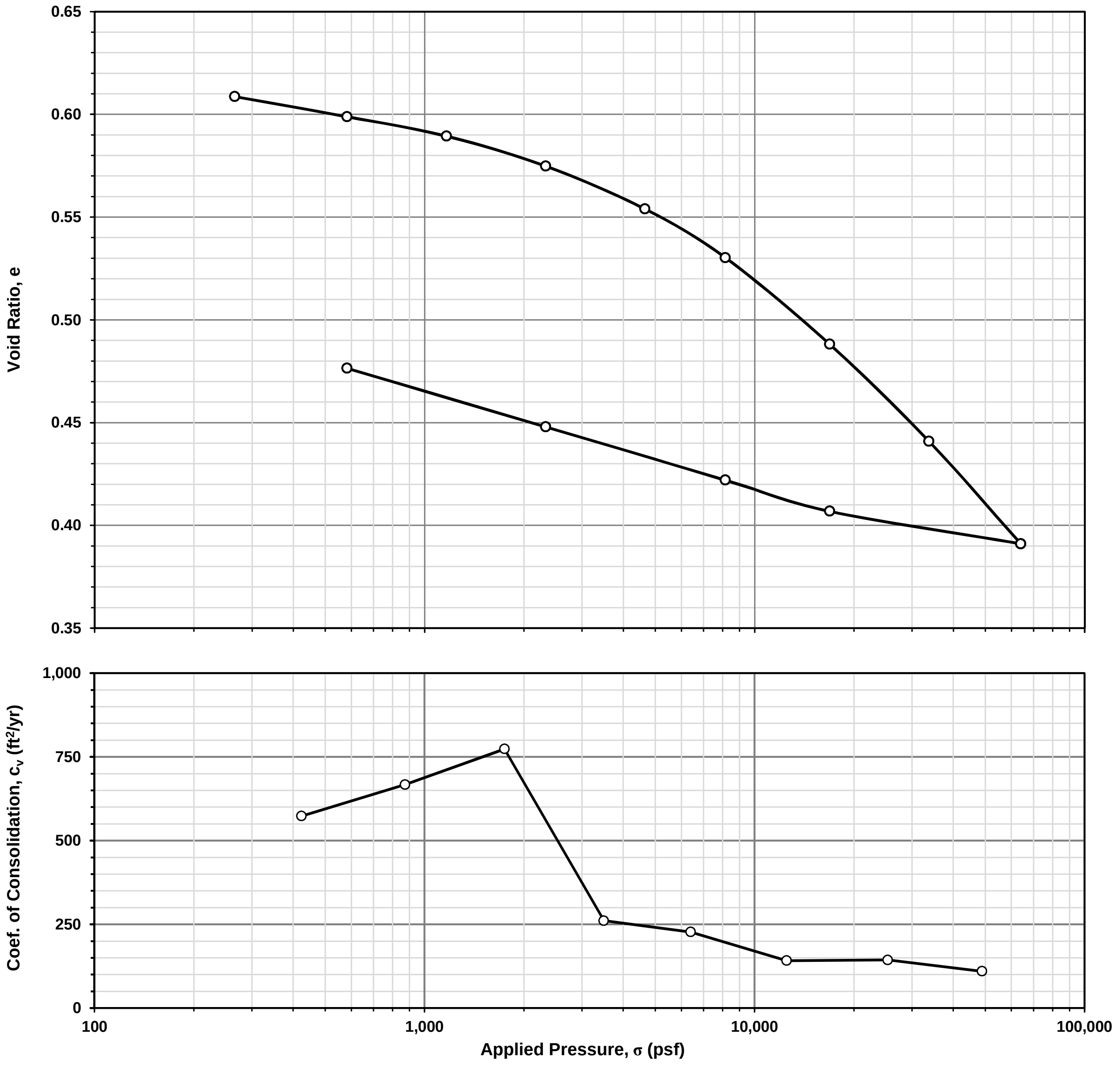
Project Number: W-13-045
Project Name: FRA-70-12.68
Project Location: Columbus, Ohio
Client: GPD GROUP

Boring Number: B-023-1-13
Station / Offset: 5084+74.16, 15.0' Rt.
