Technical Design Memo

Client:	Ohio Department of Transportation, District 10		
Project:	**ATH-144-12.08 (Task Order 10-Y)** **PID 116165**		
HDR Project No:	10361033	Rev:	0
Calculation No:	1	Page:	1 of 114
Title:	Landslide Remediation Analyses and Design		
Purpose:	Prepare slope stability analyses and wall calculations for the design of a landslide repair along the northbound travel lane of State Route 144 (SR 144) in Athens County, Ohio.		
Originator:	AKB	Date:	2/20/2023
Checked by:	DCM	Date:	2/21/2023
QC Review by:	DMV	Date:	2/24/2023

Summary

1. A landslide has occurred on the slope below SR 144 near mile marker 12.08 in Athens County, Ohio, with the slide propagating upslope of the roadway. The project location is shown on the attached Site Vicinity and Topographic Map, near the base of the valley wall above the floodplain of the Hocking River. Based on observations gathered during the site reconnaissance and geotechnical explorations performed from January 16 to 19, and February 6, 2023, a soldier pile and lagging retaining wall is recommended to stabilize the landslide and repair SR 144. Presented herein are the discussion and evaluation of a soldier pile and lagging wall for landslide mitigation. This design assumes that the topography and slope geometry as presented in the surveyed cross sections are representative of the current field conditions.

2. The geotechnical exploration program consisted of a series of 3 test borings (designated as Borings B-001-0-23, B-002-0-23, and B-003-0-23), and 2 dynamic cone penetrometer (DCP) soundings (designated as D-001-1-23 and D-002-1-23) to characterize the subsurface profile in the vicinity of the existing landslide and develop a repair. The 3 test borings were drilled within the northbound lane of SR 144 and the 2 DCPs were performed on a mid-slope bench below the roadway at the locations shown on the attached Boring Location Plan. Typed boring logs and the

DCP test logs are also included. The soil profile, as encountered in the borings, generally consisted of an upper layer of medium stiff to stiff colluvium, transitioning to stiff to very stiff colluvium, underlain by hard residuum. The overburden soils were underlain by predominantly shale bedrock containing occasional layers of claystone and limestone. Free water was encountered in Borings B-001-0-23 and B-003-0-23 at depths of 19.0 feet (El. 590.3) and 22.5 feet (El. 589.3), respectively, during drilling. As the borings were backfilled upon completion given their locations within the roadway, delayed water level readings were not obtained.

The generalized soil profile developed for the design section is primarily based on the findings from Boring B-002-0-23 and DCP D-002-1-23, located near the design section at Sta. 639+50. The soil profile is assumed to be depicted as shown graphically on the attached Slope/W output plots based on the generalized soil conditions as encountered in the explorations, bedrock topographic mapping, as well as field observations gathered during our site reconnaissance.

3. Eastern Athens County is located within the Marietta Plateau region of the Allegheny (Kanawha) Plateaus section of the unglaciated and dissected Appalachian Plateaus province, described as dissected, high-relief terrain prone to landslide activity and mainly composed of fine-grained rocks, red shales, and red residual soils. Soils in the Marietta Plateau region are identified as Pleistocene (Teays)-age Minford clays and/or red and brown colluvial silty-clay loam landslide deposits. The southeastern portion of Athens County is drained by tributaries of the Hocking River, which in turn flows into the Ohio River at the southeastern corner of the county. The project site is drained directly by the Hocking River, located adjacent to the toe of the slope. Soils in the area are comprised primarily of residuum and colluvium derived from the underlying sedimentary bedrock. The bedrock at the project site is mapped within the Pennsylvanian-age Monongahela Group, with the overlying Permian-Pennsylvanian-age Dunkard Group on the hillsides above the project site, near El. 760. The Monongahela Group consists of shale, siltstone, and mudstone, with minor amounts of limestone and coal. The Dunkard Group consists of mudstone, shale, and siltstone, with minor amounts of sandstone, limestone, and coal.

4. The main coal seams of note within the Monongahela Group include the Pittsburgh No. 8, Pomeroy (Redstone) No. 8a, Meigs Creek (Sewickley) No. 9, Uniontown No. 10, and Waynesburg No. 11 coals, and the notable seam within the Dunkard Group is the Washington No. 12 coal. Most of the mining in Athens County occurred in the northwestern portion of the county. One abandoned mine point with unknown extents is mapped 1 mile northeast of the project site according to information from the Ohio Department of Natural Resources. Available information indicates the “Federal Creek Coal” as the mined commodity, with a thickness of about 8 feet. No associated coal elevation is provided. Two sand and gravel mines are mapped approximately 0.4 mile southeast and 1.8 miles west of the project site, which indicate mining of sand and gravel. All other mining is mapped further than 2 miles from the project site.

5. No base flood elevation has been established based on review of FEMA flood maps for the area in order to determine the high water elevation along the slope located below the roadway. The project site is mapped in an area designated without a base flood elevation (Zone A). The mapped extents generally range to the south side of the roadway, about El. 610.

6. HDR is unaware of any prior geotechnical explorations at the ATH-144-1.99 project site. A search of the available records on ODOT's Transportation Information Mapping System (TIMS) reveals only the geographical locations of known landslide activity in the project area. The nearest borings from prior studies were performed approximately 0.3 mile east and of the project site. An existing pile wall with guardrail lagging was noted along the slope below the roadway between the project site limits and Jewell Hollow Road (TR 189). Such structures are typical of initial landslide mitigation responses in the area. The beginning of the observed wall began at a point approximately 250 feet east of Boring B-001-0-23 and continued for a length of 150 feet. The wall was located approximately 8 feet behind the guardrail and constructed with piles spaced at approximately 5-foot center-to-center, an exposed cantilever height of 7 feet, and a waler located approximately 4 feet above the ground surface at the base of the wall.

7. In accordance with ODOT Geotechnical Design Manual (GDM) recommendations, an initial set of soil strength parameters were selected based on the boring logs, laboratory tests, and published correlations of soil strength with SPT N_{60} values. A statistical basis for selecting the initial soil parameters was performed and is in the attached printed spreadsheets entitled "Soil Strength Parameter Determination". Following development of the soil strength parameters, cross-sections perpendicular to the roadway centerline were reviewed, and the section at Station 639+50 was selected for design.

The developed soil parameters and subsurface profile were then entered into the Slope/W slope stability modeling software to re-create the landslide observed in the field by simulating a series of trial searches to determine the critical mode of failure based on a Morgenstern-Price stability model. In addition, the Slope/W optimization feature was utilized, which generates a hybrid circular and translational failure shape. Recognizing that a landslide had already occurred, strength parameters within the existing soil layers were adjusted in order to generate a reasonable slip surface (FS < 1.0) that is consistent with the field observations and engineering judgment.

Limited groundwater information was available from the borings and published sources. Groundwater levels in the borings were near or within the hard cohesive layer. However, elevated moisture contents were noted approximately 5 feet below existing grade, which may be a result of run-off infiltration and/or perched water conditions. Based on the available information and on-site observations, groundwater was modeled from the existing drainage ditch to the left of the existing roadway to the level of elevated moistures and extending to the approximate level of the Hocking River near El. 586.

Bedrock depths along the slope above and below SR 144 were estimated based on the slope of the existing terrain, limited data available on published bedrock topography maps, overburden soil thicknesses encountered in the soil borings, and refusal depths of the DCP tests. Once the soil parameters and failure surface were established, they were entered into the UA Slope Version 2.3 software program and a model was developed based on the current slope configuration (See attached UA Slope screen shot).

8. After the soil profile and parameters between Slope/W and UA Slope were confirmed and finalized, a preliminary wall location was plotted with the centerline of the proposed drilled shafts a distance of 21 feet from the centerline of the roadway. This offset allows for, at a minimum, a 10-foot travel lane, 2-foot shoulder, 1.5-foot guardrail and posts, and approximate 5-foot clearance between the back of the required guardrail to be installed and the back of the proposed 4-foot diameter drilled shaft. This recommended offset also allows for continuity with the existing features (roadway section, shoulder width, etc.) located to the east and west of the project site. A 4-foot bench was included in front of the wall, and the existing grade elevation was used as the proposed bench elevation. Downslope stability was analyzed in Slope/W based on the geometry at the section (see attached).

Once the wall location was established, the "Manually Determined Load Transfer Factor" was selected in the UA Slope program and the load transfer factor (η) was set to zero in order to determine the horizontal forces acting on the wall. The computed unfactored force per shaft is **Ps = 156,173** pounds based on 48-inch diameter drilled shafts spaced at approximate 6-foot centers. (See attached UA Slope computer screen shots of the post-construction condition of these calculations.) The numbering of soil layers for the UA Slope profile is listed as follows:

a. Layer 1 = Surcharge Load
b. Layer 2 = Item 203 Embankment Fill
c. Layer 3 = Medium Stiff to Stiff Cohesive 1
d. Layer 4 = Stiff to Very Stiff Cohesive
e. Layer 5 = Medium Stiff to Stiff Cohesive 2
f. Layer 6 = Hard Cohesive
g. Layer 7 = Bedrock

9. In accordance with ODOT design requirements, LPILE software was used to determine the pile response to the applied lateral loading from the failure wedge determined by the Slope/W and UA Slope analyses performed at the design section. At Sta. 639+50 for a 6.5-foot exposed wall height, the following were considered relative to LPILE analyses:

(a) <u>Factored Distributed Load (per GDM Section 903.1, pgs. 9-12 and 9-13)</u>

- Convert concentrated load from <u>UA Slope</u> to distributed load
  - $½(D_L)(H_T)$ = 156,173 lbs.
    D_L = distributed load
    H_T = 19.8 feet (top/wall to slip surface, see attached)
  - D_L = [(156,173 lbs)(2)]/[(19.8')(12"/ft)] = Resolution of Triangular Area
    D_L = **<u>1315 lbs/in</u>** (Service Load)
  - (1315 lbs/in)(γ_{EH}) = (1315 lbs/in)(1.5) = **<u>1972 lbs/in</u>** (Strength Load for Moment/Shear Analysis).

Loading due to conventional earth pressures were performed for comparison purposes.

- Calculate conventional earth pressure wall loading.
  - Equivalent Fluid Weight (G_H) = (γ_m) * (K) = **43 pcf**
    Ym = soil moist unit weight (see attached calculations)
    Ka = active earth pressure (see attached calculations)
  - Lateral Thrust (P) = 1/2 * G_H * H^2 = P = **1435 lbs/ft**
    H = Wall Height
  - Horizontal Force Per Shaft (P_{SH}) = P*(S_{cc}) = **8613 lbs/shaft**
    S_{cc} = Center-to-Center Shaft Spacing = 6 ft
  - Resolve Horizontal Earth Pressure to Distributed Triangular Load
    (2* P_{SH}/H) / (12 in/ft)
    = **175 lbs/in per shaft (Service Load)**
    (175 lbs/in) (γ_{EH}) = (175 lbs/in) (1.5)
    = **263 lbs/in per shaft (Strength Load)**

Based on a comparison of the two loading methods, landslide loading from UA Slope was applied to the proposed wall.

(b) Traffic Surcharge (per GDM Section 903.7, pg. 9-16)

As loading traffic may be present up to the front edge of the guardrail, traffic surcharge loading was included in the distributed load acting on the shaft (see attached calculations).

(c) Modification of p-y curves

Since the center-to-center spacing is < 3.5 shaft diameters, a reduction in soil resistance (p) should be applied from the ground surface to the bottom of shaft or bedrock (whichever is shallower).

- $\beta_a = 0.64(S/D)^{0.34} = \beta_a = 0.64(6/4)^{0.34}$
- $\beta_a =$ **0.73**

The downslope stability exhibited a Factor of Safety less than 1.3. (See the Slope/W output plot included in the attached calculations.) As such, the GDM recommendation of artificially lowering the ground surface in the LPILE analysis was included.

- Top of Wall El. 607.2 ft
  - Assumes approximately 4.3 feet of fill placement to re-establish grade.
- Maintenance Bench GS El. = 600.7 ft
- Wall Height = 607.2 ft – 600.7 ft = 6.5 ft.
- Artificially lowered surface = 1.7 feet (See attached)
- GS for LPILE analysis = 600.7 ft – 1.7 ft = 599 ft
  - Wall Height for LPILE Analysis = 6.5 ft + 1.7 ft = **8.2 ft**

(d) Pile Head Deflection

As noted in the ODOT GDM (Section 903.8, pgs. 9-16 and 9-17), for the unfactored Service Limit State analysis, pile head deflection shall be limited 1% or less of the drilled shaft length above bedrock (or the total shaft length when bedrock is not encountered). If the drilled shafts are within 10 feet of the edge of pavement, the deflection must be limited to 2 inches. The centerline of the drilled shafts is anticipated to be located less than 10 feet from the edge of pavement. As such, a limited pile head deflection of 2 inches or less was adopted.

Computed Pile Head Deflection (W 36 x 150) = **2.02 inches** ≤ 2.00 inches OK
(See attached calculations. 2.02 inches approximately equal to 2.00 inches.)

(e) Pile Length (per GDM Section 903.4, pg. 9-14)

*Minimum 10 feet below slip plane
*Slip Plane = 19.8 ft below top of wall
+10.0 ft
29.8 ft minimum pile length

- **Bottom of Drilled Shaft = 35.0 ft ≥ 29.8 ft** **OK**

The ODOT GDM requires embedding a drilled shaft a minimum of 10 feet below the failure surface and into a solid stratum such that the calculated deflection at the top of the wall is constrained to the appropriate serviceability limits. (See Section 9(d) above.) The "Top Deflection Versus Length" plot produced by the LPILE software was reviewed to determine the recommended rock socket length. Based on the encountered shale bedrock and our experience with such local bedrock types, **a minimum rock socket length of 10 feet** is recommended.

(f) Steel Reinforcement and Pile Cross Section Character

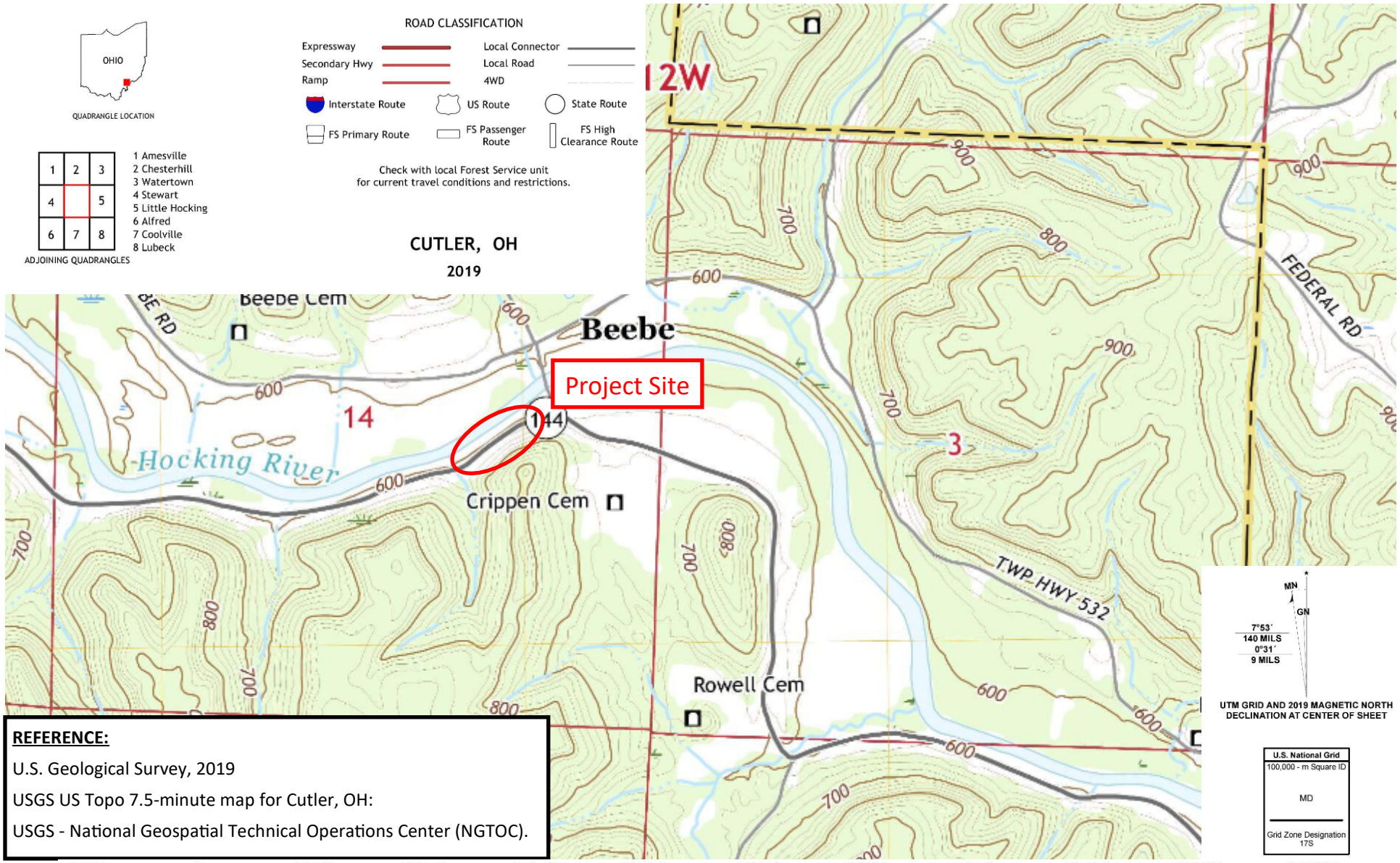
Use W 36 x 150 shaft reinforcement

A_s = Area of Steel = 44.2 in^2
I_x = Moment of Inertia around strong axis = 9040 in^4
T_w = web thickness = 0.625 in
E = Modulus of Elasticity of Steel = 29,000,000 psi
F_y = yield strength of steel = 50,000 psi
B_f = Flange Width = 12.0 in

8. It is recommended that plug piles be utilized to prevent loss of material and undermining of the concrete lagging. Please refer to the attached "Soldier Pile and Lagging Wall Details" sheet for details on the plug piles as well as further details on the wall itself.

Site Vicinity and Topographic Map

Site Vicinity and Topographic Map



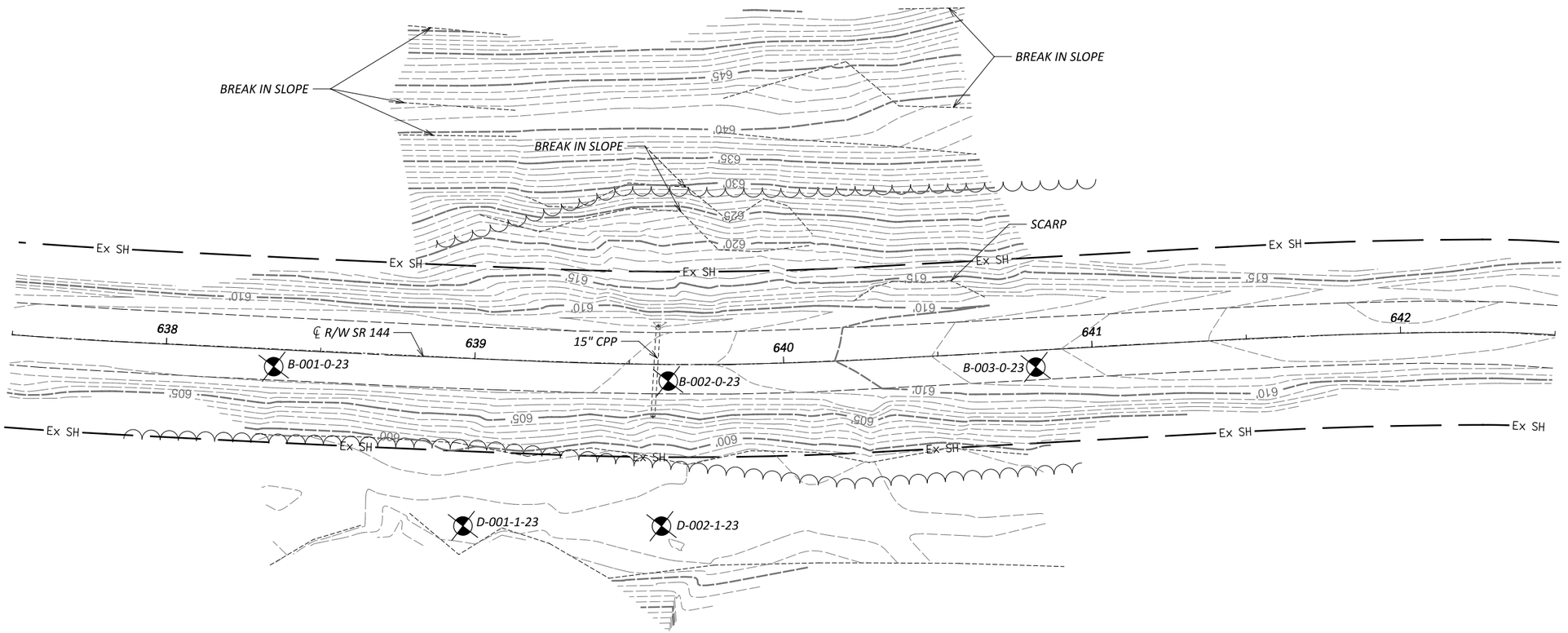
REFERENCE:

U.S. Geological Survey, 2019

USGS US Topo 7.5-minute map for Cutler, OH:

USGS - National Geospatial Technical Operations Center (NGTOC).