Sample No. / Depth: ST-4 / 8.9 ft
Date of Testing: 08/21/2013 to 09/11/2013

Soil Description: Reddish brown SILT 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%
	29	18	11	16	11	15	34	24

Natural		γ_d (pcf)	γ_{sat} (pcf)	σ_{vo}' (psf)	S_G	e_o	σ_p' (psf)	c_c	c_r
S_o	w_o								
89.5%	22.1%	102.6	124.1	1,068	2.67	0.624	7,680	0.191	0.043



APPENDIX VI

DRILLED SHAFT CALCULATIONS

Boring	Boring	Proposed Top of Shaft Elevation (ft msl)	D_w (ft)	Shaft Diameter, D (ft)	Soil Class.	Material Type [1]	Stratum Depth, z (ft)	Stratum Thickness (ft)	Bottom Elevation (ft msl)	γ (pcf)	σ_v' (Midpoint) (psf)	σ_v (Bottom) (psf)	S_u [2] (psf)	N_c [3]	α [4]	N_{60} [5]	$(N_1)_{60}$ [6]	φ'_f [7]	σ_p' [8] (psf)	β [9]	Boring	Elevation (ft msl)	Shaft Length (ft)	Nominal Tip Resistance, q_p [10,11] (ksf)	Nominal Side Resistance, q_s [12,13] (ksf)	φ_{qp} [14]	φ_{qs} [15]
Rear Abutment	B-023-1-13	728.6	14.7	5.0	A-7-6	C	4.2	4.2	724.4	120	252	504	2,750	7.0	0.55						B-023-1-13	728.6-724.4	0.0-4.2	19	1.51	0.40	0.45
					A-6a	C	9.2	5.0	719.4	120	804	1,104	1,875	8.2	0.55							724.4-719.4	4.2-9.2	15	1.03	0.40	0.45
					A-7-6	C	14.2	5.0	714.4	120	1,404	1,704	2,125	9.0	0.55							719.4-714.4	9.2-14.2	19	1.16	0.40	0.45
					A-1-b	G	18.2	4.0	710.4	130	1,870	2,224				33	31	41	10,494	0.93		714.4-710.4	14.2-18.2	39	1.73	0.50	0.55
					A-1-b	G	33.2	15.0	695.4	135	2,550	4,249				55	48	43	17,490	1.10		710.4-695.4	18.2-33.2	60	2.81	0.50	0.55
					A-6b	C	38.2	5.0	690.4	130	3,264	4,899	5,000	9.0	0.46							695.4-690.4	33.2-38.2	45	2.32	0.40	0.45
					A-1-a	G	44.2	6.0	684.4	135	3,650	5,709				95	72	45	30,210	1.31		690.4-684.4	38.2-44.2	60	4.76	0.50	0.55
	B-024-0-08	728.6	13.7	5.0	A-4a	C	13.2	13.2	715.4	120	792	1,584	2,375	9.0	0.55						B-024-0-08	728.6-715.4	0.0-13.2	21	1.30	0.40	0.45
					A-4b	G	17.2	4.0	711.4	130	1,750	2,104				28	23	40	14,327	1.16		715.4-711.4	13.2-17.2	33	2.02	0.50	0.55
					A-1-a	G	22.2	5.0	706.4	130	2,055	2,754				37	29	41	11,766	0.94		711.4-706.4	17.2-22.2	44	1.93	0.50	0.55
					A-4a	C	27.2	5.0	701.4	130	2,393	3,404	8,000	9.0	0.45							706.4-701.4	22.2-27.2	72	3.60	0.40	0.45
					A-3a	G	37.2	10.0	691.4	135	2,925	4,754				65	46	43	12,195	0.79		701.4-691.4	27.2-37.2	60	2.29	0.50	0.55
					A-1-b	G	42.2	5.0	686.4	135	3,469	5,429				100	68	44	31,800	1.37		691.4-686.4	37.2-42.2	60	4.76	0.50	0.55
					A-4a	G	47.2	5.0	681.4	135	3,832	6,104				72	47	43	30,500	1.22		686.4-681.4	42.2-47.2	60	4.67	0.50	0.55
					A-1-a	G	77.0	29.8	651.6	135	5,095	10,127				100	59	44	31,800	1.05		681.4-651.6	47.2-77.0	60	5.36	0.50	0.55
	B-024-1-13	728.6	16.2	5.0	A-4a	C	7.7	7.7	720.9	130	501	1,001	5,250	7.8	0.45						B-024-1-13	728.6-720.9	0.0-7.7	41	2.37	0.40	0.45
					A-6a	C	14.2	6.5	714.4	130	1,424	1,846	5,000	9.0	0.46							720.9-714.4	7.7-14.2	45	2.32	0.40	0.45
					A-1-a	G	34.2	20.0	694.4	135	2,697	4,546				100	70	44	31,800	1.64		714.4-694.4	14.2-34.2	60	4.41	0.50	0.55
					A-3a	G	39.2	5.0	689.4	130	3,592	5,196				44	28	41	9,650	0.57		694.4-689.4	34.2-39.2	52	2.05	0.50	0.55
					A-4a	C	44.2	5.0	684.4	130	3,930	5,846	8,000	9.0	0.45							689.4-684.4	39.2-44.2	72	3.60	0.40	0.45
					A-1-b	G	46.2	2.0	682.4	135	4,171	6,116				100	61	44	31,800	1.21		684.4-682.4	44.2-46.2	60	5.04	0.50	0.55
	B-024-2-14	728.6	11.9	5.0	A-4a	C	11.4	11.4	717.2	125	712	1,425	3,375	8.7	0.54						B-024-2-14	728.6-717.2	0.0-11.4	29	1.82	0.40	0.45
					A-4b	G	17.9	6.5	710.7	120	1,643	2,205				21	17	39	11,382	1.01		717.2-710.7	11.4-17.9	25	1.66	0.50	0.55
					A-1-b	G	22.9	5.0	705.7	125	1,987	2,830				17	14	38	5,406	0.56		710.7-705.7	17.9-22.9	20	1.10	0.50	0.55
					A-1-b	G	27.9	5.0	700.7	135	2,325	3,505				51	39	42	16,218	1.09		705.7-700.7	22.9-27.9	60	2.54	0.50	0.55
					A-4a	C	32.9	5.0	695.7	130	2,676	4,155	6,500	9.0	0.45							700.7-695.7	27.9-32.9	58	2.92	0.40	0.45
					A-1-b	G	44.9	12.0	683.7	135	3,280	5,775				100	70	44	31,800	1.43		695.7-683.7	32.9-44.9	60	4.68	0.50	0.55
	B-026-1-13	728.6	10.1	5.0	A-1-b	G	9.6	9.6	719.0	130	624	1,248				39	36	42	12,402	2.20	B-026-1-13	728.6-719.0	0.0-9.6	46	1.37	0.50	0.55
					A-1-b	G	14.6	5.0	714.0	125	1,436	1,873				52	41	42	16,536	1.53		719.0-714.0	9.6-14.6	60	2.19	0.50	0.55
					A-1-b	G	31.6	17.0	697.0	135	2,209	4,168				77	56	44	24,486	1.57		714.0-697.0	14.6-31.6	60	3.46	0.50	0.55

1. C = cohesive soil stratum; G = granular soil stratum
2. S_u = average shear strength over stratum thickness (cohesive soil layers)
3. $N_C = 6[1+0.2(Z/D)] \le 9$; Ref. Section 10.8.3.5.1c, AASHTO LRFD BDS (cohesive soil layers)
4. $\alpha = 0.55$ for $S_u/P_a \le 1.5$; $\alpha = 0.55-0.1(S_u/P_a-1.5)$ for $1.5 \le S_u/P_a \le 2.5$, where P_a = 2.12 ksf = 2,120 psf; Ref. Section 10.8.3.5.1b AASHTO LRFD BDS (cohesive soil layers)
5. N_{60} = average energy corrected N-values over stratum thickness (granular soil layers)
6. $(N_1)_{60} = C_nN_{60}$, where $C_N = [0.77\log(40/\sigma_v')] \le 2.0$ ksf, where σ_v' = vetical effective stress at midpoint of soil layer with respect to the entire soil profile for the respective boring; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS (granular soil layers)
7. $\varphi'_f = 27.5+9.2\log[(N_1)_{60}]$; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
8. $\sigma_p' = n(N_{60})^m(P_{a)}$, where n = 0.15 and m = 1.0 for A-1-a/1-b and A-2-4/2-6, n = 0.47 and m = 0.6 for A-3/3a, n = 0.47 and m = 0.8 for A-4a/4b soils, and P_a = 2.12 ksf = 2,120 psf; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
9. $\beta = \tan\varphi'_f(1-\sin\varphi'_f)(\sigma_p'/\sigma_v')\char`^(\sin\varphi'_f)$, where σ_v' = vetical effective stress at midpoint of soil layer; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
10. $q_p = N_CS_u \le 80.0$ ksf; Ref. Section 10.8.3.5.1c, AASHTO LRFD BDS (cohesive soil layers)
11. $q_p = 1.2N_{60} \le 60$ ksf; Ref. Section 10.8.3.5.2c, AASHTO LRFD BDS (granular soil layers)
12. $q_s = \alpha S_u$; Ref. Section 10.8.3.5.1b, AASHTO LRFD BDS (cohesive soil layers)
13. $q_s = \beta\sigma_v'$, where σ_v' = vetical effective stress at midpoint of soil layer; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
14. φ_{qp} = 0.50 for granular soils layers and 0.40 for cohesive soil layers; Ref. Table 10.5.5.2.4-1, AASHTO LRFD BDS
15. φ_{qs} = 0.55 for granular soils layers and 0.45 for cohesive soil layers; Ref. Table 10.5.5.2.4-1, AASHTO LRFD BDS

Substructure Unit	Boring	Proposed Top of Shaft Elevation (ft msl)	D_w (ft)	Shaft Diameter, D (ft)	Soil Class.	Material Type [1]	Stratum Depth, z (ft)	Stratum Thickness (ft)	Bottom Elevation (ft msl)	γ (pcf)	σ_v' (Midpoint) (psf)	σ_v (Bottom) (psf)	S_u [2] (psf)	N_c [3]	α [4]	N_{60} [5]	$(N_1)_{60}$ [6]	φ'_f [7]	σ_p' [8] (psf)	β [9]	Boring	Elevation (ft msl)	Shaft Length (ft)	Nominal Tip Resistance, q_p [10,11] (ksf)	Nominal Side Resistance, q_s [12,13] (ksf)	φ_{qp} [14]	φ_{qs} [15]
Pier	B-024-1-13	728.5	17.6	4.0	A-4a	C	7.6	7.6	720.9	130	494	988	5,250	8.3	0.45						B-024-1-13	728.5-720.9	0.0-7.6	43	2.37	0.40	0.45
					A-6a	C	14.1	6.5	714.4	130	1,411	1,833	5,000	9.0	0.46							720.9-714.4	7.6-14.1	45	2.32	0.40	0.45
					A-1-a	G	34.1	20.0	694.4	135	2,777	4,533				100	70	44	31,800	1.60		714.4-694.4	14.1-34.1	60	4.45	0.50	0.55
					A-3a	G	39.1	5.0	689.4	130	3,672	5,183				44	28	41	9,650	0.56		694.4-689.4	34.1-39.1	52	2.06	0.50	0.55
					A-4a	C	44.1	5.0	684.4	130	4,010	5,833	8,000	9.0	0.45							689.4-684.4	39.1-44.1	72	3.60	0.40	0.45
					A-1-b	G	46.1	2.0	682.4	135	4,252	6,103				100	61	44	31,800	1.19		684.4-682.4	44.1-46.1	60	5.07	0.50	0.55
	B-024-2-14	729.5	13.2	4.0	A-4a	C	12.3	12.3	717.2	125	769	1,537	3,375	9.0	0.54						B-024-2-14	729.5-717.2	0.0-12.3	30	1.82	0.40	0.45
					A-4b	G	18.8	6.5	710.7	120	1,781	2,317				21	17	39	11,382	0.96		717.2-710.7	12.3-18.8	25	1.71	0.50	0.55