Boring Location Plan



HORIZONTAL SCALE IN FEET
0 10 20 40

BORING LOCATION PLAN

DESIGN AGENCY

DESIGNER AKB

REVIEWER DMV 02-24-23

PROJECT ID 116165

SHEET 1 TOTAL 1

ATH-144-12.08

MODEL: CLX_RW_SR144 - Plan 1 [Sheet] PAPERSIZE: 34x22 (in.) DATE: 2/22/2023 TIME: 10:28:26 AM USER: WNUSBAUM
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 10\Athens\116165\402-Engineering_HDR\Geotechnical\Sheets\116165_YP901

Boring Logs
and
Rock Core Photos

9999 Carver Road, Suite 210, Cincinnati, OH 45242-5583 **hdrinc.com**
(513) 984-7500

PROJECT: ATH-144-12.08	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 311)	STATION / OFFSET: 638+35, 5' RT.	EXPLORATION ID B-001-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 144	
PID: 116165 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 609.3 (MSL) EOB: 50.0 ft.	PAGE 1 OF 2
START: 1/18/23 END: 1/19/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 84.9	LAT / LONG: 39.310401, -81.859024	

MATERIAL DESCRIPTION AND NOTES	ELEV. 609.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
18 inches of Asphalt	607.8	1																
STIFF TO VERY STIFF, RED-BROWN AND DARK RED-BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, DAMP (FILL)		2	4 6 5	16	44	SS-1	3.00	-	-	-	-	-	-	-	-	19	A-4a (V)	
		3																
		4																
		5	4 4 3	10	44	SS-2	-	-	-	-	-	-	-	-	-	11	A-4a (V)	
		6																
		7																
		8	3 4 3	10	44	SS-3	1.50	2	10	42	27	19	29	19	10	15	A-4a (2)	
	599.3	9																
MEDIUM DENSE, RED-BROWN AND DARK RED-BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, DAMP (FILL)		10	4 6 6	17	78	SS-4	-	6	9	48	23	14	NP	NP	NP	12	A-4a (0)	
		11																
		12																
		13	3 4 4	11	28	SS-5	-	-	-	-	-	-	-	-	-	10	A-4a (V)	
	593.8	14																
STIFF TO VERY STIFF, LIGHT BROWN, **CLAY**, SOME SILT, TRACE GRAVEL, TRACE SAND, DAMP @ 16.0' - 16.5' : Auger Grinding		15	5 7 7	20	78	SS-6	3.50	-	-	-	-	-	-	-	-	14	A-7-6 (V)	
		16																
		17																
	590.3	18	2 2 4	8	78	SS-7	1.50	2	3	4	30	61	63	27	36	46	A-7-6 (20)	
	W 590.3	19																
STIFF TO VERY STIFF, RED-BROWN TRACE LIGHT BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP @ 20.7' - 21.2' : qu = 1473 psf		20																
		21			100	ST-8	4.50	7	3	9	46	35	42	25	17	22	A-7-6 (11)	
	587.3	22																
HARD, RED-BROWN TRACE LIGHT BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP		23	11 16 20	51	89	SS-9	4.50	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
	584.3	24																
	TR	25	50/4"	-	100	SS-10	-	-	-	-	-	-	-	-	-	10	Rock (V)	
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK.		26																
		27																
		28	50/3"	-	100	SS-11	-	-	-	-	-	-	-	-	-	10	Rock (V)	
		29																

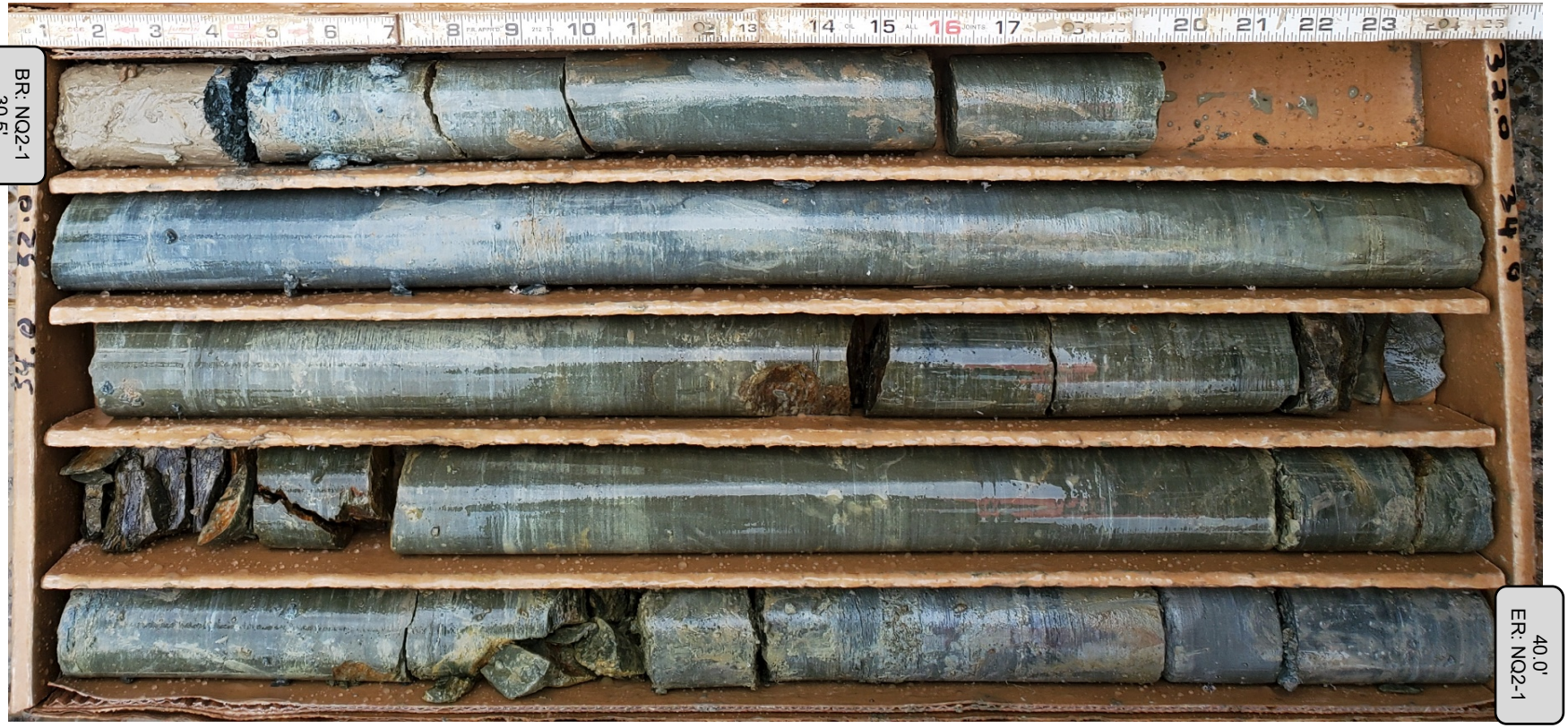
PID: 116165	SFN:	PROJECT: ATH-144-12.08	STATION / OFFSET: 638+35, 5' RT.	START: 1/18/23	END: 1/19/23	PG 2 OF 2	B-001-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
	579.3																	
	578.8		50/3"	-	100	SS-12	-	-	-	-	-	-	-	-	-	14	Rock (V)	
SHALE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, WEAK, VERY FINE TO FINE GRAINED, THIN TO MEDIUM BEDDED, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, MODERATELY TO SLIGHTLY FRACTURED, TIGHT TO NARROW APERTURE, SICKENSIDED TO SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITIONS; RQD 53%, REC 100%. @ 34.0' - 39.0' : Olive-gray @ 35.8' - 36.3' : Highly-Fractured with Staining @ 36.3' - 36.5' : Vertical Fracture with Staining @ 38.0' - 38.3' : Vertical Fracture with Staining		31 32 33 34 35 36 37 38 39 40	64		100	NQ2-1											CORE	
	567.3	41 42 43 44																
SHALE, GRAY, MODERATELY TO HIGHLY WEATHERED, VERY WEAK, VERY THIN TO THIN BEDDED, ARGILLACEOUS, JOINT AND BEDDING DISCONTINUITIES, HIGHLY FRACTURED TO FRACTURED, OPEN APERATURE, SLICKENSIDED, LAMINATED, POOR TO VERY POOR SURFACE CONDITIONS; RQD 42%, REC 100%. @ 45.3' - 45.7' : qu = 23 psi @ 46.7' - 47.3' : Dark-Gray Carbonaceous		45	35		100	NQ2-2										CORE	
	561.3	46 47 48 49																
LIMESTONE, GRAY, SLIGHTLY WEATHERED, STRONG, THIN BEDDED, CRYSTALLINE, JOINT AND BEDDING DISCONTINUITIES, MODERATELY FRACTURED TO FRACTURED, OPEN APERTURE, VERY ROUGH, VERY BLOCKY, GOOD SURFACE CONDITIONS; RQD 50%, REC 100%.	559.3	EOB 50																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

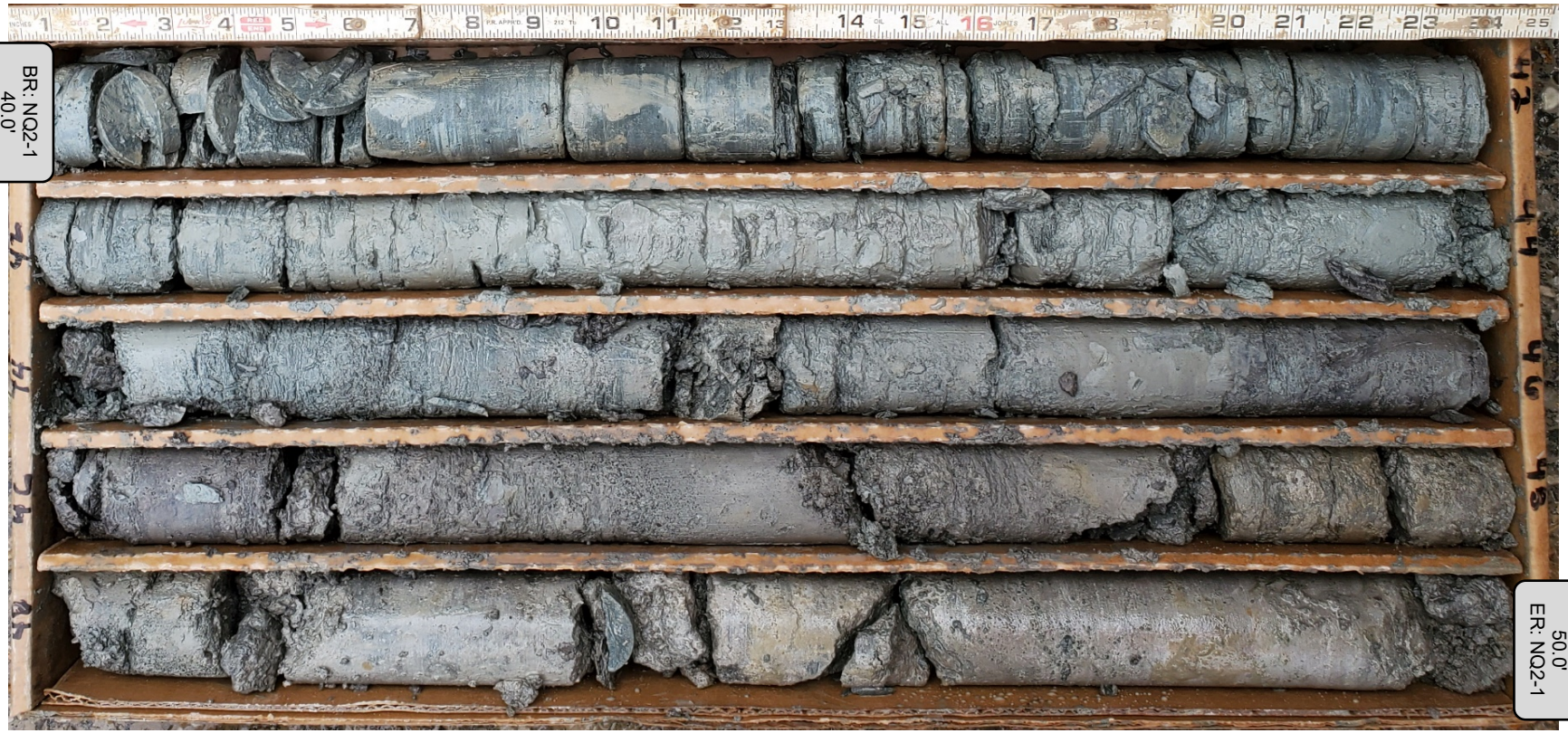
B-001-0-23



Run #	Depth (ft)		Recovery		RQD	
NQ2-1	30.5	40.0	114 in. / 114 in.	100%	73 in. / 114 in.	64%

ATH-144-12.08 PID 116165

B-001-0-23



Run #	Depth (ft)		Recovery		RQD	
NQ2-2	40.0	50.0	120 in. / 120 in.	100%	42 in. / 120 in.	35%

ATH-144-12.08 PID 116165

PROJECT: ATH-144-12.08	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 481)	STATION / OFFSET: 639+63, 5' RT.	EXPLORATION ID B-002-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 144	
PID: 116165 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 608.8 (MSL) EOB: 44.0 ft.	PAGE 1 OF 2
START: 1/16/23 END: 1/17/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.310198, -81.859393	

MATERIAL DESCRIPTION AND NOTES	ELEV. 608.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
18 inches of Asphalt	607.3	1																
MEDIUM DENSE, DARK BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP (FILL)	604.3	2	5 6 6	17	67	SS-1	-	38	25	16	14	7	19	14	5	8	A-1-b (0)	
		3	9 10 3	19	67	SS-2	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
MEDIUM STIFF TO STIFF, RED-BROWN AND GRAY-RED-BROWN, **CLAY**, SOME SAND, SOME SILT, TRACE GRAVEL, DAMP (POSSIBLE FILL)		4 5	2 3 3	9	56	SS-3	1.00	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
		6 7	2 2 2	6	78	SS-4	0.50	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
@ 8.0' - 8.5' : qu = 1205 psf	598.3	8 9 10			89	ST-5	1.50	7	10	13	31	39	48	23	25	27	A-7-6 (14)	
			5 5 5	14	89	SS-6	2.50	-	-	-	-	-	-	-	-	29	A-7-6 (V)	
STIFF TO VERY STIFF, RED-BROWN, **CLAY**, SOME SAND, SOME SILT, LITTLE GRAVEL, DAMP		11	4 5 10	22	78	SS-7	2.00	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
		12 13	4 4 6	14	100	SS-8	3.50	13	8	22	26	31	42	20	22	19	A-7-6 (9)	
	593.8	14	3 5 8	19	100	SS-9	3.00	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
MEDIUM STIFF TO STIFF, RED-BROWN, **CLAY**, SOME SILT, LITTLE SAND, TRACE GRAVEL, DAMP TO MOIST		15 16	4 4 4	12	17	SS-10	1.00	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
	590.8	17	2 3 6	13	17	SS-11	0.50	3	5	10	33	49	-	-	-	40	A-7-6 (V)	
HARD, RED-BROWN AND GRAY, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, (RELIC ROCK STRUCTURE), DAMP (RESIDUUM)		18 19	12 16 35	74	100	SS-12	4.50	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		20	13 11 15	38	100	SS-13	4.50	2	4	9	44	41	41	24	17	18	A-7-6 (11)	
		21 22	12 17 20	54	100	SS-14	4.50	-	-	-	-	-	-	-	-	13	A-7-6 (V)	
	585.8																	
@ 22.9' - 23.0' : Black, Carbonaceous	584.8	TR 23	8 30 50/3"	-	100	SS-15	-	-	-	-	-	-	-	-	-	7	Rock (V)	
SHALE, RED-BROWN AND GRAY, HIGHLY WEATHERED, VERY WEAK.		24																
SHALE, RED-BROWN AND GRAY, MODERATELY WEATHERED, VERY WEAK, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED, NARROW APERTURE, SLIGHTLY ROUGH, LAMINTATED TO VERY BLOCKY, POOR SURFACE; RQD 18%, REC 100%. @ 24.2' - 24.6' : qu = 311 psi @ 26.3' - 28.5' : Vertical Fracture @ 27.5' - 29.0' : Highly Fractured	579.7	25 26 27 28 29	18		100	NQ2-1											CORE	

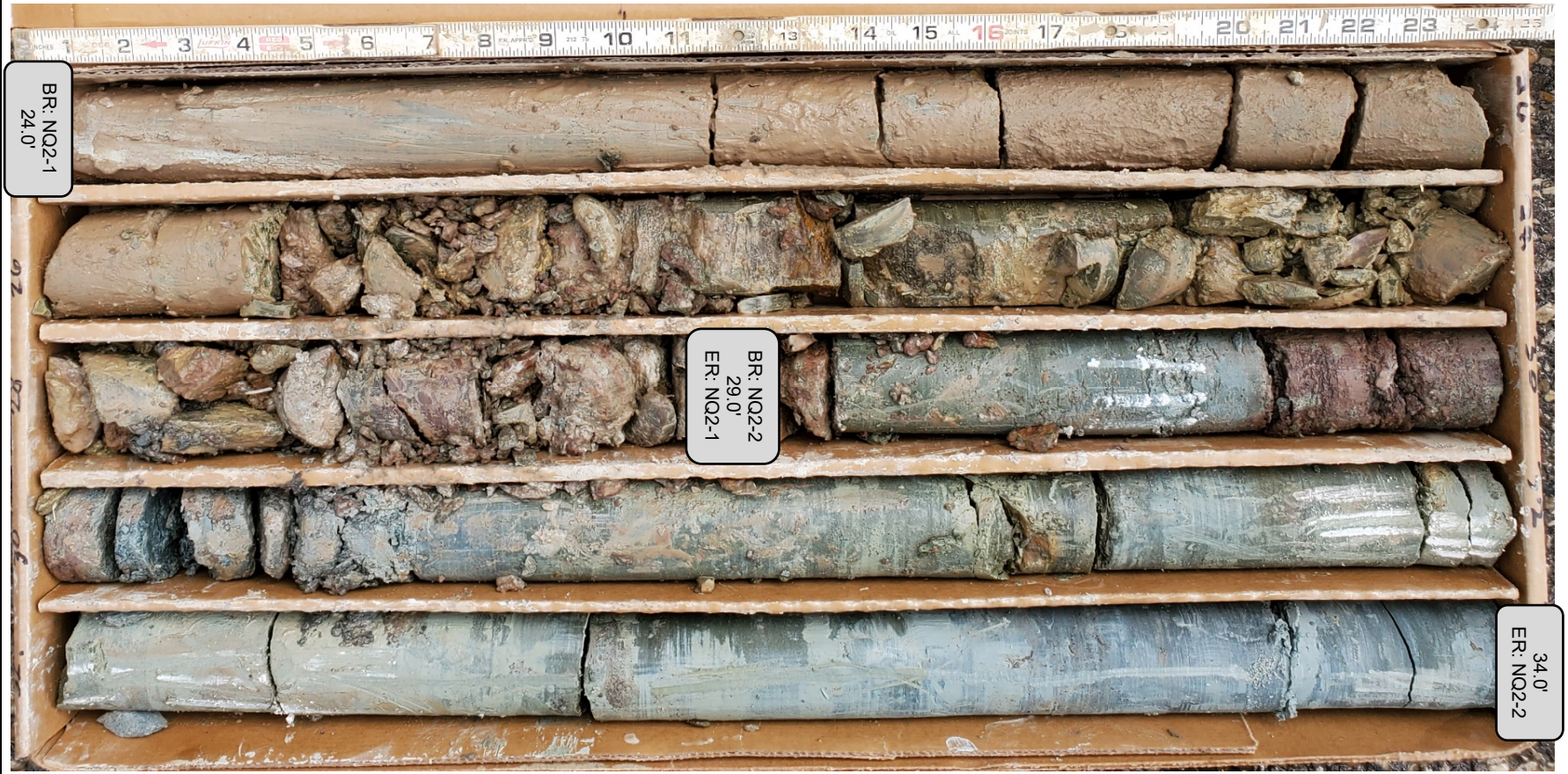
PID: 116165	SFN:	PROJECT: ATH-144-12.08	STATION / OFFSET: 639+63, 5' RT.	START: 1/16/23	END: 1/17/23	PG 2 OF 2	B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
@ 29.7' - 30.5' : Very Weak, Friable, Shale **SHALE**, GRAY, SLIGHTLY WEATHERED, WEAK, VERY FINE TO FINE GRAINED, MEDIUM TO THICK BEDDED, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, MODERATELY TO SLIGHTLY FRACTURED, NARROW TO TIGHT APERTURE, SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITIONS; RQD 54%, REC 100%. *(continued)*	578.8	31	72		100	NQ2-2											CORE	
@ 31.8' - 32.5' : Sandstone, Fine to Medium Grained		32																
@ 34.8' - 35.8' : Olive, Highly Fractured, Vertical Fracture with Staining		33																
@ 35.8' - 37.0' : Sandstone, Gray, Slightly to Moderately Weathered, Fine to Medium Grained, Slightly Strong		34																
@ 37.2' - 39.0' : Olive, Highly Fractured, Vertical Fracture with Staining		35	27		100	NQ2-3											CORE	
@ 39.0' - 39.5' : Olive		36																
		37																
		38																
		39																
		40																
		41	62		100	NQ2-4											CORE	
@ 42.0' - 44.0' : Dark Blackish Gray		42																
		43																
	564.8	EOB 44																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

B-002-0-23



Run #	Depth (ft)		Recovery		RQD	
NQ2-1	24.0	29.0	60 in. / 60 in.	100%	11 in. / 60 in.	18%
NQ2-2	29.0	34.0	60 in. / 60 in.	100%	43 in. / 60 in.	72%

ATH-144-12.08 PID 116165

B-002-0-23

Run #	Depth (ft)		Recovery		RQD	
NQ2-3	34.0	39.0	60 in. / 60 in.	100%	16 in. / 60 in.	27%
NQ2-4	39.0	44.0	60 in. / 60 in.	100%	37 in. / 60 in.	62%

ATH-144-12.08 PID 116165

PROJECT: ATH-144-12.08	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 311)	STATION / OFFSET: 640+81, 5' RT.	EXPLORATION ID B-003-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 144	
PID: 116165 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 611.6 (MSL) EOB: 44.0 ft.	PAGE 1 OF 2
START: 1/18/23 END: 1/18/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 84.9	LAT / LONG: 39.309990, -81.859718	

MATERIAL DESCRIPTION AND NOTES	ELEV. 611.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
15 inches of Asphalt	610.3	1																
STIFF TO VERY STIFF, RED-BROWN, **CLAY**, SOME SILT, LITTLE SAND, TRACE GRAVEL, DAMP (POSSIBLE FILL)		2	8 5 4	13	89	SS-1	3.00	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
@ 3.5' - 5.0' : Limestone Boulder		3																
		4																
		5	4 4 6	14	56	SS-2	3.50	9	8	9	34	40	50	23	27	21	A-7-6 (17)	
		6																
		7																
		8	3 6 5	16	33	SS-3	-	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
	601.6	9																
STIFF TO VERY STIFF, RED-BROWN, **SILTY CLAY**, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP		10	3 5 7	17	67	SS-4	2.50	-	-	-	-	-	-	-	-	22	A-6b (V)	
		11																
		12																
		13			100	ST-5	4.50	1	2	12	50	35	40	20	20	22	A-6b (12)	
@ 13.7' - 14.2' : qu = 2026 psf		14																
		15	4 5 6	16	89	SS-6	1.50	-	-	-	-	-	-	-	-	22	A-6b (V)	
		16																
@ 17.0' - 17.5' : Auger Grinding	594.1	17																
VERY STIFF TO HARD, LIGHT BROWN TRACE RED-BROWN, **CLAY**, SOME SILT, LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP		18	6 11 50/5"	-	71	SS-7	2.00	-	-	-	-	-	-	-	-	14	A-7-6 (V)	
		19																
		20																
		21	9 16 13	41	67	SS-8	3.50	17	6	5	34	38	42	20	22	18	A-7-6 (13)	
		22																
W 589.1		23	50/5"	-	100	SS-9	-	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
@ 22.5' - 24.5' : Auger Grinding	587.1	24																
TR		25																
LIMESTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, STRONG, THICK BEDDED, CRYSTALLINE, BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED, SLIGHTLY ROUGH, INTACT, GOOD TO VERY GOOD SURFACE CONDITIONS; RQD 79%, REC 100%.	585.1	26																
		27																
		28																
CLAYSTONE, RED-BROWN TO PURPLE, MODERATELY TO HIGHLY WEATHERED, VERY WEAK, THIN BEDDED, FRIABLE, JOINT AND BEDDING DISCONTINUITIES, FRACTURED, NARROW TO OPEN APERTURE, SLIGHTLY	581.6	29	58		95	NQ2-1											CORE	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 2/23/23 10:21 - C:\PWWORKING\EAST01\D3052797\20230118_ATH-144-12.08_10-Y_BORING LOGS.GPJ