					A-1-b	G	23.8	5.0	705.7	125	2,125	2,942				17	14	38	5,406	0.53		710.7-705.7	18.8-23.8	20	1.13	0.50	0.55
					A-1-b	G	28.8	5.0	700.7	135	2,463	3,617				51	39	42	16,218	1.05		705.7-700.7	23.8-28.8	60	2.58	0.50	0.55
					A-4a	C	33.8	5.0	695.7	130	2,813	4,267	6,500	9.0	0.45							700.7-695.7	28.8-33.8	58	2.92	0.40	0.45
					A-1-b	G	45.8	12.0	683.7	135	3,418	5,887				100	70	44	31,800	1.39		695.7-683.7	33.8-45.8	60	4.74	0.50	0.55
	B-025-0-08	728.5	14.1	4.0	A-4a	C	13.1	13.1	715.4	120	786	1,572	2,750	9.0	0.55						B-025-0-08	728.5-715.4	0.0-13.1	24	1.51	0.40	0.45
					A-6b	C	16.6	3.5	711.9	120	1,735	1,992	2,875	9.0	0.55							715.4-711.9	13.1-16.6	25	1.58	0.40	0.45
					A-1-b	G	26.6	10.0	701.9	135	2,199	3,342				83	67	44	26,394	1.66		711.9-701.9	16.6-26.6	60	3.64	0.50	0.55
					A-4a	C	31.6	5.0	696.9	130	2,731	3,992	8,000	9.0	0.45							701.9-696.9	26.6-31.6	72	3.60	0.40	0.45
					A-1-b	G	38.1	6.5	690.4	135	3,136	4,870				69	50	43	21,942	1.12		696.9-690.4	31.6-38.1	60	3.50	0.50	0.55
					A-6a	C	45.1	7.0	683.4	130	3,609	5,780	7,500	9.0	0.45							690.4-683.4	38.1-45.1	67	3.37	0.40	0.45
					A-3a	G	47.1	2.0	681.4	135	3,918	6,050				100	67	44	15,792	0.78		683.4-681.4	45.1-47.1	60	3.04	0.50	0.55
	B-026-2-13	726.0	7.7	4.0	A-1-b	G	9.7	9.7	716.3	120	582	1,164				20	20	39	6,360	1.35	B-026-2-13	726.0-716.3	0.0-9.7	24	0.78	0.50	0.55
					A-1-b	G	30.7	21.0	695.3	135	1,802	3,999				86	73	45	27,348	2.00		716.3-695.3	9.7-30.7	60	3.61	0.50	0.55
					A-3a	G	36.2	5.5	689.8	125	2,736	4,687				14	11	37	4,854	0.42		695.3-689.8	30.7-36.2	16	1.15	0.50	0.55
					A-3a	G	41.2	5.0	684.8	135	3,090	5,362				51	37	42	10,543	0.68		689.8-684.8	36.2-41.2	60	2.09	0.50	0.55
					A-3a	G	51.2	10.0	674.8	135	3,634	6,712				69	48	43	12,640	0.69		684.8-674.8	41.2-51.2	60	2.52	0.50	0.55
					A-4a	C	61.2	10.0	664.8	130	4,335	8,012	8,000	9.0	0.45							674.8-664.8	51.2-61.2	72	3.60	0.40	0.45
					A-3a	G	71.2	10.0	654.8	135	5,036	9,362				83	51	43	14,121	0.60		664.8-654.8	61.2-71.2	60	3.01	0.50	0.55
					A-6b	C	78.7	7.5	647.3	130	5,653	10,337	8,000	9.0	0.45							654.8-647.3	71.2-78.7	72	3.60	0.40	0.45
	B-002-F-59	724.5	6.0	4.0	A-1-b	G	12.4	12.4	712.1	135	825	1,674				88	63	44	27,984	3.41	B-002-F-59	724.5-712.1	0.0-12.4	60	2.81	0.50	0.55
					A-1-a	G	33.4	21.0	691.1	135	2,037	4,509				100	64	44	31,800	1.99		712.1-691.1	12.4-33.4	60	4.05	0.50	0.55
					A-3a	G	43.4	10.0	681.1	135	3,162	5,859				100	58	44	15,792	0.90		691.1-681.1	33.4-43.4	60	2.84	0.50	0.55
	B-003-A-59	729.5	8.5	4.0	A-4a	C	11.6	11.6	717.9	120	696	1,392	2,250	9.0	0.55						B-003-A-59	729.5-717.9	0.0-11.6	20	1.23	0.40	0.45
					A-4b	G	16.6	5.0	712.9	130	1,368	2,042				33	33	41	16,340	1.52		717.9-712.9	11.6-16.6	39	2.08	0.50	0.55
					A-1-a	G	27.6	11.0	701.9	135	1,936	3,527				65	59	44	20,670	1.53		712.9-701.9	16.6-27.6	60	2.95	0.50	0.55
					A-3a	G	32.6	5.0	696.9	135	2,517	4,202				100	84	45	15,792	1.07		701.9-696.9	27.6-32.6	60	2.70	0.50	0.55
					A-4a	C	37.6	5.0	691.9	130	2,867	4,852	8,000	9.0	0.45							696.9-691.9	32.6-37.6	72	3.60	0.40	0.45
					A-2-4	G	42.6	5.0	686.9	135	3,218	5,527				69	54	43	21,942	1.10		691.9-686.9	37.6-42.6	60	3.53	0.50	0.55
					A-4b	C	47.1	4.5	682.4	130	3,551	6,112	7,750	9.0	0.45							686.9-682.4	42.6-47.1	69	3.48	0.40	0.45
					A-3a	G	49.6	2.5	679.9	135	3,794	6,450				100	73	45	15,792	0.80		682.4-679.9	47.1-49.6	60	3.04	0.50	0.55

1. C = cohesive soil stratum; G = granular soil stratum
2. S_u = average shear strength over stratum thickness (cohesive soil layers)
3. $N_C = 6[1+0.2(Z/D)] \leq 9$; Ref. Section 10.8.3.5.1c, AASHTO LRFD BDS (cohesive soil layers)
4. $\alpha = 0.55$ for $S_u/P_a \leq 1.5$; $\alpha = 0.55-0.1(S_u/P_a-1.5)$ for $1.5 \leq S_u/P_a \leq 2.5$, where P_a = 2.12 ksf = 2,120 psf; Ref. Section 10.8.3.5.1b AASHTO LRFD BDS (cohesive soil layers)