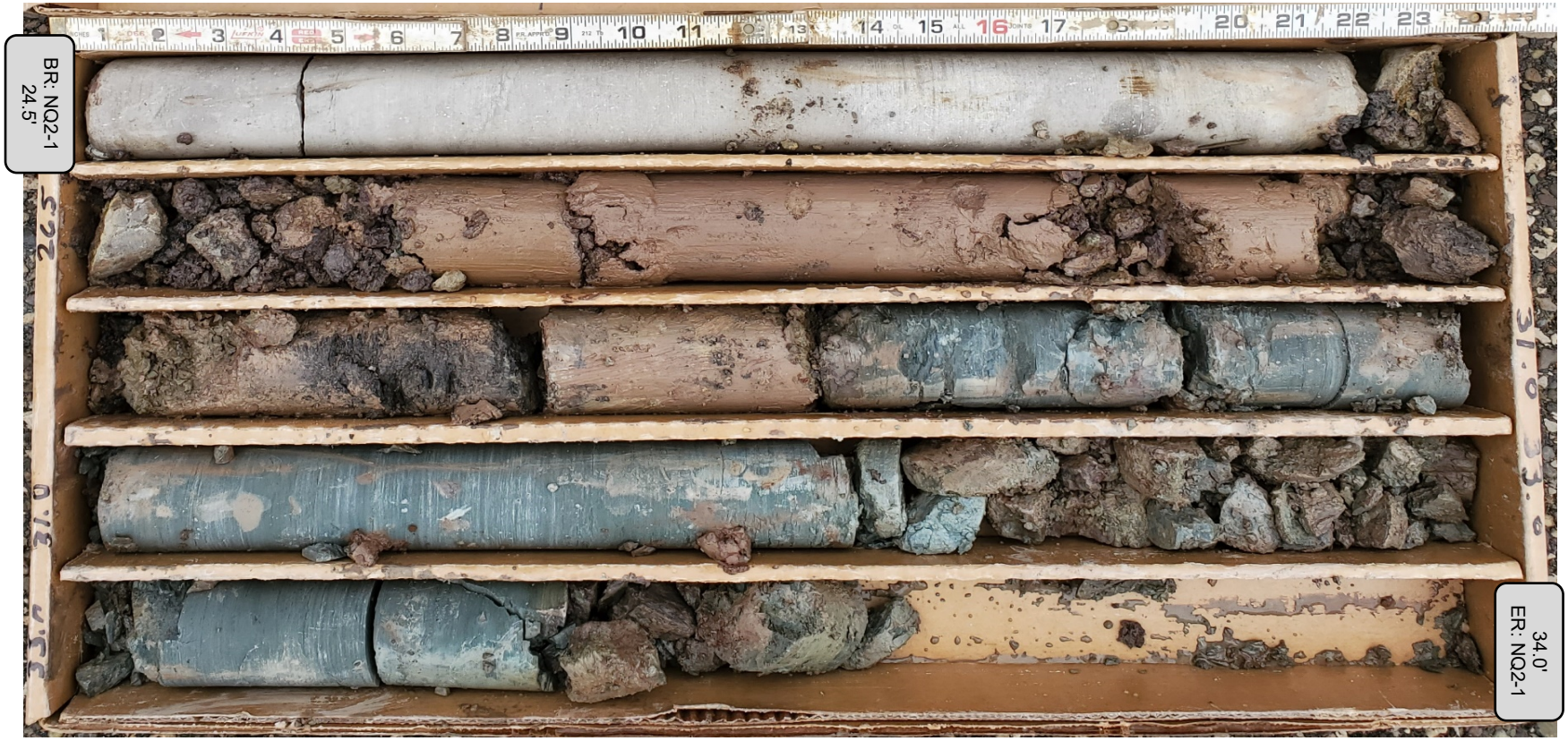
PID: 116165	SFN:	PROJECT: ATH-144-12.08	STATION / OFFSET: 640+81, 5' RT.	START: 1/18/23	END: 1/18/23	PG 2 OF 2	B-003-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ROUGH TO SLICKENSIDED, LAMINATED, POOR SURFACE CONDITIONS; RQD 36%, REC 86%. @ 28.5' - 29.5' : Dark Gray and Black, Carbonaceous with Coal	581.6	31																
SHALE, GRAY TO OLIVE-GRAY, MODERATELY WEATHERED, WEAK, VERY FINE TO FINE GRAINED, MEDIUM BEDDED, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, FRACTURE TO MODERATLY FRACTURED, NARROW TO OPEN APERTURE, SLIGHTLY ROUGH, BLOCKY, POOR TO FAIR SURFACE CONDITIONS; RQD 58%, REC 100%. @ 31.2' - 32.6' : qu = 942 psi @ 32.0' - 33.0' : Highly Fractured, Trace Red-Brown @ 33.5' - 35.5' : Trace Red-Brown @ 35.5' - 38.0' : Gray to Olive-Gray @ 36.8' - 37.5' : Vertical Fracture with Staining @ 39.3' - 39.5' : Vertical Fracture @ 40.3' - 40.8' : Very Weak, Friable, Vertical Fracture with Staining @ 40.8' - 41.8' : Gray to Olive-Gray @ 41.2' - 42.0' : Vertical Fracture (Unopened) @ 42.0' - 43.3' : Vertical Fracture with Staining, Highly Fractured @ 43.7' - 44.0' : Vertical Fracture with Staining		34 35 36 37 38 39 40 41 42 43	55		100	NQ2-2											CORE	
	567.6	EOB 44																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

B-003-0-23



Run #	Depth (ft)		Recovery		RQD	
NQ2-1	24.5	34.0	108 in. / 114 in.	95%	66 in. / 114 in.	58%

ATH-144-12.08 PID 116165

B-003-0-23

Run #	Depth (ft)		Recovery		RQD	
NQ2-2	34.0	44.0	120 in. / 120 in.	100%	66 in. / 120 in.	55%

ATH-144-12.08 PID 116165

DCP Logs

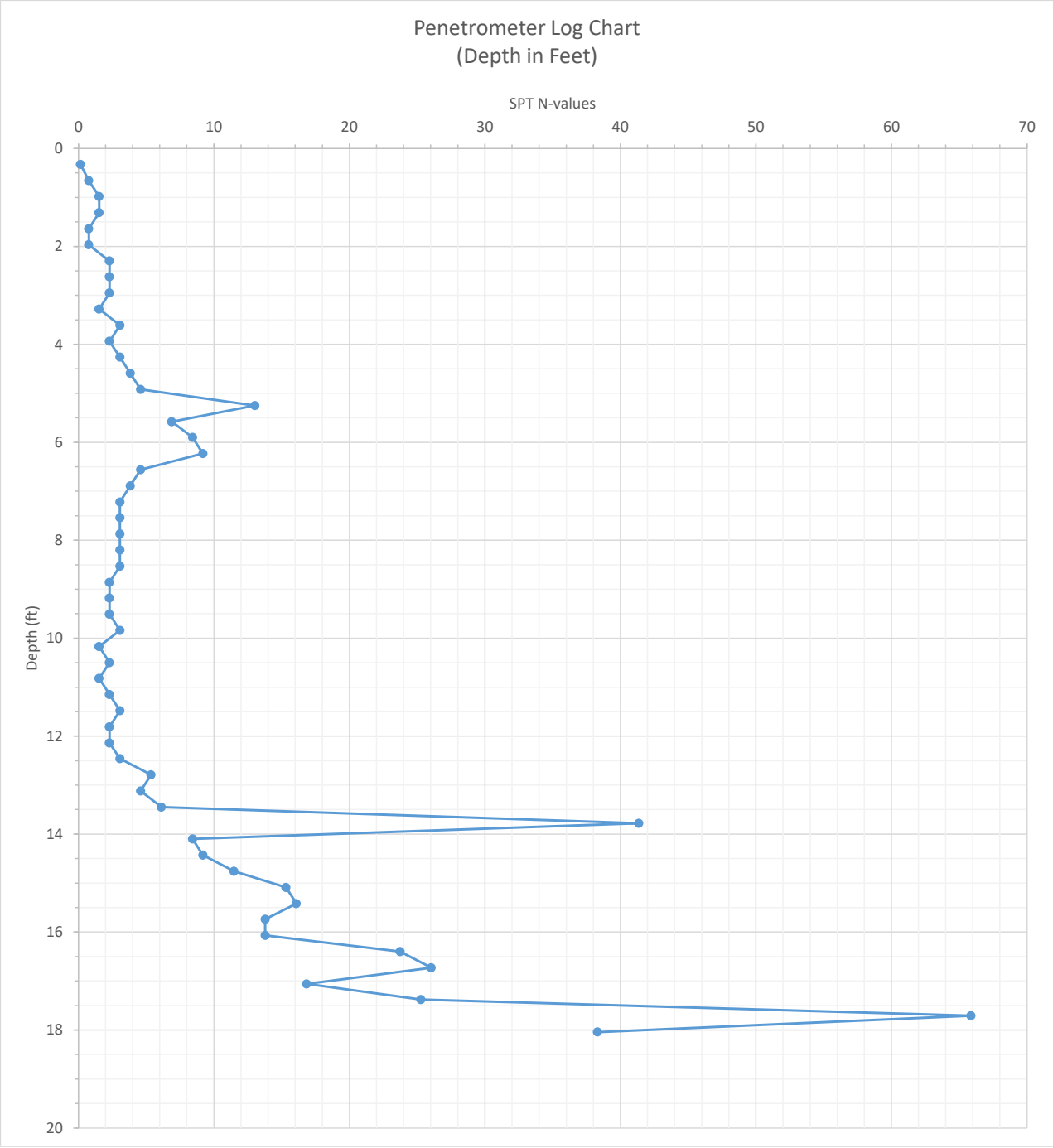
Dynamic Cone Penetration Test Log

Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-144-12.08 (10-Y)	**Lat / Long:**	39.310411 -81.859307
Location:	D-001-1-23	**North / East:**	477915 2149778
Station, Offset:	638+98, 54' RT.	**Date:**	2/6/2023
Elevation:	597.4	**Sheet:**	1 of 2
Notes:	Staked Location		

Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value
3.94	0.33	10	0.2	0.1532
7.87	0.66	20	1	0.766
11.81	0.98	30	2	1.532
15.75	1.31	40	2	1.532
19.69	1.64	50	1	0.766
23.62	1.97	60	1	0.766
27.56	2.3	70	3	2.298
31.5	2.62	80	3	2.298
35.43	2.95	90	3	2.298
39.37	3.28	100	2	1.532
43.31	3.61	110	4	3.064
47.24	3.94	120	3	2.298
51.18	4.26	130	4	3.064
55.12	4.59	140	5	3.83
59.06	4.92	150	6	4.596
62.99	5.25	160	17	13.022
66.93	5.58	170	9	6.894
70.87	5.9	180	11	8.426
74.8	6.23	190	12	9.192
78.74	6.56	200	6	4.596
82.68	6.89	210	5	3.83
86.61	7.22	220	4	3.064
90.55	7.54	230	4	3.064
94.49	7.87	240	4	3.064
98.43	8.2	250	4	3.064
102.36	8.53	260	4	3.064
106.3	8.86	270	3	2.298
110.24	9.18	280	3	2.298
114.17	9.51	290	3	2.298
118.11	9.84	300	4	3.064
122.05	10.17	310	2	1.532
125.98	10.5	320	3	2.298
129.92	10.82	330	2	1.532
133.86	11.15	340	3	2.298
137.8	11.48	350	4	3.064
141.73	11.81	360	3	2.298
145.67	12.14	370	3	2.298
149.61	12.46	380	4	3.1
153.54	12.79	390	7	5.4
157.48	13.12	400	6	4.6
161.42	13.45	410	8	6.1
165.35	13.78	420	54	41.4
169.29	14.1	430	11	8.4
173.23	14.43	440	12	9.2
177.17	14.76	450	15	11.5
181.1	15.09	460	20	15.3
185.04	15.42	470	21	16.1
188.98	15.74	480	18	13.8
192.91	16.07	490	18	13.8
196.85	16.4	500	31	23.7
200.79	16.73	510	34	26.0
204.72	17.06	520	22	16.9
208.66	17.38	530	33	25.3
212.6	17.71	540	86	65.9
216.54	18.04	550	50	38.3

Dynamic Cone Penetration Test Log

Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-144-12.08 (10-Y)	**Lat / Long:**	39.310411 -81.859307
Location:	D-001-1-23	**North / East:**	477915 2149778
Station, Offset:	638+98, 54' RT.	**Date:**	2/6/2023
Elevation:	597.4	**Sheet:**	2 of 2
Notes:	Staked Location		



Dynamic Cone Penetration Test Log

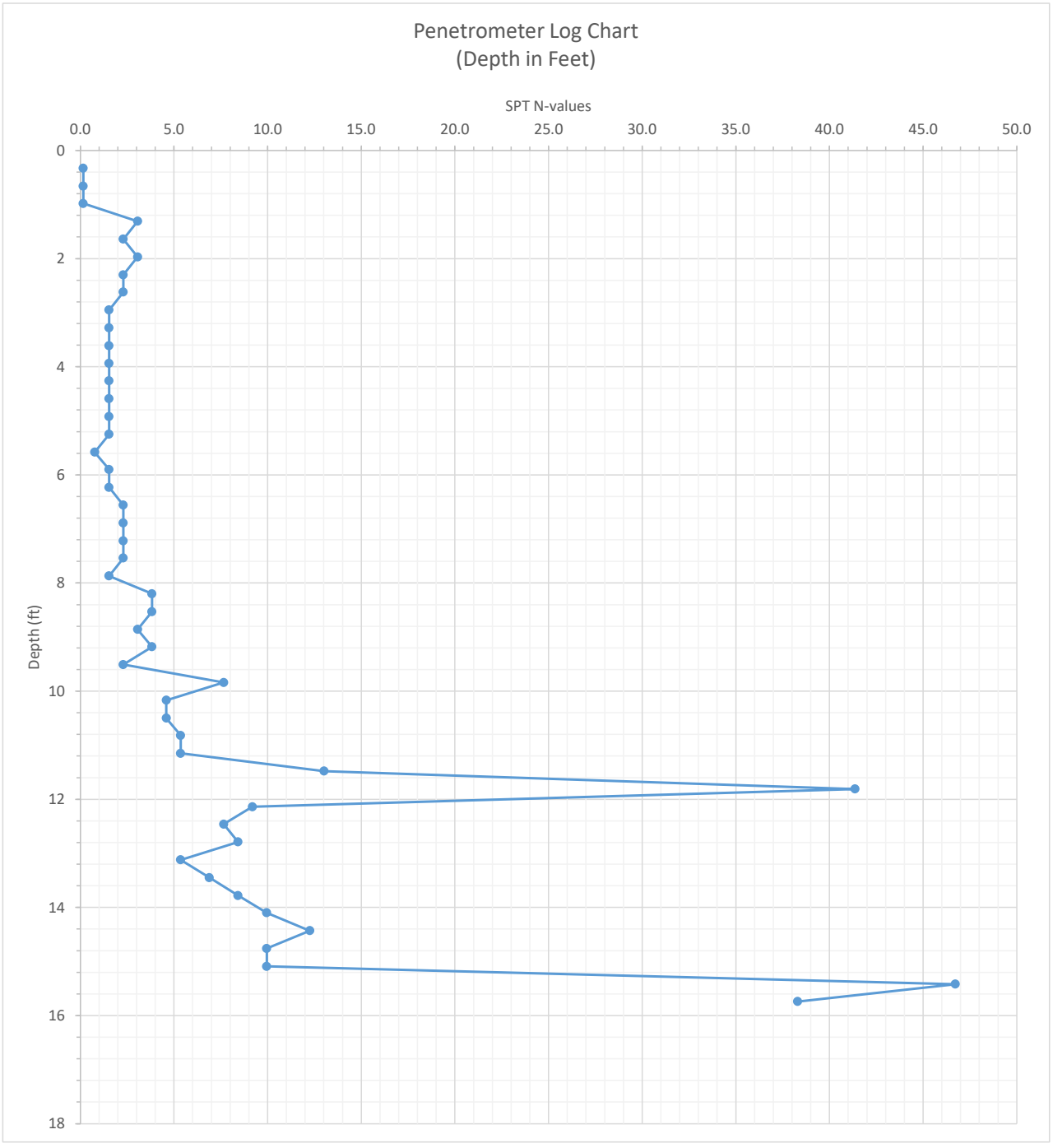
Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-144-12.08 (10-Y)	**Lat / Long:**	39.310305 -81.859488
Location:	D-002-1-23	**North / East:**	477876 2149727
Station, Offset:	639+61, 52' RT.	**Date:**	2/6/2023
Elevation:	597.6	**Sheet:**	1 of 2
Notes:	Staked Location		

Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value
3.94	0.33	10	0.2	0.2
7.87	0.66	20	0.2	0.2
11.81	0.98	30	0.2	0.2
15.75	1.31	40	4	3.1
19.69	1.64	50	3	2.3
23.62	1.97	60	4	3.1
27.56	2.3	70	3	2.3
31.5	2.62	80	3	2.3
35.43	2.95	90	2	1.5
39.37	3.28	100	2	1.5
43.31	3.61	110	2	1.5
47.24	3.94	120	2	1.5
51.18	4.26	130	2	1.5
55.12	4.59	140	2	1.5
59.06	4.92	150	2	1.5
62.99	5.25	160	2	1.5
66.93	5.58	170	1	0.8
70.87	5.9	180	2	1.5
74.8	6.23	190	2	1.5
78.74	6.56	200	3	2.3
82.68	6.89	210	3	2.3
86.61	7.22	220	3	2.3
90.55	7.54	230	3	2.3
94.49	7.87	240	2	1.5
98.43	8.2	250	5	3.8
102.36	8.53	260	5	3.8
106.3	8.86	270	4	3.1
110.24	9.18	280	5	3.8
114.17	9.51	290	3	2.3
118.11	9.84	300	10	7.7
122.05	10.17	310	6	4.6
125.98	10.5	320	6	4.6
129.92	10.82	330	7	5.4
133.86	11.15	340	7	5.362
137.8	11.48	350	17	13.022
141.73	11.81	360	54	41.364
145.67	12.14	370	12	9.192
149.61	12.46	380	10	7.66
153.54	12.79	390	11	8.426
157.48	13.12	400	7	5.362
161.42	13.45	410	9	6.894
165.35	13.78	420	11	8.426
169.29	14.1	430	13	9.958
173.23	14.43	440	16	12.256
177.17	14.76	450	13	9.958
181.1	15.09	460	13	9.958
185.04	15.42	470	61	46.726
188.98	15.74	480	50	38.3

Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value

Dynamic Cone Penetration Test Log

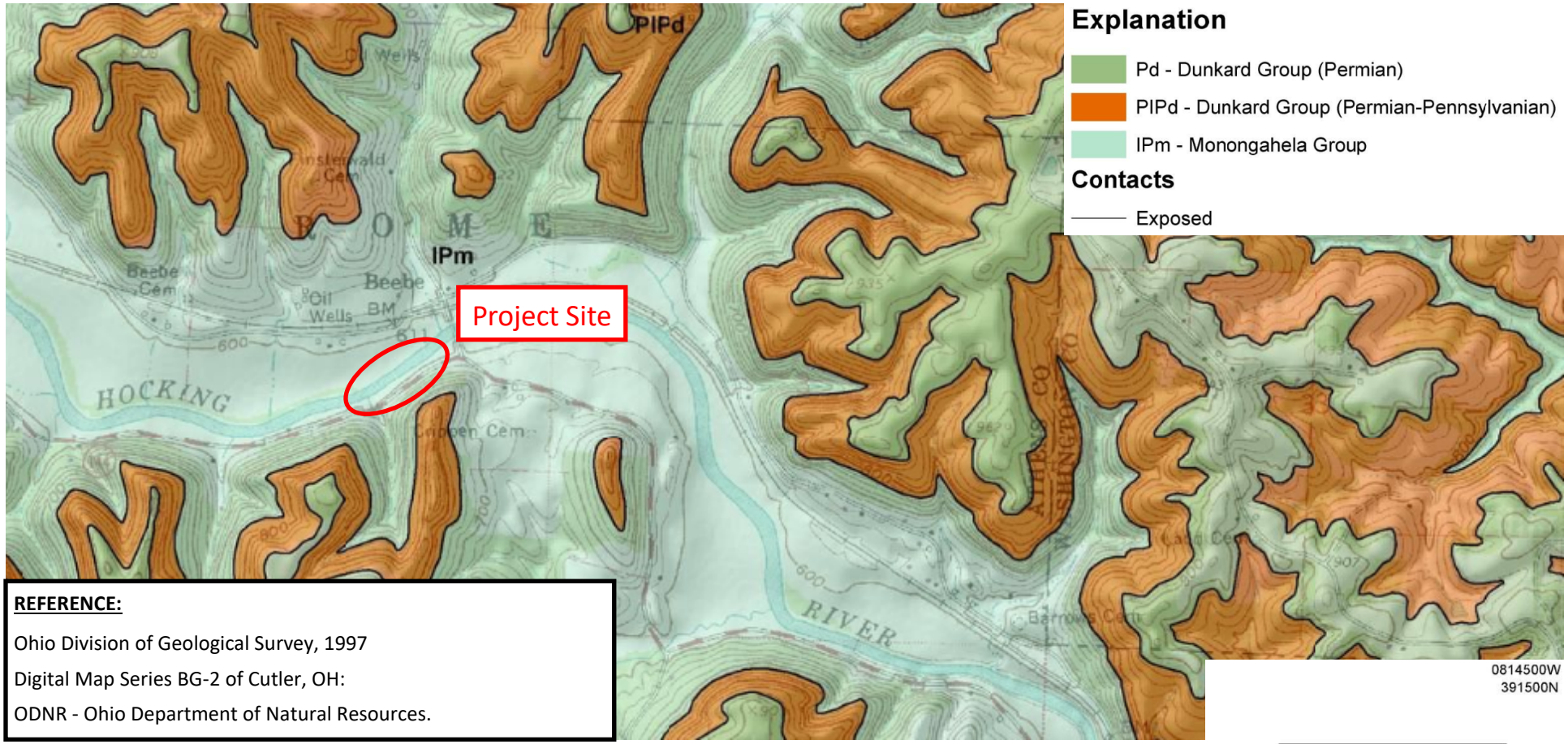
Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-144-12.08 (10-Y)	**Lat / Long:**	39.310305 -81.859488
Location:	D-002-1-23	**North / East:**	477876 2149727
Station, Offset:	639+61, 52' RT.	**Date:**	2/6/2023
Elevation:	597.6	**Sheet:**	2 of 2
Notes:	Staked Location		



Bedrock Geology and Topography Maps

9999 Carver Road, Suite 210, Cincinnati, OH 45242-5583 **hdrinc.com**
(513) 984-7500

Bedrock Geology Map



REFERENCE:

Ohio Division of Geological Survey, 1997

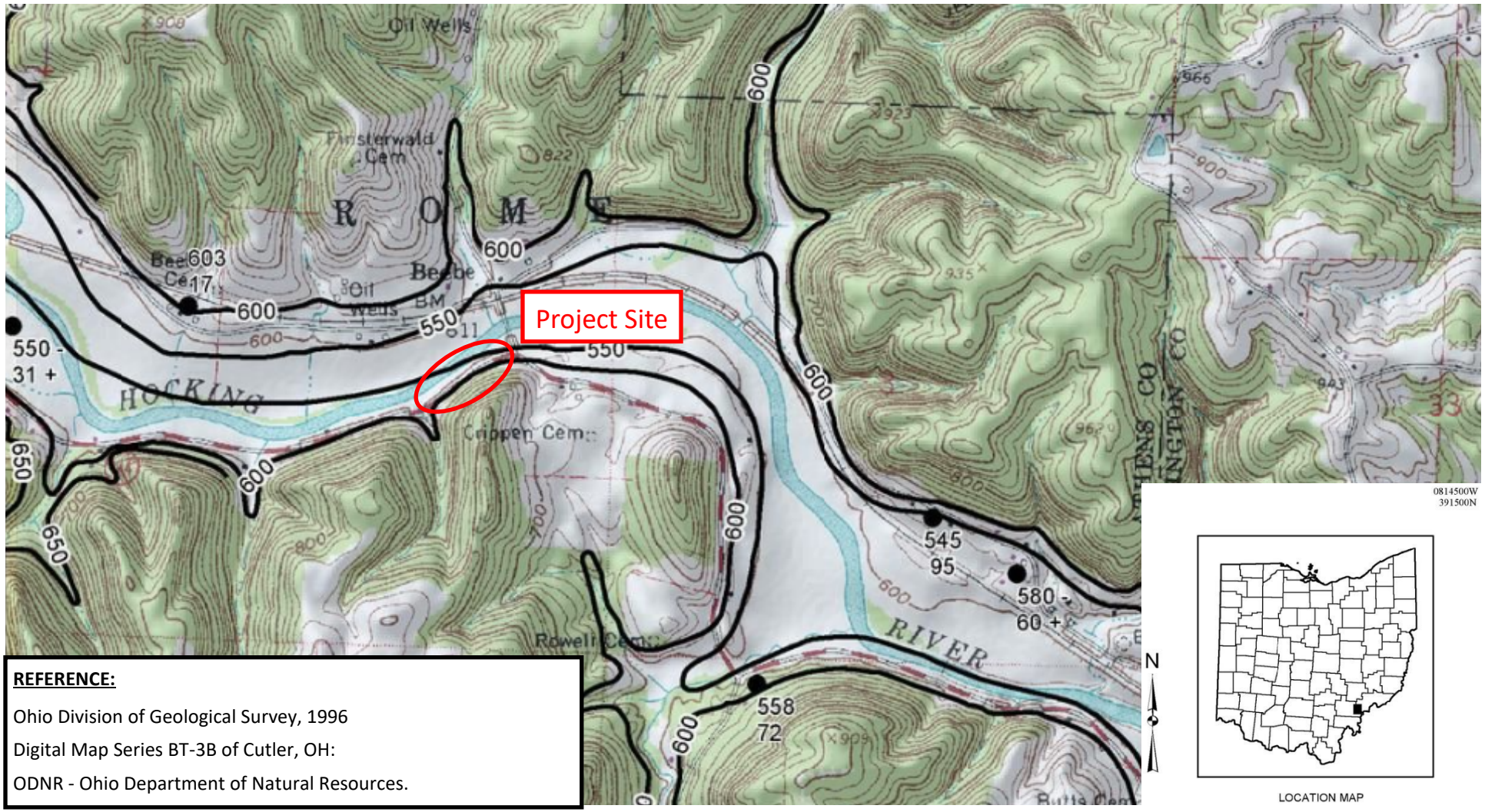
Digital Map Series BG-2 of Cutler, OH:

ODNR - Ohio Department of Natural Resources.

1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 Feet

LOCATION MAP

Bedrock Topography Map



REFERENCE:

Ohio Division of Geological Survey, 1996

Digital Map Series BT-3B of Cutler, OH:

ODNR - Ohio Department of Natural Resources.

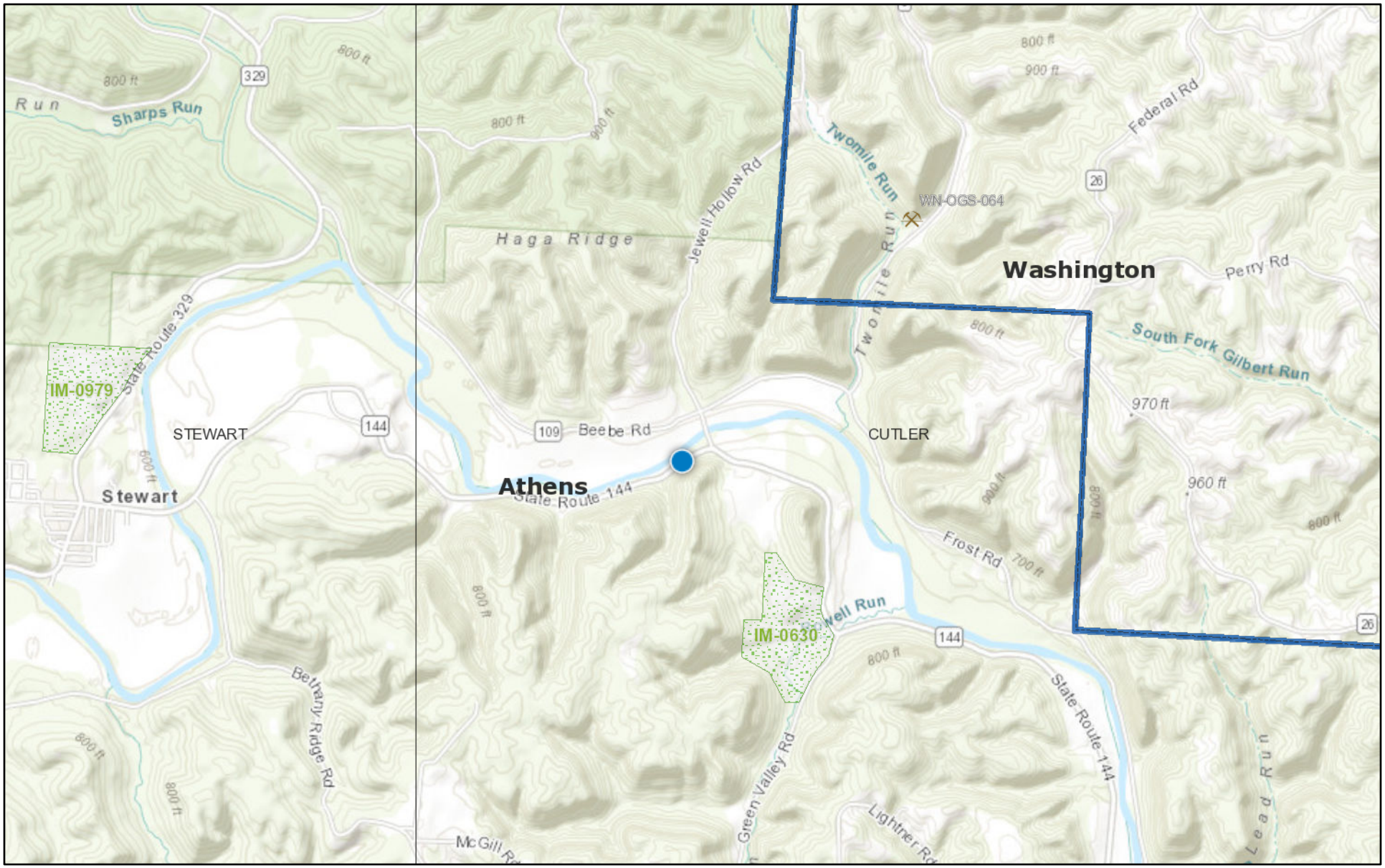
LOCATION MAP

1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000

Feet

Mine Map

ATH-144-12.08



February 20, 2023

1:36,112

0 0.23 0.45 0.9 mi

0 0.38 0.75 1.5 km

- Quadrangle 24K (7.5 min)
- Abandoned before 1977
- Past
- Current
- Proposed
- Original Application
- Adjacent Area Application
- Historic - From Geology Maps
- Past
- Current
- Proposed
- Original Application

VITA, West Virginia GIS, Esri, HERE, Garmin, INCREMENT P, USGS, METI/ NASA, NGA, EPA, USDA

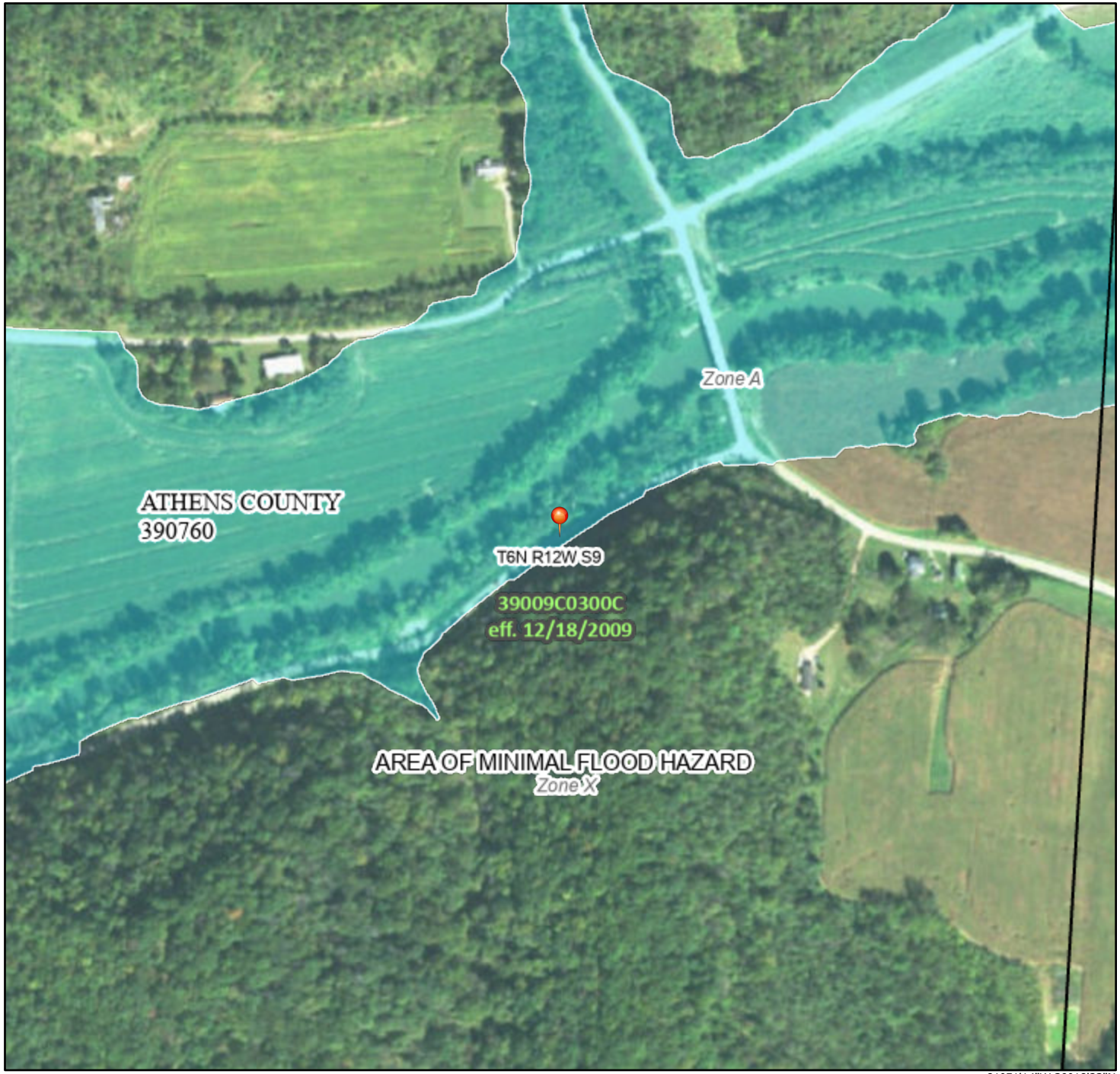
Ohio Dept. of Natural Resources

FEMA Flood Map

National Flood Hazard Layer FIRMette

FEMA

81°51'51"W 39°18'51"N



81°51'14"W 39°18'23"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Basemap: USGS National Map: Orthoimagery: Data refreshed October, 2020

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 2/16/2023 at 10:37 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Soil Strength Parameter Determination

9999 Carver Road, Suite 210, Cincinnati, OH 45242-5583 **hdrinc.com**
(513) 984-7500

ODOT District 10
ATH-144-12.08

Soil Strength Parameter Determination

Computed By = AKB
Checked By = DCM

Layer		Undrained Shear Strength (Su) (psf)				Dry Unit Weight (pcf)		Moist Unit Wt. (pcf)		Adopted Short Term Parameters	Long-Term Strength Values					Adopted Long Term Strength Parameters
		PPR	N-values		Tested							N_{60} Value	ODOT GB-7 Correlations		Tested		
			Sowers	T and P	Values	Correlation	Tested	Correlation	Tested				Cohesion (psf)	phi (deg)	Cohesion (psf)	phi (deg)	(Back-Calculated from SlopeW)
Layer 1 MEDIUM STIFF TO STIFF COHESIVE 1	Max	3000	3500	2128	603	105	94	125	122		Max	16	153	24			
	Min	500	750	798	603	95	94	120	122	S_u= 600 psf	Min	6	75	21			c' = 140 psf
	Average	1667	1658	1441	603	103	94	123	122	Φ = 0 deg	Average	11	118	23			Φ' = 24 deg
	Std Dev	931	1061	479		4		3			Std Dev	4	28	1			
										Y_{dry} = 95 pcf							Y_{dry} = 95 pcf
	Avg + Std	2598	2719	1920		107		126		Y_{moist} = 120 pcf	Avg + Std	14	145	24			Y_{moist} = 120 pcf
	Avg - Std	736	597	962		98		121			Avg - Std	7	90	22			
Layer 2 STIFF TO VERY STIFF COHESIVE	Max	4500	4000	2926	1013	115	102	130	127		Max	22	173	26			
	Min	1500	2800	1729	1013	100	102	120	127	S_u = 1500 psf	Min	11	136	23			c' = 160 psf
	Average	3000	3558	2231	1013	111	102	128	127	Φ = 0 deg	Average	16	154	24			Φ' = 25 deg
	Std Dev	901	474	403		5		3			Std Dev	3	12	1			
										Y_{dry} = 100 pcf							Y_{dry} = 100 pcf
	Avg + Std	3901	4032	2635		116		131		Y_{moist} = 125 pcf	Avg + Std	20	166	25			Y_{moist} = 125 pcf
	Avg - Std	2099	3084	1828		106		124			Avg - Std	13	142	24			
Layer 3 MEDIUM STIFF TO STIFF COHESIVE 2	Max	4500	3250	1729	737	110	104	125	128		Max	13	136	23			
	Min	500	2000	1064	737	95	104	120	128	S_u = 750 psf	Min	8	100	22			c' = 0 psf
	Average	1875	2750	1463	737	105	104	123	128	Φ = 0 deg	Average	11	122	23			Φ' = 17 deg
	Std Dev	1797	661	352		9		3			Std Dev	3	19	1			
										Y_{dry} = 105 pcf							Y_{dry} = 105 pcf
	Avg + Std	3672	3411	1815		114		126		Y_{moist} = 130 pcf	Avg + Std	14	141	24			Y_{moist} = 130 pcf
	Avg - Std	78	2089	1111		96		120			Avg - Std	8	103	22			
Layer 4 HARD COHESIVE	Max	4500	4000	4000		130		140			Max	74	250	28			
	Min	2000	4000	4000		125		135		S_u = 4000 psf	Min	38	200	28			c' = 220 psf
	Average	3917	4000	4000		128		138		Φ = 0 deg	Average	52	243	28			Φ' = 28 deg
	Std Dev	1021	0	0		3		3			Std Dev	14	19	0			
										Y_{dry} = 130 pcf							Y_{dry} = 130 pcf
	Avg + Std	4937	4000	4000		131		141		Y_{moist} = 140 pcf	Avg + Std	66	262	28			Y_{moist} = 140 pcf
	Avg - Std	2896	4000	4000		125		135			Avg - Std	37	224	28			

Note: Layer 3 long-term parameters determined similar to the "Weak Rock" methodology discussed in the GDM, as the moisture contents of 40+, as well as relatively lower SPT and Unconfined Strength tests, suggest the location of a slip surface.

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 1

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)
Max	16	89	3.0	7	10	42	31	39	48	23	25	29	3000	3500	2128	153	24	10.0	607.3	105	125	0.342	2.72	0.741	94	122	603
Min	6	44	0.5	2	10	13	27	19	29	19	10	11	500	750	798	75	21	2.0	598.8	95	120	0.171	2.65	0.575	94	122	603
Average	11	63	1.7	5	10	28	29	29	39	21	18	20	1667	1658	1441	118	23	6.6	602.4	103	123	0.257	2.68	0.636	94	122	603
Std Dev	4	21	0.9	4	0	21	3	14	13	3	11	6	931	1061	479	28	1	2.6	2.7	4	3	0.121	0.04	0.057	N/A	N/A	N/A
Avg + Std	14	85	2.6	8	10	48	32	43	52	24	28	26	2598	2719	1920	145	24	9.1	605.1	107	126	0.377	2.72	0.693	N/A	N/A	N/A
Avg - Std	7	42	0.7	1	10	7	26	15	25	18	7	13	736	597	962	90	22	4.0	599.7	98	121	0.136	2.64	0.580	N/A	N/A	N/A

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)
SR 144	609.3	B-001-0-23	1.5	-	3	SS-1	16	44	3	-	-	-	-	-	-	-	-	19	A-4a	Cohesive	1	3000	1200	2128	153	24	2.0	607.3	105	125		2.72	0.616			
SR 144	609.3	B-001-0-23	5	-	6.5	SS-2	10	44	-	-	-	-	-	-	-	-	-	11	A-4a	Cohesive	1	N/A	750	1330	114	23	6.0	603.3	105	125		2.72	0.616			
SR 144	609.3	B-001-0-23	7.5	-	9	SS-3	10	44	1.5	2	10	42	27	19	29	19	10	15	A-4a	Cohesive	1	1500	750	1330	114	23	8.0	601.3	105	125	0.171	2.72	0.616			
SR 144	608.8	B-002-0-23	4.5	-	6	SS-3	9	56	1	-	-	-	-	-	-	-	-	21	A-7-6	Cohesive	1	1000	2250	1197	107	22	5.0	603.8	100	120		2.65	0.654			
SR 144	608.8	B-002-0-23	6	-	7.5	SS-4	6	78	0.5	-	-	-	-	-	-	-	-	16	A-7-6	Cohesive	1	500	1500	798	75	21	7.0	601.8	95	120		2.65	0.741			
SR 144	608.8	B-002-0-23	7.5	-	9	ST-5	ST	89	1.5	7	10	13	31	39	48	23	25	27	A-7-6	Cohesive	1	1500	N/A	N/A			8.0	600.8			0.342	2.65		94.4	122.4	602.5
SR 144	608.8	B-002-0-23	9	-	10.5	SS-6	14	89	2.5	-	-	-	-	-	-	-	-	29	A-7-6	Cohesive	1	2500	3500	1862	143	24	10.0	598.8	105	125		2.65	0.575			

ODOT District 10
ATH-144-12.08

Soil Strength Parameter Determination

Computed By = AKB
Checked By = DCM

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 2

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC
Max	22	100	4.5	13	9	48	50	40	50	23	27	23
Min	11	28	1.5	1	2	9	23	14	40	20	20	10
Average	16	75	3.0	7	7	23	33	30	44	21	23	18
Std Dev	3	25	0.9	5	3	18	12	11	5	2	4	4
Avg + Std	20	99	3.9	12	10	40	45	41	49	23	27	23
Avg - Std	13	50	2.1	2	4	5	21	19	39	19	19	14

	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)
Max	4500	4000	2926	173	26	16.0	609.6	115	130	0.360	2.72	0.654	102	127	1013
Min	1500	2800	1729	136	23	2.0	593.3	100	120	0.270	2.65	0.438	102	127	1013
Average	3000	3558	2231	154	24	11.2	599.2	111	128	0.306	2.67	0.506	102	127	1013
Std Dev	901	474	403	12	1	4.1	4.8	5	3	0.048	0.03	0.068	N/A	N/A	N/A
Avg + Std	3901	4032	2635	166	25	15.2	604.0	116	131	0.354	2.70	0.574	N/A	N/A	N/A
Avg - Std	2099	3084	1828	142	24	7.1	594.3	106	124	0.258	2.64	0.438	N/A	N/A	N/A