5. N_{60} = average energy corrected N-values over stratum thickness (granular soil layers)
6. $(N_1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_v')] \leq 2.0$ ksf, where σ_v' = vetical effective stress at midpoint of soil layer with respect to the entire soil profile for the respective boring; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS (granular soil layers)
7. $\varphi'_f = 27.5+9.2\log[(N_1)_{60}]$; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
8. $\sigma_p' = n(N_{60})^m(P_{a)}$, where n = 0.15 and m = 1.0 for A-1-a/1-b and A-2-4/2-6, n = 0.47 and m = 0.6 for A-3/3a, n = 0.47 and m = 0.8 for A-4a/4b soils, and P_a = 2.12 ksf = 2,120 psf; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
9. $\beta = \tan\varphi'_f(1-\sin\varphi'_f)(\sigma_p'/\sigma_v')$^$(\sin\varphi'_f)$, where σ_v' = vetical effective stress at midpoint of soil layer; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
10. $q_p = N_C S_u \leq 80.0$ ksf; Ref. Section 10.8.3.5.1c, AASHTO LRFD BDS (cohesive soil layers)
11. $q_p = 1.2N_{60} \leq 60$ ksf; Ref. Section 10.8.3.5.2c, AASHTO LRFD BDS (granular soil layers)
12. $q_s = \alpha S_u$; Ref. Section 10.8.3.5.1b, AASHTO LRFD BDS (cohesive soil layers)
13. $q_s = \beta\sigma_v'$, where σ_v' = vetical effective stress at midpoint of soil layer; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
14. φ_{qp} = 0.50 for granular soils layers and 0.40 for cohesive soil layers; Ref. Table 10.5.5.2.4-1, AASHTO LRFD BDS
15. φ_{qs} = 0.55 for granular soils layers and 0.45 for cohesive soil layers; Ref. Table 10.5.5.2.4-1, AASHTO LRFD BDS

Substructure Unit	Boring	Proposed Top of Shaft Elevation (ft msl)	D_w (ft)	Shaft Diameter, D (ft)	Soil Class.	Material Type[1]	Stratum Depth, z (ft)	Stratum Thickness (ft)	Bottom Elevation (ft msl)	γ (pcf)	σ_v' (Midpoint) (psf)	σ_v (Bottom) (psf)	S_u[2] (psf)	N_c[3]	α[4]	N_{60}[5]	$(N_1)_{60}$[6]	φ'_f[7]	σ_p'[8] (psf)	β[9]	Boring	Elevation (ft msl)	Shaft Length (ft)	Nominal Tip Resistance, q_p[10,11] (ksf)	Nominal Side Resistance, q_s[12,13] (ksf)	φ_{qp}[14]	φ_{qs}[15]
Forward Abutment	B-025-0-08	732.0	17.6	5.0	A-4a	C	16.6	16.6	715.4	120	996	1,992	2,750	9.0	0.55						B-025-0-08	732.0-715.4	0.0-16.6	24	1.51	0.40	0.45
					A-6b	C	20.1	3.5	711.9	120	2,155	2,412	2,875	9.0	0.55							715.4-711.9	16.6-20.1	25	1.58	0.40	0.45
					A-1-b	G	30.1	10.0	701.9	135	2,619	3,762				83	67	44	26,394	1.47		711.9-701.9	20.1-30.1	60	3.84	0.50	0.55
					A-4a	C	35.1	5.0	696.9	130	3,151	4,412	8,000	9.0	0.45							701.9-696.9	30.1-35.1	72	3.60	0.40	0.45
					A-1-b	G	41.6	6.5	690.4	135	3,556	5,290				69	50	43	21,942	1.03		696.9-690.4	35.1-41.6	60	3.64	0.50	0.55
					A-6a	C	48.6	7.0	683.4	130	4,029	6,200	7,500	9.0	0.45							690.4-683.4	41.6-48.6	67	3.37	0.40	0.45
					A-3a	G	50.6	2.0	681.4	135	4,338	6,470				100	67	44	15,792	0.72		683.4-681.4	48.6-50.6	60	3.13	0.50	0.55
	B-026-0-08	732.0	19.0	5.0	A-6a	C	9.0	9.0	723.0	120	540	1,080	2,500	8.2	0.55						B-026-0-08	732.0-723.0	0.0-9.0	20	1.37	0.40	0.45
					A-4a	C	20.0	11.0	712.0	120	1,740	2,400	2,625	9.0	0.55							723.0-712.0	9.0-20.0	23	1.44	0.40	0.45
					A-2-4	G	28.0	8.0	704.0	135	2,628	3,480				69	47	43	21,942	1.26		712.0-704.0	20.0-28.0	60	3.31	0.50	0.55
					A-6a	C	35.0	7.0	697.0	130	3,155	4,390	8,000	9.0	0.45							704.0-697.0	28.0-35.0	72	3.60	0.40	0.45
					A-1-b	G	45.0	10.0	687.0	135	3,755	5,740				89	54	43	28,302	1.18		697.0-687.0	35.0-45.0	60	4.41	0.50	0.55
					A-6a	C	53.0	8.0	679.0	130	4,388	6,780	5,625	9.0	0.45							687.0-679.0	45.0-53.0	50	2.53	0.40	0.45
					A-1-a	G	60.0	7.0	672.0	135	4,913	7,725				100	56	44	31,800	1.08		679.0-672.0	53.0-60.0	60	5.30	0.50	0.55
					A-4a	C	68.0	8.0	664.0	130	5,437	8,765	8,000	9.0	0.45							672.0-664.0	60.0-68.0	72	3.60	0.40	0.45
	B-026-2-13	728.4	10.1	3.5	A-2-4	G	2.1	2.1	726.3	125	131	263				29	36	42	9,222	5.13	B-026-2-13	728.4-726.3	0.0-2.1	34	0.67	0.50	0.55