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)
SR 144	609.3	B-001-0-23	10	-	11.5	SS-4	17	78	-	6	9	48	23	14	NP	NP	NP	12	A-4a	NP SILT	2	N/A				26	11.0	598.3	110	130	N/A		2.72	0.543			
SR 144	609.3	B-001-0-23	12.5	-	14	SS-5	11	28	-	-	-	-	-	-	-	-	NP	10	A-4a	NP SILT	2	N/A				25	13.0	596.3	110	130			2.72	0.543			
SR 144	609.3	B-001-0-23	15	-	16.5	SS-6	20	78	3.5	-	-	-	-	-	-	-	-	14	A-7-6	Cohesive	2	3500	4000	2660	167	25	16.0	593.3	115	130			2.65	0.438			
SR 144	608.8	B-002-0-23	10.5	-	12	SS-7	22	78	2	-	-	-	-	-	-	-	-	23	A-7-6	Cohesive	2	2000	4000	2926	173	25	11.0	597.8	115	130			2.65	0.438			
SR 144	608.8	B-002-0-23	12	-	13.5	SS-8	14	100	3.5	13	8	22	26	31	42	20	22	19	A-7-6	Cohesive	2	3500	3500	1862	143	24	13.0	595.8	110	125	0.288	2.65	0.503			
SR 144	608.8	B-002-0-23	13.5	-	15	SS-9	19	100	3	-	-	-	-	-	-	-	-	20	A-7-6	Cohesive	2	3000	4000	2527	163	25	14.0	594.8	115	130			2.65	0.438			
SR 144	611.6	B-003-0-23	1.5	-	3	SS-1	13	89	3	-	-	-	-	-	-	-	-	16	A-7-6	Cohesive	2	3000	3250	1729	136	23	2.0	609.6	100	120			2.65	0.654			
SR 144	611.6	B-003-0-23	5	-	6.5	SS-2	14	56	3.5	9	8	9	34	40	50	23	27	21	A-7-6	Cohesive	2	3500	3500	1862	143	24	6.0	605.6	105	125	0.36	2.65	0.575			
SR 144	611.6	B-003-0-23	7.5	-	9	SS-3	16	33	-	-	-	-	-	-	-	-	-	19	A-7-6	Cohesive	2	N/A	4000	2128	153	24	8.0	603.6	110	125			2.65	0.503			
SR 144	611.6	B-003-0-23	10	-	11.5	SS-4	17	67	2.5	-	-	-	-	-	-	-	-	22	A-6b	Cohesive	2	2500	2975	2261	157	24	11.0	600.6	115	130			2.70	0.465			
SR 144	611.6	B-003-0-23	12.5	-	14.5	ST-5	ST	100	4.5	1	2	12	50	35	40	20	20	22	A-6b	Cohesive	2	4500	N/A	N/A			14.0	597.6			0.27	2.70		102.4	126.6	1013
SR 144	611.6	B-003-0-23	14.5	-	16	SS-6	16	89	1.5	-	-	-	-	-	-	-	-	22	A-6b	Cohesive	2	1500	2800	2128	153	24	15.0	596.6	115	130			2.70	0.465			

ODOT District 10
ATH-144-12.08

Soil Strength Parameter Determination

Computed By = AKB
Checked By = DCM

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 3

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)
Max	13	100	4.5	7	5	10	46	61	63	27	36	46	Max	4500	3250	1729	136	23	21.0	592.8	110	125	0.477	2.65	0.741	104	128	737
Min	8	17	0.5	2	3	4	30	35	42	25	17	17	Min	500	2000	1064	100	22	16.0	588.3	95	120	0.288	2.65	0.503	104	128	737
Average	11	53	1.9	4	4	8	36	48	53	26	27	31	Average	1875	2750	1463	122	23	18.0	591.1	105	123	0.383	2.65	0.582	104	128	737
Std Dev	3	43	1.8	3	1	3	9	13	15	1	13	14	Std Dev	1797	661	352	19	1	2.2	1.9	9	3	0.134	0.00	0.137	N/A	N/A	N/A
Avg + Std	14	96	3.7	7	5	11	45	61	67	27	40	45	Avg + Std	3672	3411	1815	141	24	20.2	593.0	114	126	0.516	2.65	0.719	N/A	N/A	N/A
Avg - Std	8	10	0.1	1	3	4	28	35	38	25	13	17	Avg - Std	78	2089	1111	103	22	15.8	589.1	96	120	0.249	2.65	0.445	N/A	N/A	N/A

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)	Strength Testing Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)
SR 144	609.3	B-001-0-23	17.5	-	19	SS-7	8	78	1.5	2	3	4	30	61	63	27	36	46	A-7-6	Cohesive	3	1500	2000	1064	100	22	18.0	591.3	95	120	0.477	2.65	0.741			
SR 144	609.3	B-001-0-23	20	-	22	ST-8	ST	100	4.5	7	3	9	46	35	42	25	17	22	A-7-6	Cohesive	3	4500	N/A	N/A			21.0	588.3			0.288	2.65		104.3	127.5	736.5
SR 144	608.8	B-002-0-23	15	-	16.5	SS-10	12	17	1	-	-	-	-	-	-	-	-	17	A-7-6	Cohesive	3	1000	3000	1596	129	23	16.0	592.8	110	125		2.65	0.503			
SR 144	608.8	B-002-0-23	16.5	-	18	SS-11	13	17	0.5	3	5	10	33	49	-	-	-	40	A-7-6	Cohesive	3	500	3250	1729	136	23	17.0	591.8	110	125		2.65	0.503			

ODOT District 10
ATH-144-12.08

Soil Strength Parameter Determination

Computed By = AKB
Checked By = DCM

Values for Soil Strength Correlation	
Reference	Value
HI PI (Sowers)	0.25
MD PI (Sowers)	0.175
LO PI (Sowers)	0.075
T&P	0.133

Layer 4

	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
Max	74	100	4.5	17	6	9	44	41	42	24	22	19	Max	4500	4000	4000	250	28	23.0	593.6	130	140	0.288	2.65	0.323
Min	38	67	2.0	2	4	5	34	38	41	20	17	13	Min	2000	4000	4000	200	28	18.0	586.3	125	135	0.279	2.65	0.272
Average	52	90	3.9	10	5	7	39	40	42	22	20	17	Average	3917	4000	4000	243	28	20.9	589.2	128	138	0.284	2.65	0.292
Std Dev	14	15	1.0	11	1	3	7	2	1	3	4	2	Std Dev	1021	0	0	19	0	2.0	2.5	3	3	0.006	0.00	0.028
Avg + Std	66	104	4.9	20	6	10	46	42	42	25	23	19	Avg + Std	4937	4000	4000	262	28	22.8	591.7	131	141	0.290	2.65	0.320
Avg - Std	37	75	2.9	-1	4	4	32	37	41	19	16	14	Avg - Std	2896	4000	4000	224	28	18.9	586.8	125	135	0.277	2.65	0.264

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N_{60}	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf) N-values PPR	Sowers	T & P	Correlated LT Cohesion (psf) per GB-7	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated Dry Unit Wt. (pcf) per GB-7	Correlated Moist Unit Wt. (pcf) per GB-7	Correlated C_c	Assumed Specific Gravity (G_s)	Computed Void Ratio (e)
SR 144	609.3	B-001-0-23	22	-	23.5	SS-9	51	89	4.5	-	-	-	-	-	-	-	-	19	A-7-6	Cohesive	4	4500	4000	4000	250	28	23.0	586.3	130	140		2.65	0.272
SR 144	608.8	B-002-0-23	18	-	19.5	SS-12	74	100	4.5	-	-	-	-	-	-	-	-	17	A-7-6	Cohesive	4	4500	4000	4000	250	28	19.0	589.8	125	135		2.65	0.323
SR 144	608.8	B-002-0-23	19.5	-	21	SS-13	38	100	4.5	2	4	9	44	41	41	24	17	18	A-7-6	Cohesive	4	4500	4000	4000	200	28	20.0	588.8	125	135	0.279	2.65	0.323
SR 144	608.8	B-002-0-23	21	-	22.5	SS-14	54	100	4.5	-	-	-	-	-	-	-	-	13	A-7-6	Cohesive	4	4500	4000	4000	250	28	22.0	586.8	130	140		2.65	0.272
SR 144	611.6	B-003-0-23	17.5	-	18.92	SS-7	Refusal	71	2	-	-	-	-	-	-	-	-	14	A-7-6	Cohesive	4	2000	N/A	N/A	250	28	18.0	593.6				2.65	
SR 144	611.6	B-003-0-23	20	-	21.5	SS-8	41	67	3.5	17	6	5	34	38	42	20	22	18	A-7-6	Cohesive	4	3500	4000	4000	250	28	21.0	590.6	130	140	0.288	2.65	0.272
SR 144	611.6	B-003-0-23	22.5	-	22.92	SS-9	Refusal	100	-	-	-	-	-	-	-	-	-	17	A-7-6	Cohesive	4	N/A	N/A	N/A	250	28	23.0	588.6				2.65	

National Engineering & Architectural Services Inc.
5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Cohesive Soil (ASTM D2166)

(Project: ATH-144-12.08 (10-Y), Boring Location: B-001-0-23, ST-8, Depth: 20.7 - 21.2ft)

Tested Date: 2/1/2023

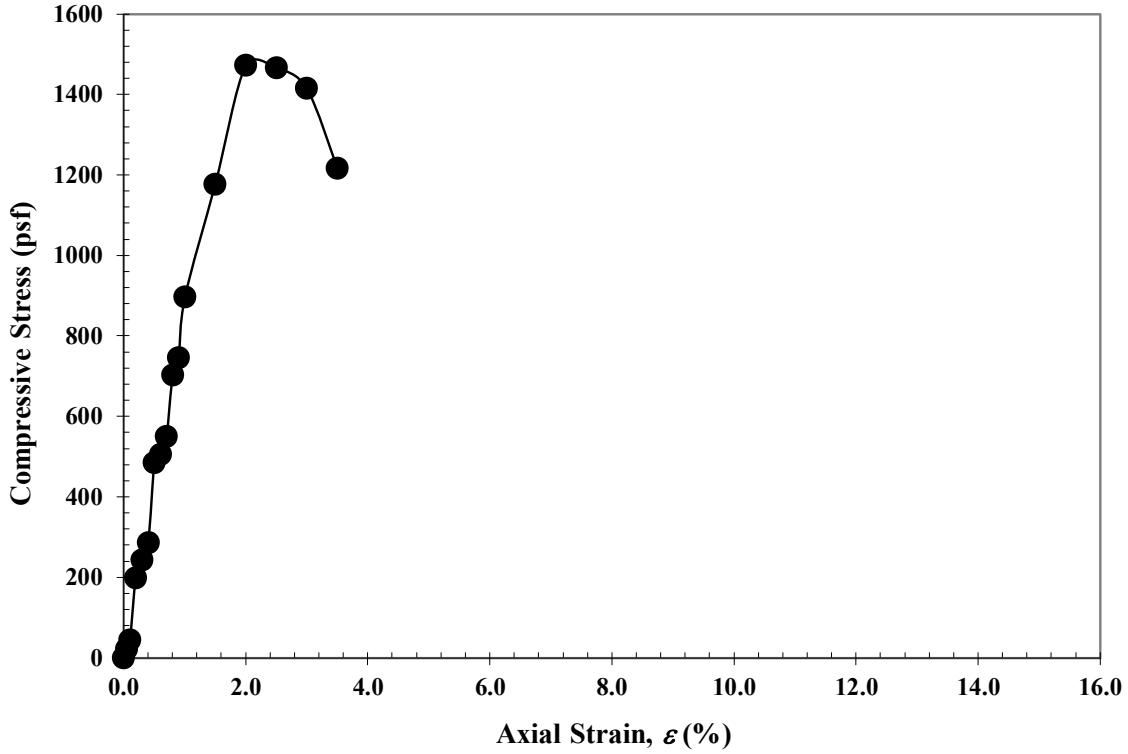
Specimen Properties

Average Dia., D_{avg} (in):	2.88
Average Height, H_{avg} (in):	5.75
Area, A (in^2):	6.51
Volume, V (in^3):	37.44
Wet Mass of Specimen (lb):	2.8
Moisture Content (%):	22.2
Dry Mass of Specimen (lb):	2.3
Wet Unit Weight, γ (lb/ft^3):	127.5
Dry Unit Weight, γ_d (lb/ft^3):	104.3

Final Specimen Figure

Results

Unconfined Compressive Strength (psf):	**1473**
Strain (%):	**2.0**



Notes: Medium stiff, brownish gray, CLAY, "and" silt, little sand, trace gravel, damp.

National Engineering & Architectural Services Inc.
5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Cohesive Soil (ASTM D2166)

(Project: ATH-144-12.08 (10-Y), Boring Location: B-002-0-23, ST-5, Depth: 8.0 - 8.5ft)

Tested Date: 2/2/2023

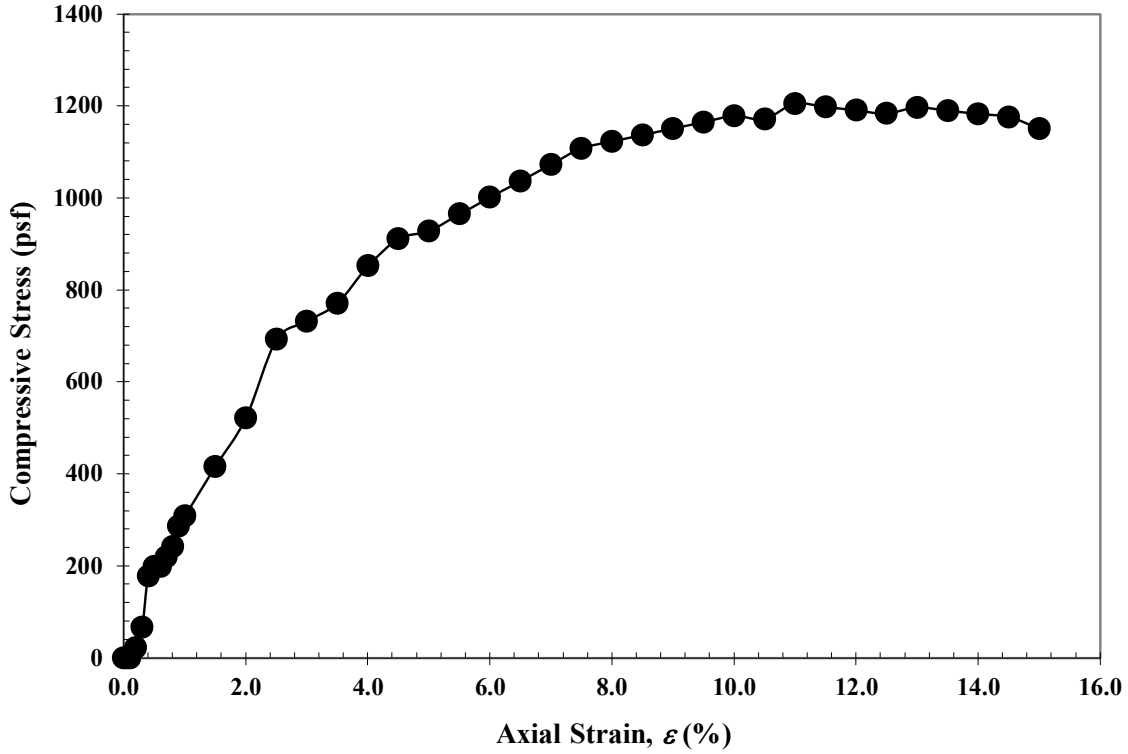
Specimen Properties

Average Dia., D_{avg} (in):	2.87
Average Height, H_{avg} (in):	5.72
Area, A (in^2):	6.49
Volume, V (in^3):	37.14
Wet Mass of Specimen (lb):	2.6
Moisture Content (%):	29.6
Dry Mass of Specimen (lb):	2.0
Wet Unit Weight, γ (lb/ft^3):	122.4
Dry Unit Weight, γ_d (lb/ft^3):	94.4

Final Specimen Figure

Results

Unconfined Compressive Strength (psf):	**1205**
Strain (%):	**11.0**



Notes: Medium stiff, brown, CLAY, some silt, some sand, trace gravel, moist. Specimen contains gravel >1/6 specimen diameter. Results reported may differ from a specimen that meets the maximum particle size allowance of D2166.

National Engineering & Architectural Services Inc.
5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Cohesive Soil (ASTM D2166)

(Project: ATH-144-12.08 (10-Y), Boring Location: B-003-0-23, ST-5, Depth: 13.7 - 14.2ft)

Tested Date: 2/3/2023

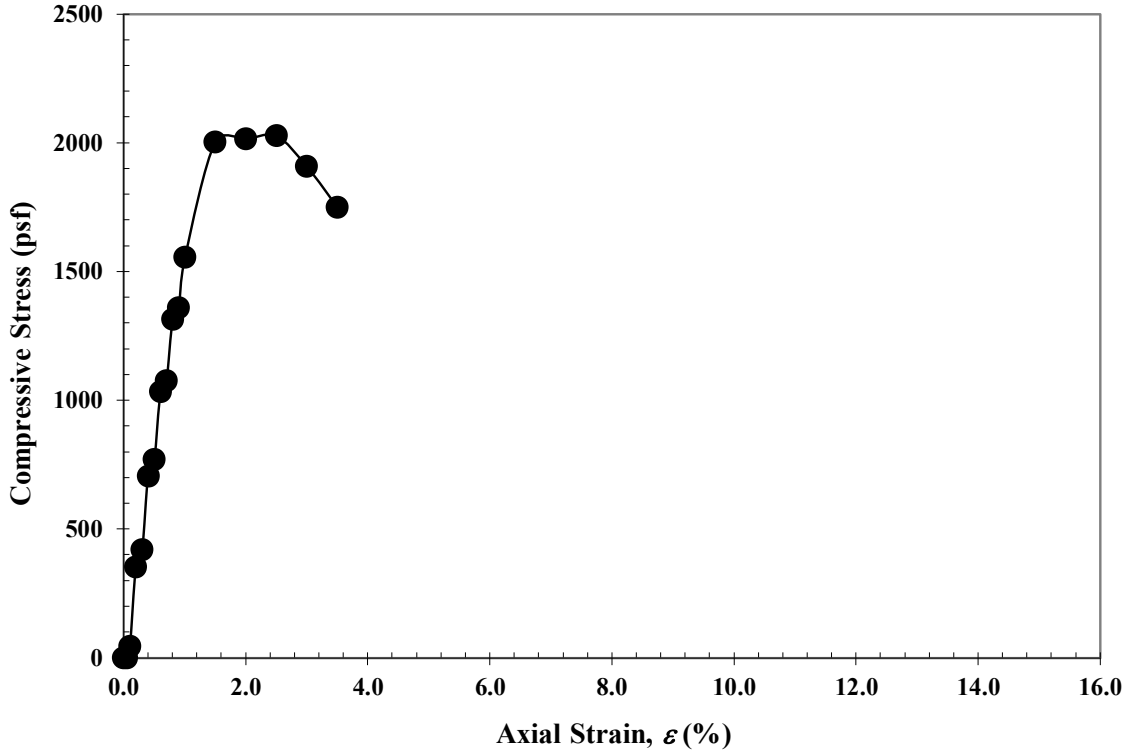
Specimen Properties

Average Dia., D_{avg} (in):	2.88
Average Height, H_{avg} (in):	5.73
Area, A (in^2):	6.52
Volume, V (in^3):	37.36
Wet Mass of Specimen (lb):	2.7
Moisture Content (%):	23.6
Dry Mass of Specimen (lb):	2.2
Wet Unit Weight, γ (lb/ft^3):	126.6
Dry Unit Weight, γ_d (lb/ft^3):	102.4

Final Specimen Figure

Results

Unconfined Compressive Strength (psf):	**2026**
Strain (%):	**2.5**



Notes: Stiff, reddish brown, SILTY CLAY, little sand, trace gravel, moist. Specimen contains gravel >1/6 specimen diameter. Results reported may differ from a specimen that meets the maximum particle size allowance of D2166.

PROJECT: ATH-144-12.08	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 311)	STATION / OFFSET: 638+35, 5' RT.	EXPLORATION ID B-001-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 144	
PID: 116165 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 609.3 (MSL) EOB: 50.0 ft.	PAGE 1 OF 2
START: 1/18/23 END: 1/19/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 84.9	LAT / LONG: 39.310401, -81.859024	

MATERIAL DESCRIPTION AND NOTES	ELEV. 609.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
18 inches of Asphalt	607.8	1																
STIFF TO VERY STIFF, RED-BROWN AND DARK RED-BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, DAMP (FILL)		2	4 6 5	16	44	SS-1	3.00	-	-	-	-	-	-	-	-	19	A-4a (V)	
Layer 1 - Medium Stiff to Stiff Cohesive 1		3																
		4																
		5	4 4 3	10	44	SS-2	-	-	-	-	-	-	-	-	-	11	A-4a (V)	
		6																
		7																
		8	3 4 3	10	44	SS-3	1.50	2	10	42	27	19	29	19	10	15	A-4a (2)	
	599.3	9																
MEDIUM DENSE, RED-BROWN AND DARK RED-BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, DAMP (FILL)		10																
Layer 2 - Stiff to Very Stiff Cohesive		11	4 6 6	17	78	SS-4	-	6	9	48	23	14	NP	NP	NP	12	A-4a (0)	
		12																
		13	3 4 4	11	28	SS-5	-	-	-	-	-	-	-	-	-	10	A-4a (V)	
		14																
	593.8	15																
STIFF TO VERY STIFF, LIGHT BROWN, **CLAY**, SOME SILT, TRACE GRAVEL, TRACE SAND, DAMP @ 16.0' - 16.5' : Auger Grinding		16	5 7 7	20	78	SS-6	3.50	-	-	-	-	-	-	-	-	14	A-7-6 (V)	
		17																
	590.3	18	2 2 4	8	78	SS-7	1.50	2	3	4	30	61	63	27	36	46	A-7-6 (20)	
STIFF TO VERY STIFF, RED-BROWN TRACE LIGHT BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP @ 20.7' - 21.2' : qu = 1473 psf	W 590.3	19																
Layer 3 - Medium Stiff to Stiff Cohesive 2		20																
		21			100	ST-8	4.50	7	3	9	46	35	42	25	17	22	A-7-6 (11)	
	587.3	22																
HARD, RED-BROWN TRACE LIGHT BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP		23	11 16 20	51	89	SS-9	4.50	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
Layer 4 - Hard Cohesive		24																
	584.3	25	50/4"	-	100	SS-10	-	-	-	-	-	-	-	-	-	10	Rock (V)	
SHALE, GRAY, MODERATELY WEATHERED, VERY WEAK.	TR	26																
		27																
Bedrock		28	50/3"	-	100	SS-11	-	-	-	-	-	-	-	-	-	10	Rock (V)	
		29																

PID: 116165	SFN:	PROJECT: ATH-144-12.08	STATION / OFFSET: 638+35, 5' RT.	START: 1/18/23	END: 1/19/23	PG 2 OF 2	B-001-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
	579.3																	
	578.8		50/3"	-	100	SS-12	-	-	-	-	-	-	-	-	-	14	Rock (V)	
SHALE, GRAY, SLIGHTLY TO MODERATELY WEATHERED, WEAK, VERY FINE TO FINE GRAINED, THIN TO MEDIUM BEDDED, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, MODERATELY TO SLIGHTLY FRACTURED, TIGHT TO NARROW APERTURE, SICKENSIDED TO SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITIONS; RQD 53%, REC 100%. @ 34.0' - 39.0' : Olive-gray @ 35.8' - 36.3' : Highly-Fractured with Staining @ 36.3' - 36.5' : Vertical Fracture with Staining @ 38.0' - 38.3' : Vertical Fracture with Staining		31 32 33 34 35 36 37 38 39 40	64		100	NQ2-1											CORE	
	567.3	41 42 43 44																
SHALE, GRAY, MODERATELY TO HIGHLY WEATHERED, VERY WEAK, VERY THIN TO THIN BEDDED, ARGILLACEOUS, JOINT AND BEDDING DISCONTINUITIES, HIGHLY FRACTURED TO FRACTURED, OPEN APERATURE, SLICKENSIDED, LAMINATED, POOR TO VERY POOR SURFACE CONDITIONS; RQD 42%, REC 100%. @ 45.3' - 45.7' : qu = 23 psi @ 46.7' - 47.3' : Dark-Gray Carbonaceous		45	35		100	NQ2-2										CORE	
	561.3	46 47 48 49																
LIMESTONE, GRAY, SLIGHTLY WEATHERED, STRONG, THIN BEDDED, CRYSTALLINE, JOINT AND BEDDING DISCONTINUITIES, MODERATELY FRACTURED TO FRACTURED, OPEN APERTURE, VERY ROUGH, VERY BLOCKY, GOOD SURFACE CONDITIONS; RQD 50%, REC 100%.	559.3	EOB 50																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

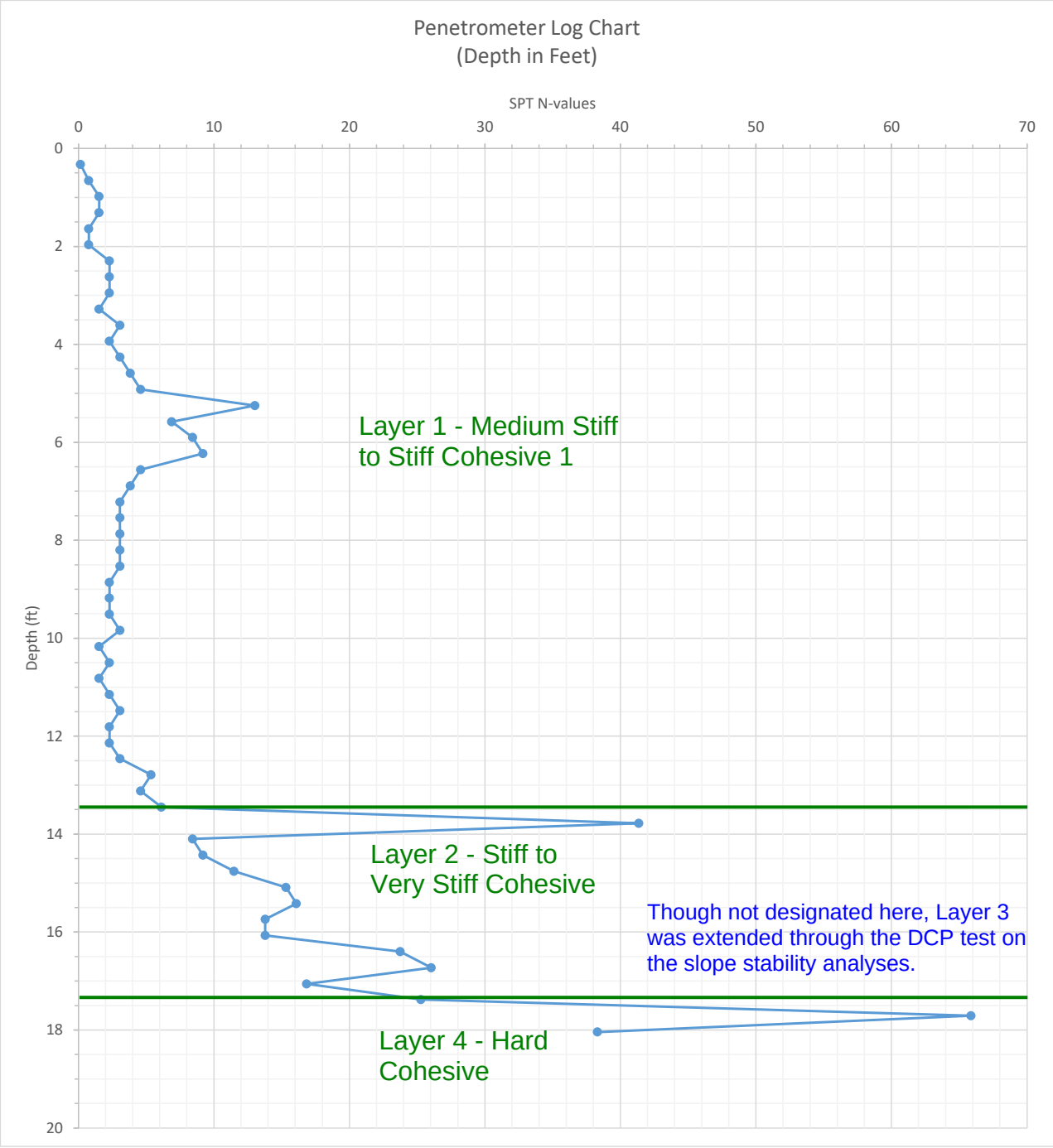
Dynamic Cone Penetration Test Log

Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-144-12.08 (10-Y)	**Lat / Long:**	39.310411 -81.859307
Location:	D-001-1-23	**North / East:**	477915 2149778
Station, Offset:	638+98, 54' RT.	**Date:**	2/6/2023
Elevation:	597.4	**Sheet:**	1 of 2
Notes:	Staked Location		

Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value
3.94	0.33	10	0.2	0.1532
7.87	0.66	20	1	0.766
11.81	0.98	30	2	1.532
15.75	1.31	40	2	1.532
19.69	1.64	50	1	0.766
23.62	1.97	60	1	0.766
27.56	2.3	70	3	2.298
31.5	2.62	80	3	2.298
35.43	2.95	90	3	2.298
39.37	3.28	100	2	1.532
43.31	3.61	110	4	3.064
47.24	3.94	120	3	2.298
51.18	4.26	130	4	3.064
55.12	4.59	140	5	3.83
59.06	4.92	150	6	4.596
62.99	5.25	160	17	13.022
66.93	5.58	170	9	6.894
70.87	5.9	180	11	8.426
74.8	6.23	190	12	9.192
78.74	6.56	200	6	4.596
82.68	6.89	210	5	3.83
86.61	7.22	220	4	3.064
90.55	7.54	230	4	3.064
94.49	7.87	240	4	3.064
98.43	8.2	250	4	3.064
102.36	8.53	260	4	3.064
106.3	8.86	270	3	2.298
110.24	9.18	280	3	2.298
114.17	9.51	290	3	2.298
118.11	9.84	300	4	3.064
122.05	10.17	310	2	1.532
125.98	10.5	320	3	2.298
129.92	10.82	330	2	1.532
133.86	11.15	340	3	2.298
137.8	11.48	350	4	3.064
141.73	11.81	360	3	2.298
145.67	12.14	370	3	2.298
149.61	12.46	380	4	3.1
153.54	12.79	390	7	5.4
157.48	13.12	400	6	4.6
161.42	13.45	410	8	6.1
165.35	13.78	420	54	41.4
169.29	14.1	430	11	8.4
173.23	14.43	440	12	9.2
177.17	14.76	450	15	11.5
181.1	15.09	460	20	15.3
185.04	15.42	470	21	16.1
188.98	15.74	480	18	13.8
192.91	16.07	490	18	13.8
196.85	16.4	500	31	23.7
200.79	16.73	510	34	26.0
204.72	17.06	520	22	16.9
208.66	17.38	530	33	25.3
212.6	17.71	540	86	65.9
216.54	18.04	550	50	38.3

Dynamic Cone Penetration Test Log

Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-144-12.08 (10-Y)	**Lat / Long:**	39.310411 -81.859307
Location:	D-001-1-23	**North / East:**	477915 2149778
Station, Offset:	638+98, 54' RT.	**Date:**	2/6/2023
Elevation:	597.4	**Sheet:**	2 of 2
Notes:	Staked Location		



PROJECT: ATH-144-12.08	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 481)	STATION / OFFSET: 639+63, 5' RT.	EXPLORATION ID B-002-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 144	
PID: 116165 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 608.8 (MSL) EOB: 44.0 ft.	PAGE 1 OF 2
START: 1/16/23 END: 1/17/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 86.8	LAT / LONG: 39.310198, -81.859393	

MATERIAL DESCRIPTION AND NOTES	ELEV. 608.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
18 inches of Asphalt	607.3	1																
MEDIUM DENSE, DARK BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP (FILL) Granular material omitted from analysis as isolated fill material.	604.3	2 3 4	5 6 6	17	67	SS-1	-	38	25	16	14	7	19	14	5	8	A-1-b (0)	
			9 10 3	19	67	SS-2	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
MEDIUM STIFF TO STIFF, RED-BROWN AND GRAY-RED-BROWN, **CLAY**, SOME SAND, SOME SILT, TRACE GRAVEL, DAMP (POSSIBLE FILL) Layer 1 - Medium Stiff to Stiff Cohesive 1		5 6 7	2 3 3	9	56	SS-3	1.00	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
@ 8.0' - 8.5' : qu = 1205 psf			2 2 2	6	78	SS-4	0.50	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
		8			89	ST-5	1.50	7	10	13	31	39	48	23	25	27	A-7-6 (14)	
	598.3	9 10	5 5 5	14	89	SS-6	2.50	-	-	-	-	-	-	-	-	29	A-7-6 (V)	
STIFF TO VERY STIFF, RED-BROWN, **CLAY**, SOME SAND, SOME SILT, LITTLE GRAVEL, DAMP Layer 2 - Stiff to Very Stiff Cohesive		11 12 13	4 5 10	22	78	SS-7	2.00	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
			4 4 6	14	100	SS-8	3.50	13	8	22	26	31	42	20	22	19	A-7-6 (9)	
	593.8	14	3 5 8	19	100	SS-9	3.00	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
MEDIUM STIFF TO STIFF, RED-BROWN, **CLAY**, SOME SILT, LITTLE SAND, TRACE GRAVEL, DAMP TO MOIST Layer 3 - Medium Stiff to Stiff Cohesive 2		15 16 17	4 4 4	12	17	SS-10	1.00	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
	590.8		2 3 6	13	17	SS-11	0.50	3	5	10	33	49	-	-	-	40	A-7-6 (V)	
HARD, RED-BROWN AND GRAY, **CLAY**, "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, (RELIC ROCK STRUCTURE), DAMP (RESIDUUM) Layer 4 - Hard Cohesive		18 19 20	12 16 35	74	100	SS-12	4.50	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
			13 11 15	38	100	SS-13	4.50	2	4	9	44	41	41	24	17	18	A-7-6 (11)	
	585.8	21 22	12 17 20	54	100	SS-14	4.50	-	-	-	-	-	-	-	-	13	A-7-6 (V)	
@ 22.9' - 23.0' : Black, Carbonaceous		23 TR	8 30 50/3"	-	100	SS-15	-	-	-	-	-	-	-	-	-	7	Rock (V)	
SHALE, RED-BROWN AND GRAY, HIGHLY WEATHERED, VERY WEAK.	584.8	24																
SHALE, RED-BROWN AND GRAY, MODERATELY WEATHERED, VERY WEAK, THIN TO MEDIUM BEDDED, JOINT AND BEDDING DISCONTINUITIES, FRACTURED, NARROW APERTURE, SLIGHTLY ROUGH, LAMINTATED TO VERY BLOCKY, POOR SURFACE; RQD 18%, REC 100%. @ 24.2' - 24.6' : qu = 311 psi @ 26.3' - 28.5' : Vertical Fracture @ 27.5' - 29.0' : Highly Fractured Bedrock	579.7	25 26 27 28 29	18		100	NQ2-1											CORE	

PID: 116165	SFN:	PROJECT: ATH-144-12.08	STATION / OFFSET: 639+63, 5' RT.	START: 1/16/23	END: 1/17/23	PG 2 OF 2	B-002-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
@ 29.7' - 30.5' : Very Weak, Friable, Shale **SHALE**, GRAY, SLIGHTLY WEATHERED, WEAK, VERY FINE TO FINE GRAINED, MEDIUM TO THICK BEDDED, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, MODERATELY TO SLIGHTLY FRACTURED, NARROW TO TIGHT APERTURE, SLIGHTLY ROUGH, BLOCKY, FAIR SURFACE CONDITIONS; RQD 54%, REC 100%. *(continued)*	578.8	31	72		100	NQ2-2											CORE	
@ 31.8' - 32.5' : Sandstone, Fine to Medium Grained		32																
@ 34.8' - 35.8' : Olive, Highly Fractured, Vertical Fracture with Staining		33																
@ 35.8' - 37.0' : Sandstone, Gray, Slightly to Moderately Weathered, Fine to Medium Grained, Slightly Strong		34																
@ 37.2' - 39.0' : Olive, Highly Fractured, Vertical Fracture with Staining		35	27		100	NQ2-3											CORE	
@ 39.0' - 39.5' : Olive		36																
		37																
		38																
		39																
		40																
		41	62		100	NQ2-4											CORE	
@ 42.0' - 44.0' : Dark Blackish Gray		42																
		43																
	564.8	EOB 44																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

Dynamic Cone Penetration Test Log

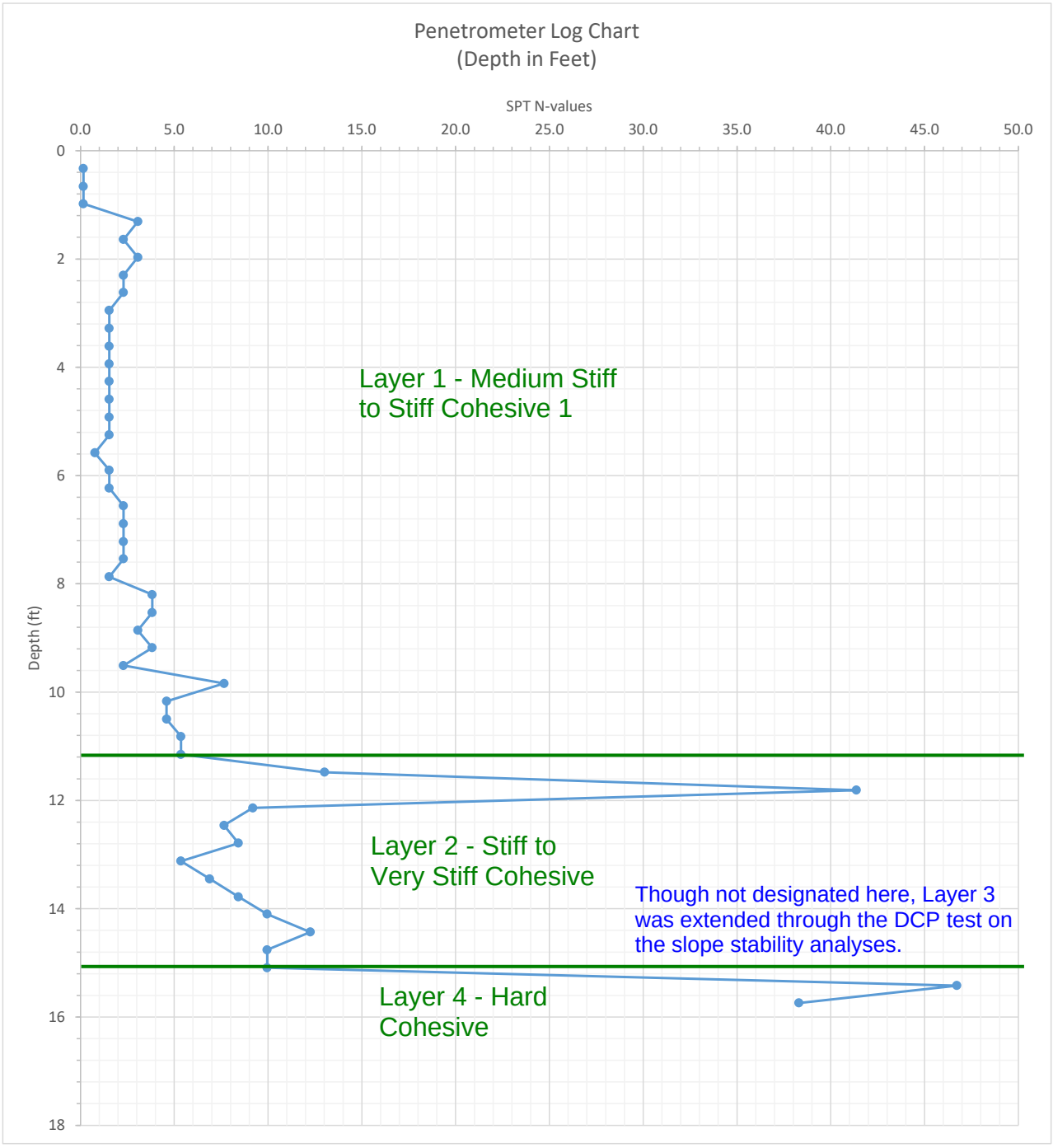
Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-144-12.08 (10-Y)	**Lat / Long:**	39.310305 -81.859488
Location:	D-002-1-23	**North / East:**	477876 2149727
Station, Offset:	639+61, 52' RT.	**Date:**	2/6/2023
Elevation:	597.6	**Sheet:**	1 of 2
Notes:	Staked Location		

Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value
3.94	0.33	10	0.2	0.2
7.87	0.66	20	0.2	0.2
11.81	0.98	30	0.2	0.2
15.75	1.31	40	4	3.1
19.69	1.64	50	3	2.3
23.62	1.97	60	4	3.1
27.56	2.3	70	3	2.3
31.5	2.62	80	3	2.3
35.43	2.95	90	2	1.5
39.37	3.28	100	2	1.5
43.31	3.61	110	2	1.5
47.24	3.94	120	2	1.5
51.18	4.26	130	2	1.5
55.12	4.59	140	2	1.5
59.06	4.92	150	2	1.5
62.99	5.25	160	2	1.5
66.93	5.58	170	1	0.8
70.87	5.9	180	2	1.5
74.8	6.23	190	2	1.5
78.74	6.56	200	3	2.3
82.68	6.89	210	3	2.3
86.61	7.22	220	3	2.3
90.55	7.54	230	3	2.3
94.49	7.87	240	2	1.5
98.43	8.2	250	5	3.8
102.36	8.53	260	5	3.8
106.3	8.86	270	4	3.1
110.24	9.18	280	5	3.8
114.17	9.51	290	3	2.3
118.11	9.84	300	10	7.7
122.05	10.17	310	6	4.6
125.98	10.5	320	6	4.6
129.92	10.82	330	7	5.4
133.86	11.15	340	7	5.362
137.8	11.48	350	17	13.022
141.73	11.81	360	54	41.364
145.67	12.14	370	12	9.192
149.61	12.46	380	10	7.66
153.54	12.79	390	11	8.426
157.48	13.12	400	7	5.362
161.42	13.45	410	9	6.894
165.35	13.78	420	11	8.426
169.29	14.1	430	13	9.958
173.23	14.43	440	16	12.256
177.17	14.76	450	13	9.958
181.1	15.09	460	13	9.958
185.04	15.42	470	61	46.726
188.98	15.74	480	50	38.3

Depth (in)	Depth (ft)	Depth (cm)	Pre Blows	SPT N-Value

Dynamic Cone Penetration Test Log

Client:	ODOT District 10	**Operator Name / Company:**	JK / Advanced Materials, LLC
Project Name:	ATH-144-12.08 (10-Y)	**Lat / Long:**	39.310305 -81.859488
Location:	D-002-1-23	**North / East:**	477876 2149727
Station, Offset:	639+61, 52' RT.	**Date:**	2/6/2023
Elevation:	597.6	**Sheet:**	2 of 2
Notes:	Staked Location		



PROJECT: ATH-144-12.08	DRILLING FIRM / OPERATOR: CENTRAL STAR / TS	DRILL RIG: DIEDRICH D-50 (SN 311)	STATION / OFFSET: 640+81, 5' RT.	EXPLORATION ID B-003-0-23
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: HDR / DM	HAMMER: AUTOMATIC HAMMER	ALIGNMENT: SR 144	
PID: 116165 SFN:	DRILLING METHOD: 2.25 HSA / NQ2	CALIBRATION DATE: 3/7/22	ELEVATION: 611.6 (MSL) EOB: 44.0 ft.	PAGE 1 OF 2
START: 1/18/23 END: 1/18/23	SAMPLING METHOD: SPT / ST / NQ2	ENERGY RATIO (%): 84.9	LAT / LONG: 39.309990, -81.859718	

MATERIAL DESCRIPTION AND NOTES	ELEV. 611.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
15 inches of Asphalt	610.3	1																
STIFF TO VERY STIFF, RED-BROWN, **CLAY**, SOME SILT, LITTLE SAND, TRACE GRAVEL, DAMP (POSSIBLE FILL)		2	8 5 4	13	89	SS-1	3.00	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
@ 3.5' - 5.0' : Limestone Boulder		3																
Layer 2 - Stiff to Very Stiff Cohesive		4																
		5	4 4 6	14	56	SS-2	3.50	9	8	9	34	40	50	23	27	21	A-7-6 (17)	
		6																
		7																
	601.6	8	3 6 5	16	33	SS-3	-	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
STIFF TO VERY STIFF, RED-BROWN, **SILTY CLAY**, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP		9																
		10																
		11	3 5 7	17	67	SS-4	2.50	-	-	-	-	-	-	-	-	22	A-6b (V)	
		12																
@ 13.7' - 14.2' : qu = 2026 psf		13			100	ST-5	4.50	1	2	12	50	35	40	20	20	22	A-6b (12)	
		14																
		15	4 5 6	16	89	SS-6	1.50	-	-	-	-	-	-	-	-	22	A-6b (V)	
		16																
@ 17.0' - 17.5' : Auger Grinding	594.1	17																
VERY STIFF TO HARD, LIGHT BROWN TRACE RED-BROWN, **CLAY**, SOME SILT, LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP		18	6 11 50/5"	-	71	SS-7	2.00	-	-	-	-	-	-	-	-	14	A-7-6 (V)	
Layer 4 - Hard Cohesive		19																
		20																
		21	9 16 13	41	67	SS-8	3.50	17	6	5	34	38	42	20	22	18	A-7-6 (13)	
		22																
W 589.1		23	50/5"	-	100	SS-9	-	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
@ 22.5' - 24.5' : Auger Grinding		24																
	587.1	25																
TR		26																
LIMESTONE, GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, STRONG, THICK BEDDED, CRYSTALLINE, BEDDING DISCONTINUITIES, SLIGHTLY FRACTURED, SLIGHTLY ROUGH, INTACT, G / GOOD SURFACE CONDITIONS; RQD %.	585.1	27																
Bedrock		28																
CLAYSTONE, RED-BROWN TO PURPLE, MODERATELY TO HIGHLY WEATHERED, VERY WEAK, THIN BEDDED, FRIABLE, JOINT AND BEDDING DISCONTINUITIES, FRACTURED, NARROW TO OPEN APERTURE, SLIGHTLY	581.6	29	58		95	NQ2-1											CORE	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 2/23/23 10:21 - C:\PWWORKING\EAST01\D3052797\20230118_ATH-144-12.08_10-Y_BORING LOGS.GPJ