					A-1-b	G	12.1	10.0	716.3	120	863	1,463				20	20	39	6,360	1.06		726.3-716.3	2.1-12.1	24	0.91	0.50	0.55
					A-1-b	G	33.1	21.0	695.3	135	2,100	4,298				86	73	45	27,348	1.80		716.3-695.3	12.1-33.1	60	3.77	0.50	0.55
					A-3a	G	38.6	5.5	689.8	125	3,034	4,985				14	11	37	4,854	0.40		695.3-689.8	33.1-38.6	16	1.20	0.50	0.55
					A-3a	G	43.6	5.0	684.8	135	3,388	5,660				51	37	42	10,543	0.64		689.8-684.8	38.6-43.6	60	2.15	0.50	0.55
					A-3a	G	53.6	10.0	674.8	135	3,933	7,010				69	48	43	12,640	0.66		684.8-674.8	43.6-53.6	60	2.58	0.50	0.55
					A-4a	C	63.6	10.0	664.8	130	4,634	8,310	8,000	9.0	0.45							674.8-664.8	53.6-63.6	72	3.60	0.40	0.45
					A-3a	G	73.6	10.0	654.8	135	5,335	9,660				83	51	43	14,121	0.58		664.8-654.8	63.6-73.6	60	3.07	0.50	0.55
					A-6b	C	81.1	7.5	647.3	130	5,951	10,635	8,000	9.0	0.45							654.8-647.3	73.6-81.1	72	3.60	0.40	0.45
	B-026-3-13	730.0	9.1	5.0	A-1-b	G	5.1	5.1	724.9	130	332	663				34	28	41	10,812	2.94	B-026-3-13	730.0-724.9	0.0-5.1	40	0.97	0.50	0.55
					A-4a	C	10.1	5.0	719.9	130	988	1,313	7,875	8.4	0.45							724.9-719.9	5.1-10.1	66	3.54	0.40	0.45
					A-1-b	G	25.1	15.0	704.9	135	1,795	3,338				79	54	43	25,122	1.79		719.9-704.9	10.1-25.1	60	3.21	0.50	0.55
					A-4a	C	35.1	10.0	694.9	130	2,678	4,638	8,000	9.0	0.45							704.9-694.9	25.1-35.1	72	3.60	0.40	0.45
					A-2-4	G	40.1	5.0	689.9	135	3,197	5,313				100	60	44	31,800	1.45		694.9-689.9	35.1-40.1	60	4.64	0.50	0.55
					A-1-b	G	60.1	20.0	669.9	135	4,105	8,013				76	43	43	24,168	0.99		689.9-669.9	40.1-60.1	60	4.07	0.50	0.55
					A-3a	G	63.1	3.0	666.9	135	4,940	8,418				100	52	43	15,792	0.66		669.9-666.9	60.1-63.1	60	3.23	0.50	0.55
	B-001-C-59	730.0	9.0	5.0	A-2-4	G	6.6	6.6	723.4	135	446	891				57	43	43	18,126	3.71	B-001-C-59	730.0-723.4	0.0-6.6	60	1.65	0.50	0.55
					A-3a	G	16.6	10.0	713.4	135	1,404	2,241				78	51	43	13,605	1.40		723.4-713.4	6.6-16.6	60	1.95	0.50	0.55
					A-1-a	G	24.6	8.0	705.4	135	2,057	3,321				71	44	43	22,578	1.52		713.4-705.4	16.6-24.6	60	3.12	0.50	0.55
					A-1-b	G	35.6	11.0	694.4	135	2,747	4,806				100	59	44	31,800	1.62		705.4-694.4	24.6-35.6	60	4.43	0.50	0.55
					A-4a	G	38.6	3.0	691.4	135	3,255	5,211				100	56	44	39,667	1.67		694.4-691.4	35.6-38.6	60	5.45	0.50	0.55
	B-005-F-59	730.0	11.5	5.0	A-4a	C	9.3	9.3	720.7	135	628	1,255	8,000	8.2	0.45						B-005-F-59	730.0-720.7	0.0-9.3	65	3.60	0.40	0.45
					A-1-a	G	20.3	11.0	709.7	135	1,792	2,740				100	67	44	31,800	2.17		720.7-709.7	9.3-20.3	60	3.89	0.50	0.55
					A-1-b	G	30.3	10.0	699.7	135	2,554	4,090				100	63	44	31,800	1.70		709.7-699.7	20.3-30.3	60	4.34	0.50	0.55
					A-6a	C	38.3	8.0	691.7	130	3,188	5,130	8,000	9.0	0.45							699.7-691.7	30.3-38.3	72	3.60	0.40	0.45

1. C = cohesive soil stratum; G = granular soil stratum
2. S_u = average shear strength over stratum thickness (cohesive soil layers)
3. $N_C = 6[1+0.2(Z/D)] \leq 9$; Ref. Section 10.8.3.5.1c, AASHTO LRFD BDS (cohesive soil layers)
4. $\alpha = 0.55$ for $S_u/P_a \leq 1.5$; $\alpha = 0.55-0.1(S_u/P_a-1.5)$ for $1.5 \leq S_u/P_a \leq 2.5$, where P_a = 2.12 ksf = 2,120 psf; Ref. Section 10.8.3.5.1b AASHTO LRFD BDS (cohesive soil layers)
5. N_{60} = average energy corrected N-values over stratum thickness (granular soil layers)
6. $(N_1)_{60} = C_nN_{60}$, where $C_N = [0.77\log(40/\sigma_v')] \leq 2.0$ ksf, where σ_v' = vetical effective stress at midpoint of soil layer with respect to the entire soil profile for the respective boring; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS (granular soil layers)
7. $\varphi'_f = 27.5+9.2\log[(N_1)_{60}]$; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
8. $\sigma_p' = n(N_{60})^m(P_{a)}$, where n = 0.15 and m = 1.0 for A-1-a/1-b and A-2-4/2-6, n = 0.47 and m = 0.6 for A-3/3a, n = 0.47 and m = 0.8 for A-4a/4b soils, and P_a = 2.12 ksf = 2,120 psf; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