PID: 116165	SFN:	PROJECT: ATH-144-12.08	STATION / OFFSET: 640+81, 5' RT.	START: 1/18/23	END: 1/18/23	PG 2 OF 2	B-003-0-23

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ROUGH TO SLICKENSIDED, LAMINATED, POOR SURFACE CONDITIONS; RQD 36%, REC 86%. @ 28.5' - 29.5' : Dark Gray and Black, Carbonaceous with Coal	581.6	31																
SHALE, GRAY TO OLIVE-GRAY, MODERATELY WEATHERED, WEAK, VERY FINE TO FINE GRAINED, MEDIUM BEDDED, ARENACEOUS, JOINT AND BEDDING DISCONTINUITIES, FRACTURE TO MODERATLY FRACTURED, NARROW TO OPEN APERTURE, SLIGHTLY ROUGH, BLOCKY, POOR TO FAIR SURFACE CONDITIONS; RQD 58%, REC 100%. @ 31.2' - 32.6' : qu = 942 psi @ 32.0' - 33.0' : Highly Fractured, Trace Red-Brown @ 33.5' - 35.5' : Trace Red-Brown @ 35.5' - 38.0' : Gray to Olive-Gray @ 36.8' - 37.5' : Vertical Fracture with Staining @ 39.3' - 39.5' : Vertical Fracture @ 40.3' - 40.8' : Very Weak, Friable, Vertical Fracture with Staining @ 40.8' - 41.8' : Gray to Olive-Gray @ 41.2' - 42.0' : Vertical Fracture (Unopened) @ 42.0' - 43.3' : Vertical Fracture with Staining, Highly Fractured @ 43.7' - 44.0' : Vertical Fracture with Staining		34 35 36 37 38 39 40 41 42 43	55		100	NQ2-2											CORE	
	567.6	EOB 44																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 20 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

Rock Strength Parameter Determination
and
Laboratory Testing

9999 Carver Road, Suite 210, Cincinnati, OH 45242-5583 **hdrinc.com**
(513) 984-7500

ODOT District 10
ATH-144-12.08

Rock Strength Parameter Determination

Computed By = AKB
Checked By = DCM

BEDROCK TESTING

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	(MPa)	Er Modulus (psi)	(MPa)	GSI Range	GSI USE	Em (Hoek & Brown) Modulus (GPa)	(psi)	Lesser of Er vs Em (psi)	Em (Yang) Modulus (MPa)	(psi)
ATH-144-12.08	B-001-0-23	45.3 - 45.7	NQ2-2	Shale	Gray	137.1	23	0.2	965	7	10 - 20	15	0.1	7702	965	0.1	19
ATH-144-12.08	B-002-0-23	24.2 - 24.6	NQ2-1	Shale	Gray	157.5	311	2.1	26,810	185	15 - 25	20	0.3	37768	26810	4.6	674
ATH-144-12.08	B-003-0-23	31.2 - 31.6	NQ2-1	Shale	Gray	161.2	942	6.5	21,493	148	20 - 30	25	0.6	87653	21493	4.7	680
				Shale	Maximum	161.2	942						Shale	Maximum	26810		
					Minimum	137.1	23							Minimum	965		
					Average	152	425							Average	16423		
					Std Dev	13	470							Std Dev	13648		
					Adopted Value	150	400							Adopted Value	16400		

Project	Exploration ID	Sample Depth (ft)	Sample ID	Rock Type	Color	Moist Unit Weight (pcf)	Compressive Strength (psi)	(MPa)	Er Modulus (psi)	(MPa)	GSI Range	GSI USE	Em (Hoek & Brown) Modulus (GPa)	(psi)	Lesser of Er vs Em (psi)	Em (Yang) Modulus (MPa)	(psi)
					Maximum	0	0							Maximum	0		
					Minimum	0	0							Minimum	0		
					Average	N/A	N/A							Average	N/A		
					Std Dev	N/A	N/A							Std Dev	N/A		
					Adopted Value									Adopted Value			

BEDROCK QUALITY

Project	Exploration ID	Rock Type	Depth Range (ft.) From	To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
ATH-144-12.08	B-001-0-23	Shale	30.5	42	11.5	53	11.1
ATH-144-12.08	B-001-0-23	Shale	42	48	6	42	4.6
ATH-144-12.08	B-002-0-23	Shale	24	29.1	5.1	18	1.7
ATH-144-12.08	B-002-0-23	Shale	29.1	44	14.9	54	14.6
ATH-144-12.08	B-003-0-23	Claystone	26.5	30	3.5	36	2.3
ATH-144-12.08	B-003-0-23	Shale	30	44	14	58	14.8
				Shale	55	RQD SUM	49
				Maximum	14.9	58	
				Minimum	3.5	18	
				Average	9.2	43.5	
				Adopted Value			49

Project	Exploration ID	Rock Type	Depth Range (ft.) From	To	Thickness (ft)	Layer RQD (%)	Weighted RQD*(Length / Total Length)
ATH-144-12.08	B-001-0-23	Limestone	48	50	2	50	25.0
ATH-144-12.08	B-003-0-23	Limestone	24.5	26.5	2	79	39.5
				Limestone	4	RQD SUM	65
				Maximum	2	79	
				Minimum	2	50	
				Average	2.0	64.5	
				Adopted Value			65

Table 10.4.6.5-1—Estimation of E_m Based on GSI

Expression	Notes/Remarks	Reference
$E_m\left(GPa\right) = \sqrt{\frac{q_u}{100}} 10^{\frac{GSI-10}{40}}$ for $q_u \le 100$ MPa $E_m\left(GPa\right) = 10^{\frac{GSI-10}{40}}$ for $q_u \le 100$ MPa	Accounts for rocks with $q_u < 100$ MPa; notes q_u in MPa	Hoek and Brown (1997); Hoek et al. (2002)
$E_m = \frac{E_R}{100} e^{GSI/21.7}$	Reduction factor on intact modulus, based on *GSI*	Yang (2006)

Notes: E_r = modulus of intact rock, E_m = equivalent rock mass modulus, *GSI* = geological strength index, q_u = uniaxial compressive strength, and 1 MPa = 2.09 ksf.

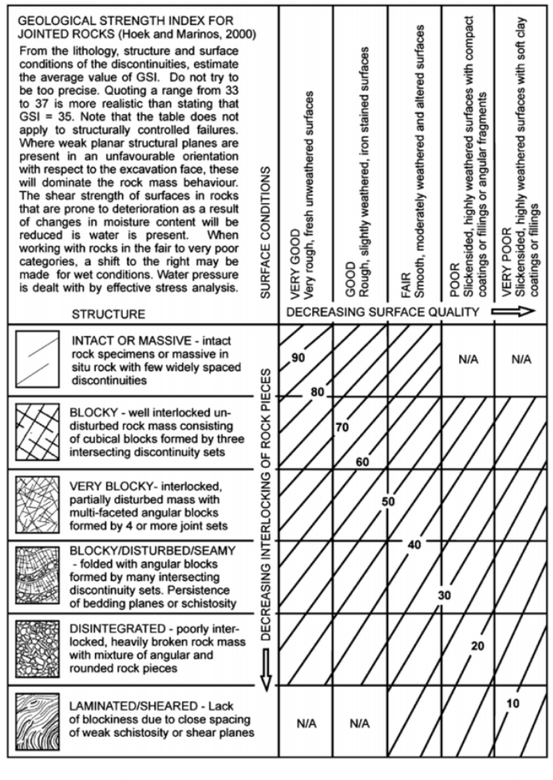


Figure 10.4.6.4-1—Determination of *GSI* for Jointed Rock Mass (Hoek and Marinos, 2000)

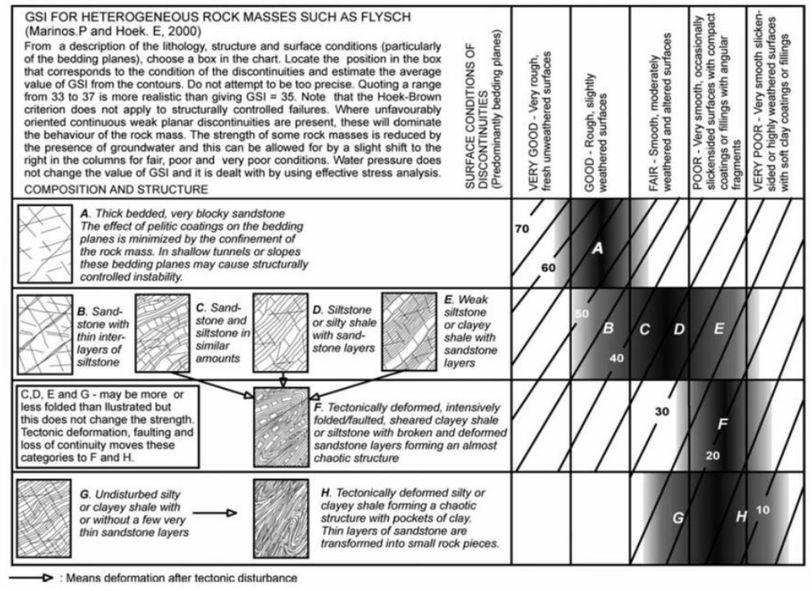


Figure 10.4.6.4-2—Determination of *GSI* for Tectonically Deformed Heterogeneous Rock Masses (Marinos and Hoek 2000)

National Engineering & Architectural Services Inc.
5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Rock Core (ASTM D7012 Method C)

(Project: ATH-144-12.08 (10-Y), Boring Location: B-001-0-23, NQ2-2, Depth: 45.3 - 45.7ft)

Tested Date: 1/31/2023

Specimen Properties

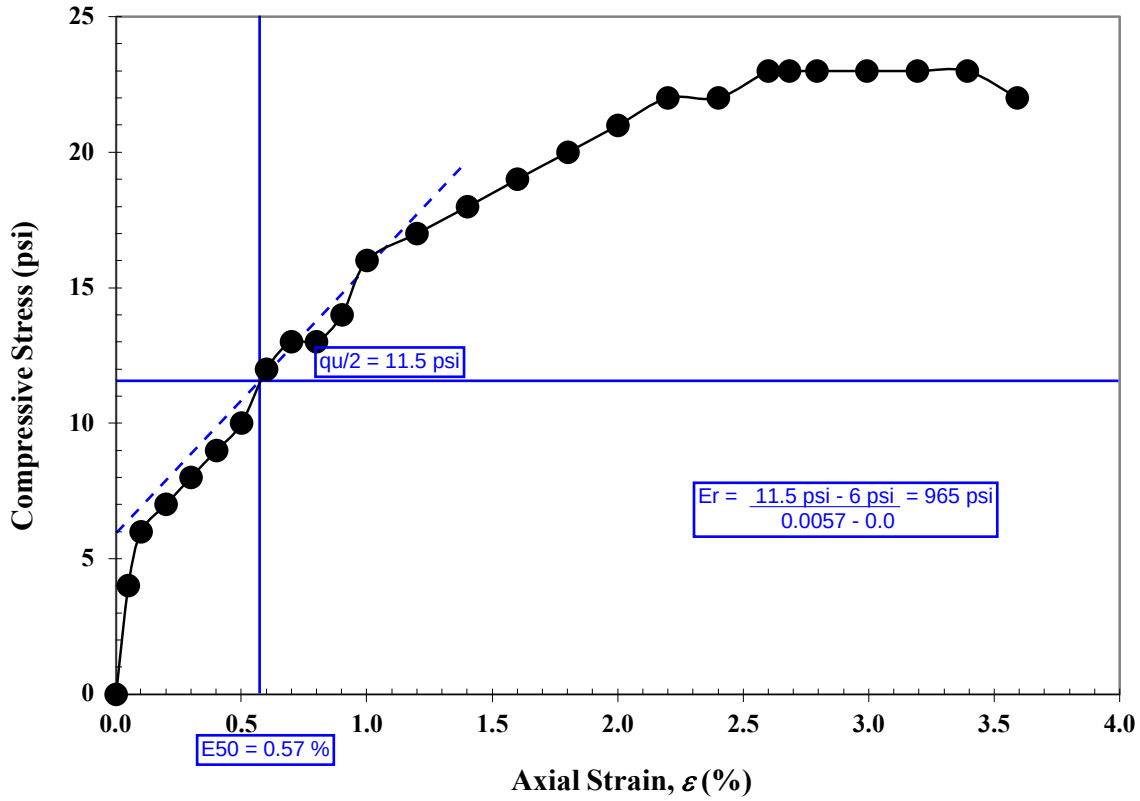
Average Dia., D_{avg} (in):	2.01
Average Height, H_{avg} (in):	4.51
Length to Diameter Ratio:	2.25
Area, A (in^2):	3.16
Volume, V (in^3):	14.26
Wet Mass of Specimen (lb):	1.1
Moisture Content (%):	13.9
Dry Mass of Specimen (lb):	1.0
Wet Unit Weight, γ (lb/ft^3):	137.1
Dry Unit Weight, γ_d (lb/ft^3):	120.4

Final Specimen Figure

Results

Unconfined Compressive Strength (psi): **23** **0.2** (MPa)

Strain (%): **2.6**



Notes: SHALE, gray, highly weathered, extremely weak, fissile, slickensided (after testing).

Sample trimming procedure does not conform to ASTM D4543 and the results reported may differ from the results obtained from a test specimen that meets the requirements of Practice D4543.

National Engineering & Architectural Services Inc.
5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Rock Core (ASTM D7012 Method C)

(Project: ATH-144-12.08 (10-Y), Boring Location: B-002-0-23, NQ2-1, Depth: 24.2 - 24.6ft)

Tested Date: 1/31/2023

Specimen Properties

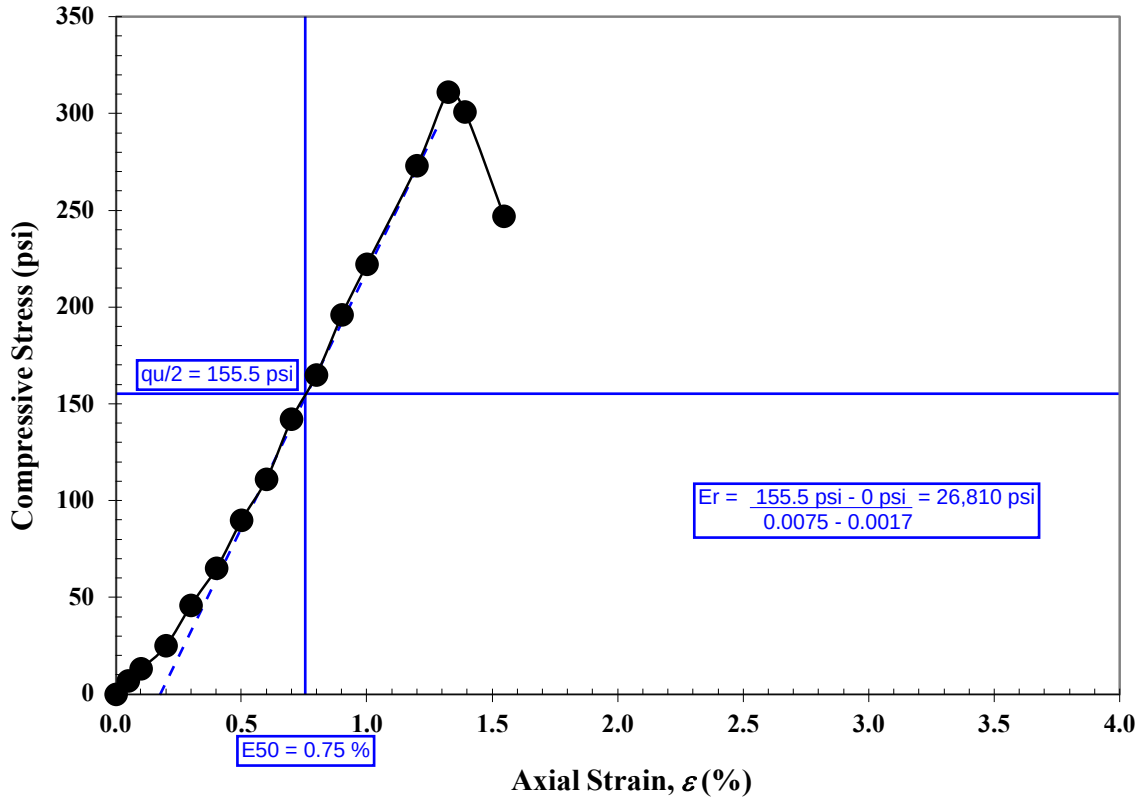
Average Dia., D_{avg} (in):	1.98
Average Height, H_{avg} (in):	4.53
Length to Diameter Ratio:	2.29
Area, A (in^2):	3.08
Volume, V (in^3):	13.93
Wet Mass of Specimen (lb):	1.3
Moisture Content (%):	5.4
Dry Mass of Specimen (lb):	1.2
Wet Unit Weight, γ (lb/ft^3):	157.5
Dry Unit Weight, γ_d (lb/ft^3):	149.5

Final Specimen Figure

Results

Unconfined Compressive Strength (psi): **311** **2** (MPa)

Strain (%): **1.3**



Notes: SHALE, gray, moderately weathered, very weak, silty.

Sample trimming procedure does not conform to ASTM D4543 and the results reported may differ from the results obtained from a test specimen that meets the requirements of Practice D4543.

National Engineering & Architectural Services Inc.
5710 Westbourne Avenue
Columbus, OH 43213
614-892-0162

Unconfined Compressive Strength of Rock Core (ASTM D7012 Method C)

(Project: ATH-144-12.08 (10-Y), Boring Location: B-003-0-23, NQ2-1, Depth: 31.2 - 31.6ft)

Tested Date: 1/31/2023

Specimen Properties

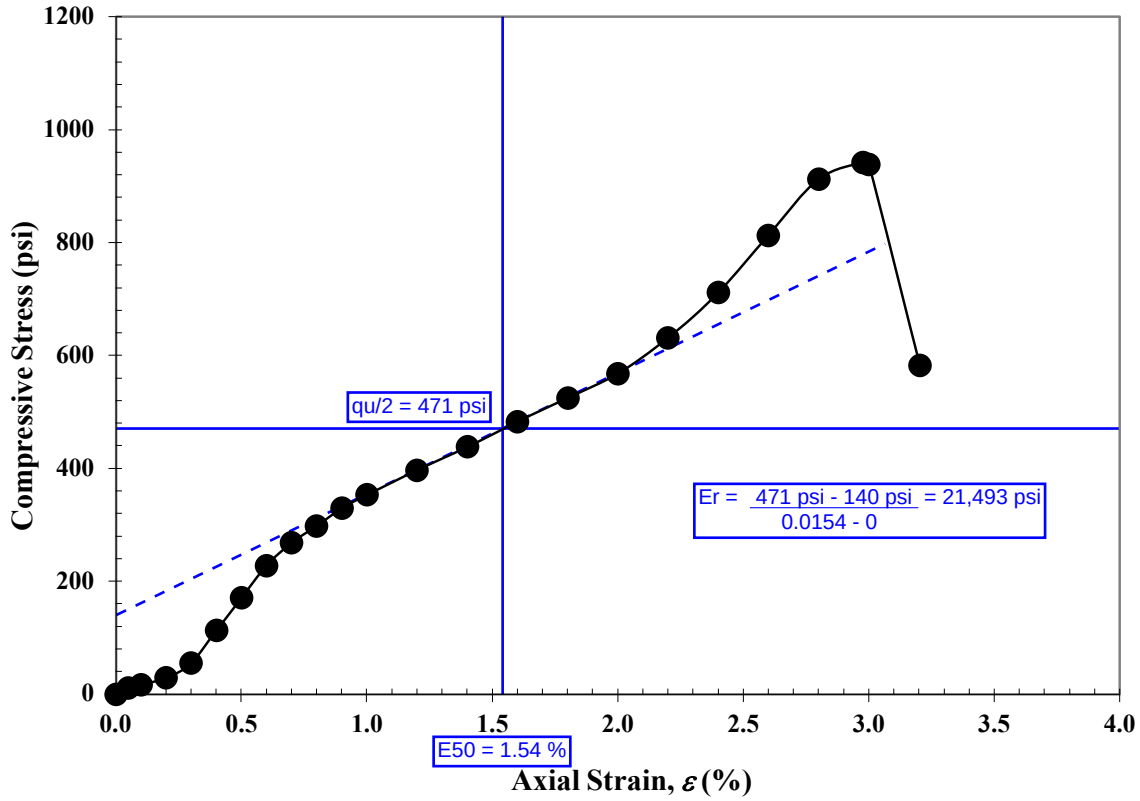
Average Dia., D_{avg} (in):	1.97
Average Height, H_{avg} (in):	4.43
Length to Diameter Ratio:	2.25
Area, A (in^2):	3.05
Volume, V (in^3):	13.55
Wet Mass of Specimen (lb):	1.3
Moisture Content (%):	3.6
Dry Mass of Specimen (lb):	1.2
Wet Unit Weight, γ (lb/ft^3):	161.2
Dry Unit Weight, γ_d (lb/ft^3):	155.5

Final Specimen Figure

Results

Unconfined Compressive Strength (psi): **942** **6** (MPa)

Strain (%): **3.0**



Notes: SHALE, gray, slightly weathered, weak, silty.