9. $\beta = \tan\varphi'_f(1-\sin\varphi'_f)(\sigma_p'/\sigma_v')$^$(\sin\varphi'_f)$, where σ_v' = vetical effective stress at midpoint of soil layer; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
10. $q_p = N_CS_u \leq 80.0$ ksf; Ref. Section 10.8.3.5.1c, AASHTO LRFD BDS (cohesive soil layers)
11. $q_p = 1.2N_{60} \leq 60$ ksf; Ref. Section 10.8.3.5.2c, AASHTO LRFD BDS (granular soil layers)
12. $q_s = \alpha S_u$; Ref. Section 10.8.3.5.1b, AASHTO LRFD BDS (cohesive soil layers)
13. $q_s = \beta\sigma_v'$, where σ_v' = vetical effective stress at midpoint of soil layer; Ref. Section 10.8.3.5.2b, AASHTO LRFD BDS (granular soil layers)
14. φ_{qp} = 0.50 for granular soils layers and 0.40 for cohesive soil layers; Ref. Table 10.5.5.2.4-1, AASHTO LRFD BDS
15. φ_{qs} = 0.55 for granular soils layers and 0.45 for cohesive soil layers; Ref. Table 10.5.5.2.4-1, AASHTO LRFD BDS

APPENDIX VII

LATERAL DESIGN PARAMETERS

Boring No.	Elevation (feet msl)	Soil Class.	Soil Type	Strata	N_{60}	$N1_{60}$	γ (pcf)	γ' (pcf)	Strength Parameter	k (soil) k_{rm} (rock)	ε_{50} (soil) E_r (rock)	RQD (rock)
B-023-1-13	732.4 to 724.4	A-7-6	C	3	22	22	120 psf	120 psf	Su = 2,750 psf	915 pci	0.0053	-
	724.4 to 719.4	A-6a	C	3	15	15	120 psf	120 psf	Su = 1,875 psf	625 pci	0.0065	-
	719.4 to 714.4	A-7-6	C	3	17	17	120 psf	120 psf	Su = 2,125 psf	710 pci	0.0062	-
	714.4 to 710.4	A-1-b	G	4	33	31	130 psf	67.6 psf	φ = 39°	140 pci	-	-
	710.4 to 695.4	A-1-b	G	4	55	48	135 psf	72.6 psf	φ = 41°	175 pci	-	-
	695.4 to 690.4	A-6b	C	2	40	40	130 psf	67.6 psf	Su = 5,000 psf	1,665 pci	0.0043	-
	690.4 to 684.4	A-1-a	G	4	95	72	135 psf	72.6 psf	φ = 43°	215 pci	-	-
B-024-0-08	743.4 to 732.9	A-6b	C	3	16	16	120 psf	120 psf	Su = 2,000 psf	665 pci	0.0063	-
	732.9 to 727.9	A-6b	C	3	37	37	125 psf	125 psf	Su = 4,625 psf	1,540 pci	0.0045	-
	727.9 to 715.4	A-4a	C	3	19	19	120 psf	120 psf	Su = 2,375 psf	790 pci	0.0058	-
	715.4 to 711.4	A-4b	G	4	28	23	130 psf	67.6 psf	φ = 34°	70 pci	-	-
	711.4 to 706.4	A-1-a	G	4	37	29	130 psf	67.6 psf	φ = 40°	155 pci	-	-
	706.4 to 701.4	A-4a	C	2	72	72	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	701.4 to 691.4	A-3a	G	4	65	46	135 psf	72.6 psf	φ = 39°	140 pci	-	-
	691.4 to 686.4	A-1-b	G	4	100	68	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	686.4 to 681.4	A-4a	G	4	72	47	135 psf	72.6 psf	φ = 37°	110 pci	-	-
	681.4 to 651.6	A-1-a	G	4	100	59	135 psf	72.6 psf	φ = 43°	215 pci	-	-
	651.6 to 631.9	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 1,650 psi	0.0001	100,000 psi	60
B-024-1-13	746.4 to 738.4	A-6a	C	3	18	18	120 psf	120 psf	Su = 2,250 psf	750 pci	0.0060	-
	738.4 to 720.9	A-4a	C	3	42	42	130 psf	130 psf	Su = 5,250 psf	1,750 pci	0.0043	-
	720.9 to 714.4	A-6a	C	3	40	40	130 psf	130 psf	Su = 5,000 psf	1,665 pci	0.0043	-
	714.4 to 694.4	A-1-a	G	4	100	70	135 psf	72.6 psf	φ = 43°	215 pci	-	-
	694.4 to 689.4	A-3a	G	4	44	28	130 psf	67.6 psf	φ = 37°	110 pci	-	-
	689.4 to 684.4	A-4a	C	2	100	100	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	684.4 to 682.4	A-1-b	G	4	100	61	135 psf	72.6 psf	φ = 42°	195 pci	-	-
B-024-2-14	742.7 to 729.7	A-4a	C	3	17	17	120 psf	120 psf	Su = 2,125 psf	710 pci	0.0062	-
	729.7 to 717.2	A-4a	C	3	27	27	125 psf	125 psf	Su = 3,375 psf	1,125 pci	0.0049	-
	717.2 to 710.7	A-4b	G	4	21	17	120 psf	57.6 psf	φ = 33°	60 pci	-	-
	710.7 to 705.7	A-1-b	G	4	17	14	125 psf	62.6 psf	φ = 36°	95 pci	-	-
	705.7 to 700.7	A-1-b	G	4	51	39	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	700.7 to 695.7	A-4a	C	2	52	52	130 psf	67.6 psf	Su = 6,500 psf	2,165 pci	0.0038	-
	695.7 to 683.7	A-1-b	G	4	100	70	135 psf	72.6 psf	φ = 42°	195 pci	-	-
B-025-0-08	740.4 to 715.4	A-4a	C	3	22	22	120 psf	120 psf	Su = 2,750 psf	915 pci	0.0053	-
	715.4 to 711.9	A-6b	C	2	23	23	120 psf	57.6 psf	Su = 2,875 psf	960 pci	0.0052	-
	711.9 to 701.9	A-1-b	G	4	83	67	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	701.9 to 696.9	A-4a	C	2	100	100	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	696.9 to 690.4	A-1-b	G	4	69	50	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	690.4 to 683.4	A-6a	C	2	60	60	130 psf	67.6 psf	Su = 7,500 psf	2,500 pci	0.0035	-
	683.4 to 681.4	A-3a	G	4	100	67	135 psf	72.6 psf	φ = 40°	155 pci	-	-
B-026-0-08	754.0 to 743.5	A-7-6	C	3	16	16	120 psf	120 psf	Su = 2,000 psf	665 pci	0.0063	-
	743.5 to 735.5	A-7-6	C	3	36	36	125 psf	125 psf	Su = 4,500 psf	1,500 pci	0.0045	-
	735.5 to 723.0	A-6a	C	3	20	20	120 psf	120 psf	Su = 2,500 psf	835 pci	0.0057	-
	723.0 to 712.0	A-4a	C	3	21	21	120 psf	120 psf	Su = 2,625 psf	875 pci	0.0055	-
	712.0 to 704.0	A-2-4	G	4	69	47	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	704.0 to 697.0	A-6a	C	2	100	100	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	697.0 to 687.0	A-1-b	G	4	89	54	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	687.0 to 679.0	A-6a	C	2	45	45	130 psf	67.6 psf	Su = 5,625 psf	1,875 pci	0.0041	-
	679.0 to 672.0	A-1-a	G	4	100	56	135 psf	72.6 psf	φ = 43°	215 pci	-	-
	672.0 to 664.0	A-4a	C	2	100	100	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	664.0 to 656.2	Claystone	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	14
	656.2 to 639.0	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 2,391 psi	0.0001	100,000 psi	87
B-026-1-13	747.0 to 740.0	A-2-4	G	4	25	38	125 psf	125 psf	φ = 39°	250 pci	-	-
	740.0 to 735.0	A-2-4	G	4	70	82	135 psf	135 psf	φ = 41°	315 pci	-	-
	735.0 to 719.0	A-1-b	G	4	39	36	130 psf	130 psf	φ = 40°	280 pci	-	-
	719.0 to 714.0	A-1-b	G	4	52	41	125 psf	62.6 psf	φ = 41°	175 pci	-	-
	714.0 to 697.0	A-1-b	G	4	77	56	135 psf	72.6 psf	φ = 42°	195 pci	-	-
B-026-2-13	736.8 to 731.3	A-1-b	G	4	26	41	125 psf	125 psf	φ = 41°	315 pci	-	-
	731.3 to 726.3	A-2-4	G	4	29	36	125 psf	125 psf	φ = 39°	250 pci	-	-
	726.3 to 716.3	A-1-b	G	4	20	20	120 psf	120 psf	φ = 37°	190 pci	-	-
	716.3 to 695.3	A-1-b	G	4	86	73	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	695.3 to 689.8	A-3a	G	4	14	11	125 psf	62.6 psf	φ = 33°	60 pci	-	-
	689.8 to 684.8	A-3a	G	4	51	37	135 psf	72.6 psf	φ = 38°	125 pci	-	-
	684.8 to 674.8	A-3a	G	4	69	48	135 psf	72.6 psf	φ = 39°	140 pci	-	-
	674.8 to 664.8	A-4a	C	2	85	85	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	664.8 to 654.8	A-3a	G	4	83	51	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	654.8 to 647.3	A-6b	C	2	80	80	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
B-026-3-13	756.9 to 746.4	A-6a	C	3	14	14	120 psf	120 psf	Su = 1,750 psf	585 pci	0.0067	-
	746.4 to 736.4	A-1-b	G	4	39	40	130 psf	130 psf	φ = 40°	280 pci	-	-
	736.4 to 724.9	A-1-b	G	4	34	28	130 psf	130 psf	φ = 39°	250 pci	-	-
	724.9 to 719.9	A-4a	C	3	63	63	130 psf	130 psf	Su = 7,875 psf	2,625 pci	0.0034	-
	719.9 to 704.9	A-1-b	G	4	79	54	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	704.9 to 694.9	A-4a	C	2	84	84	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	694.9 to 689.9	A-2-4	G	4	100	60	135 psf	72.6 psf	φ = 41°	175 pci	-	-
	689.9 to 669.9	A-1-b	G	4	76	43	135 psf	72.6 psf	φ = 41°	175 pci	-	-
	669.9 to 666.9	A-3a	G	4	100	52	135 psf	72.6 psf	φ = 40°	155 pci	-	-
B-001-C-59	762.4 to 752.4	A-6a	C	1	7	7	115 psf	115 psf	Su = 875 psf	165 pci	0.0095	-
	752.4 to 749.4	A-1-a	G	4	58	66	135 psf	135 psf	φ = 43°	395 pci	-	-
	749.4 to 735.4	A-1-a	G	4	93	86	135 psf	135 psf	φ = 43°	395 pci	-	-
	735.4 to 723.4	A-2-4	G	4	57	43	135 psf	135 psf	φ = 40°	280 pci	-	-
	723.4 to 713.4	A-3a	G	4	78	51	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	713.4 to 705.4	A-1-a	G	4	71	44	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	705.4 to 694.4	A-1-b	G	4	100	59	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	694.4 to 691.4	A-4a	G	4	100	56	135 psf	72.6 psf	φ = 38°	125 pci	-	-