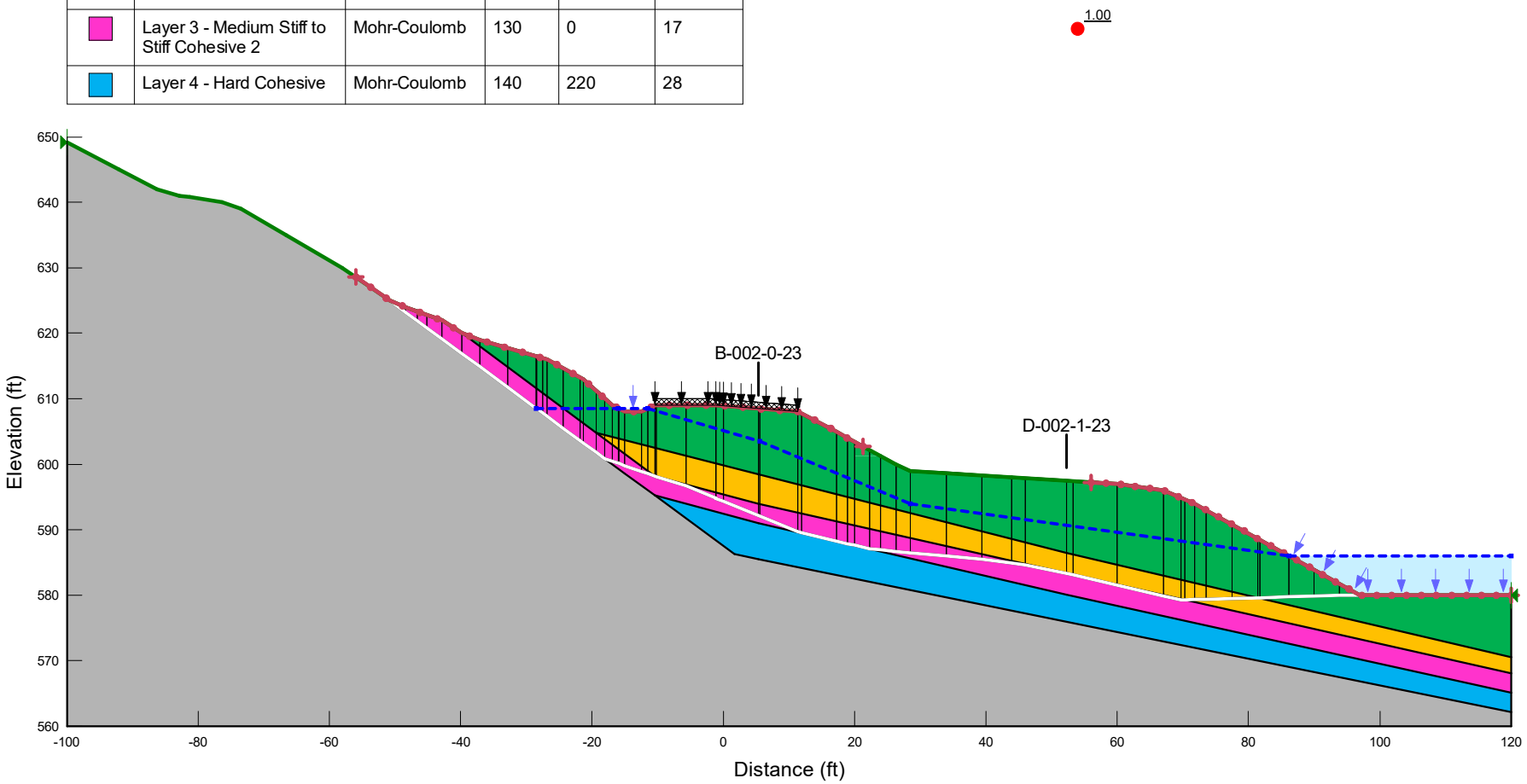
Sample trimming procedure does not conform to ASTM D4543 and the results reported may differ from the results obtained from a test specimen that meets the requirements of Practice D4543.

Slope Stability Analyses

Station 639+50
Existing Conditions

9999 Carver Road, Suite 210, Cincinnati, OH 45242-5583 **hdrinc.com**
(513) 984-7500

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Bedrock (Impenetrable)			
	Layer 1 - Medium Stiff to Stiff Cohesive 1	Mohr-Coulomb	120	140	24
	Layer 2 - Very Stiff Cohesive	Mohr-Coulomb	125	160	25
	Layer 3 - Medium Stiff to Stiff Cohesive 2	Mohr-Coulomb	130	0	17
	Layer 4 - Hard Cohesive	Mohr-Coulomb	140	220	28



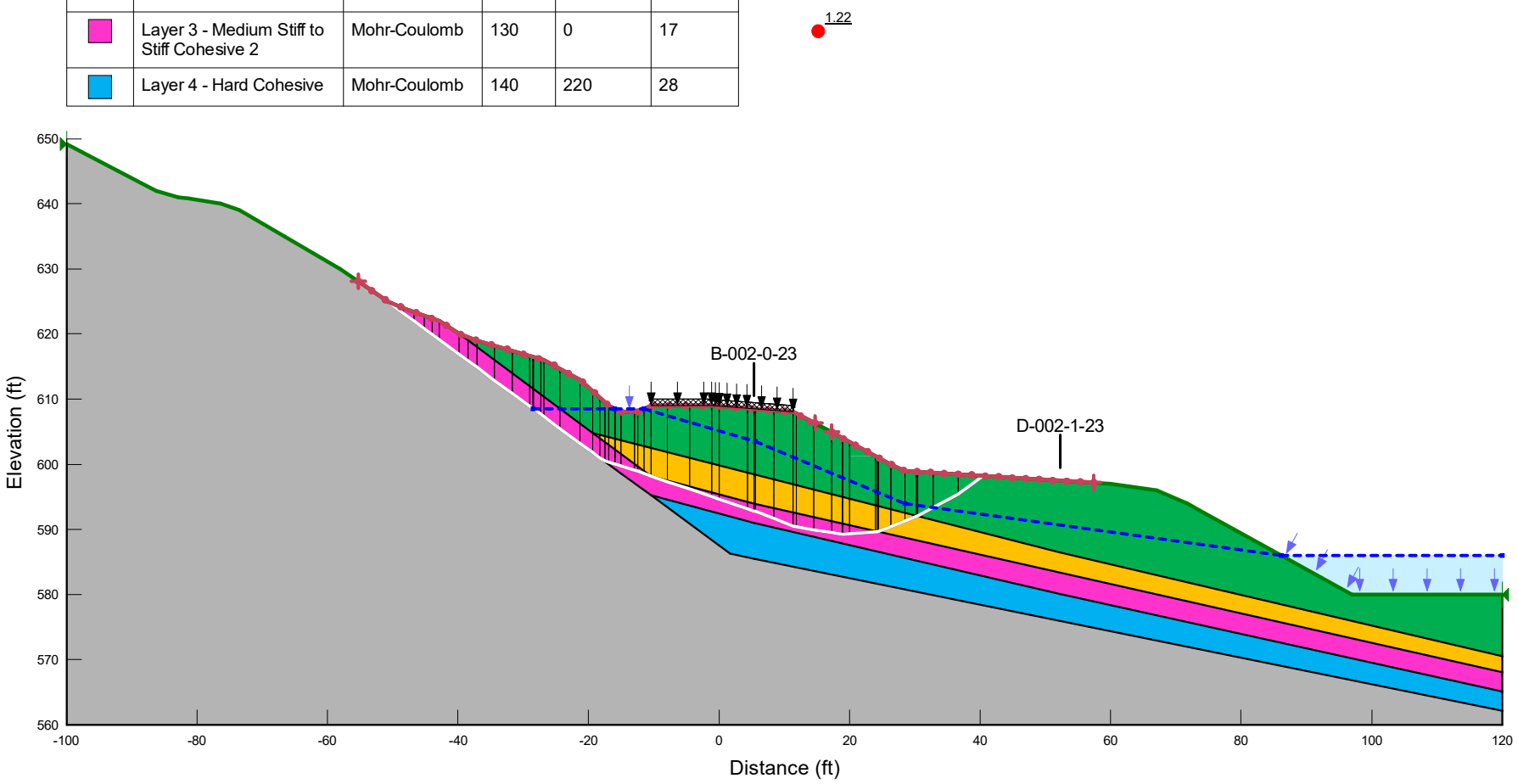
Sta. 639+50 (Global)

ATH-144-12.08 Slope Stability.gsz

02/23/2023 1:300

Local stability checked for comparison, but did not govern.

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Bedrock (Impenetrable)			
	Layer 1 - Medium Stiff to Stiff Cohesive 1	Mohr-Coulomb	120	140	24
	Layer 2 - Very Stiff Cohesive	Mohr-Coulomb	125	160	25
	Layer 3 - Medium Stiff to Stiff Cohesive 2	Mohr-Coulomb	130	0	17
	Layer 4 - Hard Cohesive	Mohr-Coulomb	140	220	28



Sta. 639+50 (Local)

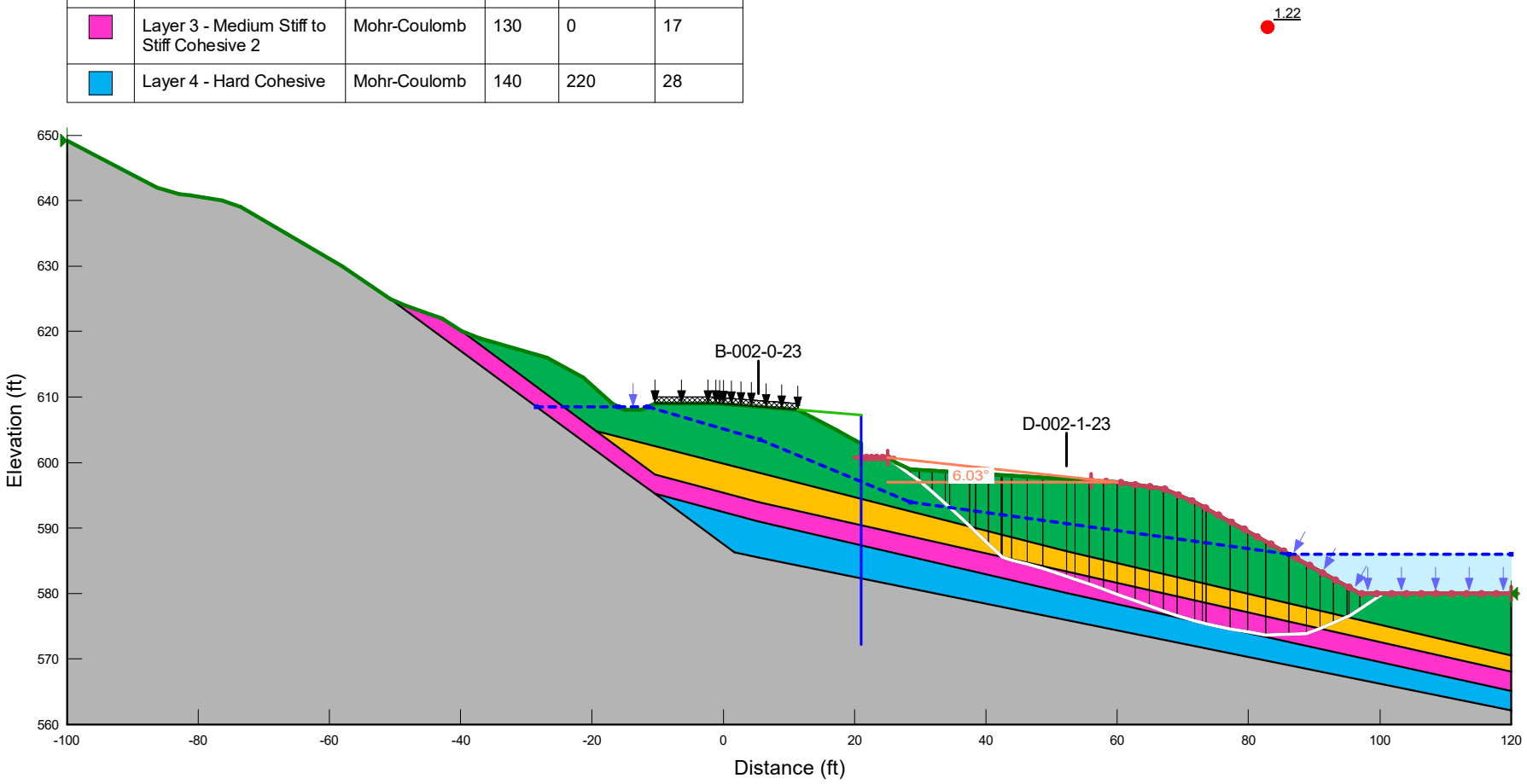
ATH-144-12.08 Slope Stability.gsz

02/23/2023 1:300

Station 639+50
Downslope Stability

9999 Carver Road, Suite 210, Cincinnati, OH 45242-5583 **hdrinc.com**
(513) 984-7500

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Bedrock (Impenetrable)			
	Layer 1 - Medium Stiff to Stiff Cohesive 1	Mohr-Coulomb	120	140	24
	Layer 2 - Very Stiff Cohesive	Mohr-Coulomb	125	160	25
	Layer 3 - Medium Stiff to Stiff Cohesive 2	Mohr-Coulomb	130	0	17
	Layer 4 - Hard Cohesive	Mohr-Coulomb	140	220	28



Sta. 639+50 (Downslope Stability)

ATH-144-12.08 Slope Stability.gsz

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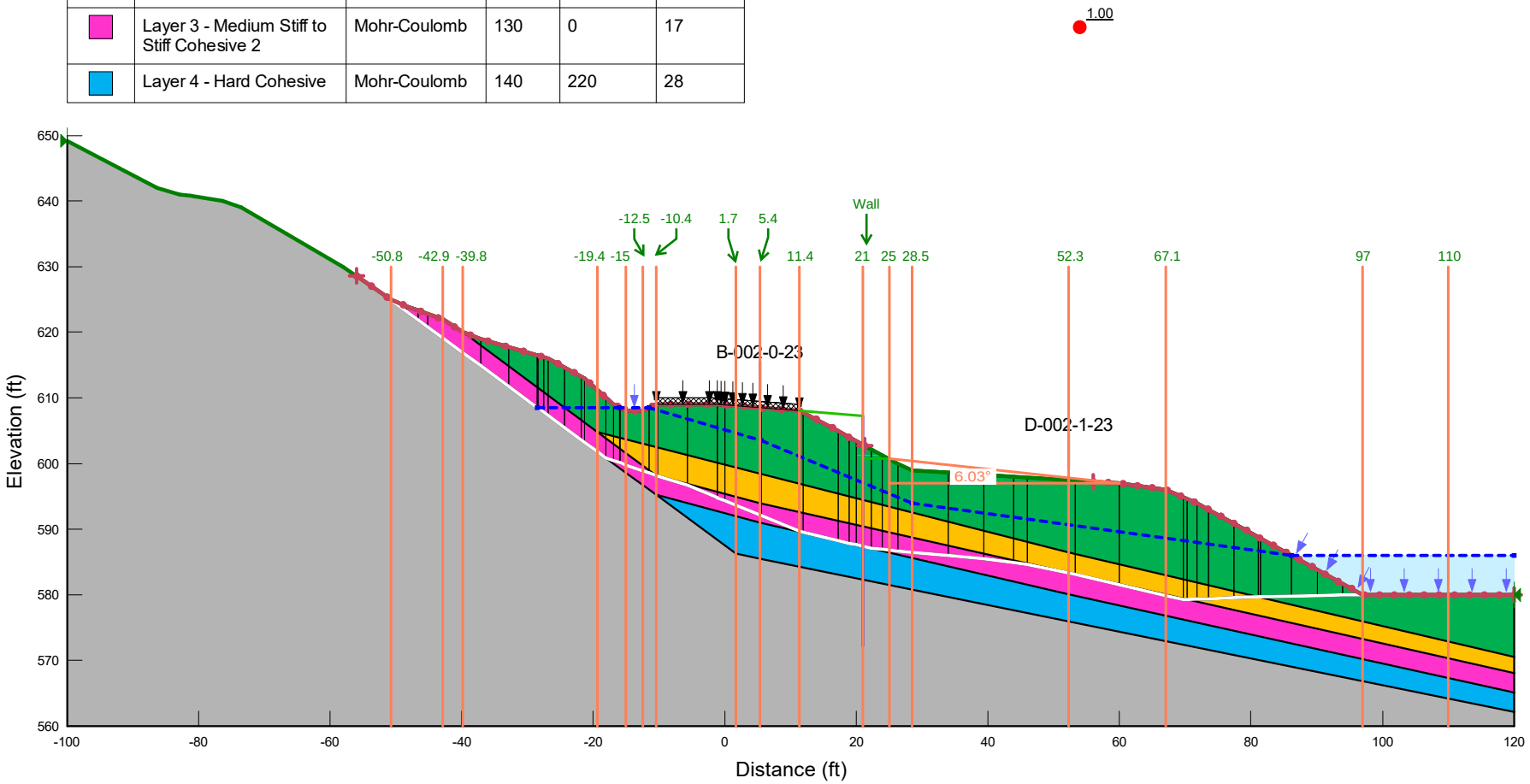
UA Slope Analyses

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Bedrock (Impenetrable)			
	Layer 1 - Medium Stiff to Stiff Cohesive 1	Mohr-Coulomb	120	140	24
	Layer 2 - Very Stiff Cohesive	Mohr-Coulomb	125	160	25
	Layer 3 - Medium Stiff to Stiff Cohesive 2	Mohr-Coulomb	130	0	17
	Layer 4 - Hard Cohesive	Mohr-Coulomb	140	220	28



Sta. 639+50 (UA Slope)	
ATH-144-12.08 Slope Stability.gsz	
02/24/2023	1:300

Station 639+50
Existing Conditions

UA Slope Program Version 2.3 - C:\Users\abaratta\Desktop\ATH-144-12.08 Existing Condition.ua3*

File Run Options Help

Calculated Results

Factor of Safety: 1.00

Force per Shaft: 0.000 lb

Acting Point X: 0.000 ft Y: 0.000 ft

Analysis Unit System

(•) English ( ) Metric

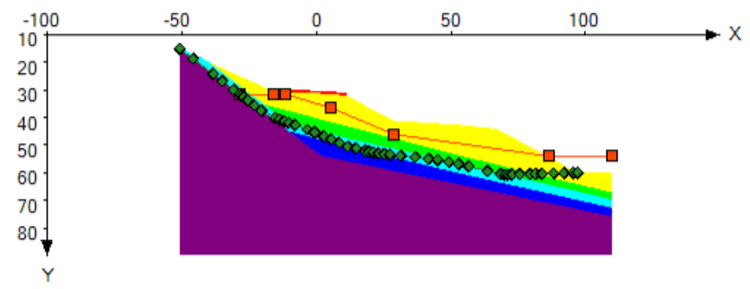
Number of Vertical Sections and Soil Layers

Vertical Section Num: 20 Soil Layer Num: 7

Analysis Method

( ) Total Stress (•) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	0.1	0.0	250.0
Layer2	200.0	28.0	120.0
Layer3	140.0	24.0	120.0
Layer4	160.0	25.0	125.0
Layer5	5.0	17.0	130.0
Layer6	220.0	28.0	140.0
Layer7	4000.0	45.0	140.0

Parameter adjusted to match Slope/W results.

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 1
X (ft)	-50.80	-42.90	-39.80	-19.40	-15.00	-12.50	-10.40	-10.40	1.70	5.40	11.40
Y1 (ft)	15.00	18.00	20.00	28.80	32.00	32.00	31.00	30.00	30.20	30.50	31.00
Y2 (ft)	15.00	18.00	20.00	28.80	32.00	32.00	31.00	31.00	31.20	31.50	32.00
Y3 (ft)	15.00	18.00	20.00	28.80	32.00	32.00	31.00	31.00	31.20	31.50	32.00
Y4 (ft)	15.00	18.00	20.00	35.20	36.30	36.90	37.50	37.50	40.60	41.50	43.00
Y5 (ft)	15.00	18.00	20.00	35.20	38.40	40.30	41.80	41.80	45.00	46.00	47.40
Y6 (ft)	15.00	20.90	23.20	38.20	41.40	43.20	44.80	44.80	48.00	49.00	50.40

Coordinates of Crest X: -50.80 ft Y: 15.00 ft Coordinates of Toe X: 97.00 ft Y: 60.00 ft

Drilled Shaft Information

(•) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

( ) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)

Xmin 0.00 Diameter: 0.30 ft

Xmax 0.00 CTC Spacing: 0.00 ft

XDelta 0.00 X Coordinate: 0.00 ft

[ ] Auto Save Data

Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
X (ft)	-28.50	-16.00	-11.50	5.50	28.50	86.20	110.00
Y (ft)	31.50	31.50	31.50	36.50	46.00	54.00	54.00

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12	Point 13	Point 14
X (ft)	-50.80	-45.84	-38.45	-34.95	-30.65	-28.46	-27.98	-27.17	-25.58	-23.10	-20.35	-15.48	-13.75	-12.00
Y (ft)	15.00	18.65	24.11	26.69	29.86	31.47	31.83	32.42	33.60	35.42	37.45	40.04	40.64	41.25

Station 639+50
Post-Construction Conditions

9999 Carver Road, Suite 210, Cincinnati, OH 45242-5583 **hdrinc.com**
(513) 984-7500

UA Slope Program Version 2.3 - C:\Users\abaratta\Desktop\ATH-144-12.08 New Wall.ua3

File Run Options Help

Calculated Results

Factor of Safety: 2.28

Force per Shaft: 156173.453 lb

Acting Point X: 21.000 ft Y: 46.076 ft

Analysis Unit System

(•) English ( ) Metric

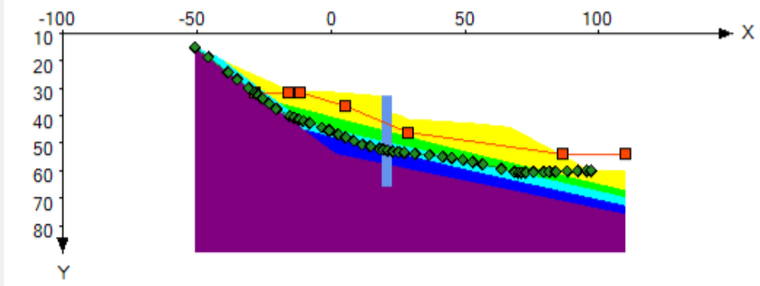
Number of Vertical Sections and Soil Layers

Vertical Section Num: 20 Soil Layer Num: 7

Analysis Method

( ) Total Stress (•) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	0.1	0.0	250.0
Layer2	200.0	28.0	120.0
Layer3	140.0	24.0	120.0
Layer4	160.0	25.0	125.0
Layer5	5.0	17.0	130.0
Layer6	220.0	28.0	140.0
Layer7	4000.0	45.0	140.0

Parameter adjusted to match Slope/W results.

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 1
Y2 (ft)	15.00	18.00	20.00	28.80	32.00	32.00	31.00	31.00	31.20	31.50	32.00
Y3 (ft)	15.00	18.00	20.00	28.80	32.00	32.00	31.00	31.00	31.20	31.50	32.00
Y4 (ft)	15.00	18.00	20.00	35.20	36.30	36.90	37.50	37.50	40.60	41.50	43.00
Y5 (ft)	15.00	18.00	20.00	35.20	38.40	40.30	41.80	41.80	45.00	46.00	47.40
Y6 (ft)	15.00	20.90	23.20	38.20	41.40	43.20	44.80	44.80	48.00	49.00	50.40
Y7 (ft)	15.00	20.90	23.20	38.20	41.40	43.20	44.80	44.80	53.70	54.50	55.70
Y8 (ft)	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00

Coordinates of Crest X: -50.80 ft Y: 15.00 ft Coordinates of Toe X: 97.00 ft Y: 60.00 ft

Drilled Shaft Information

( ) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

(•) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)

Xmin 0.00 Diameter: 4.00 ft

Xmax 0.00 CTC Spacing: 6.00 ft

XDelta 0.00 X Coordinate: 21.00 ft

[ ] Auto Save Data

Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

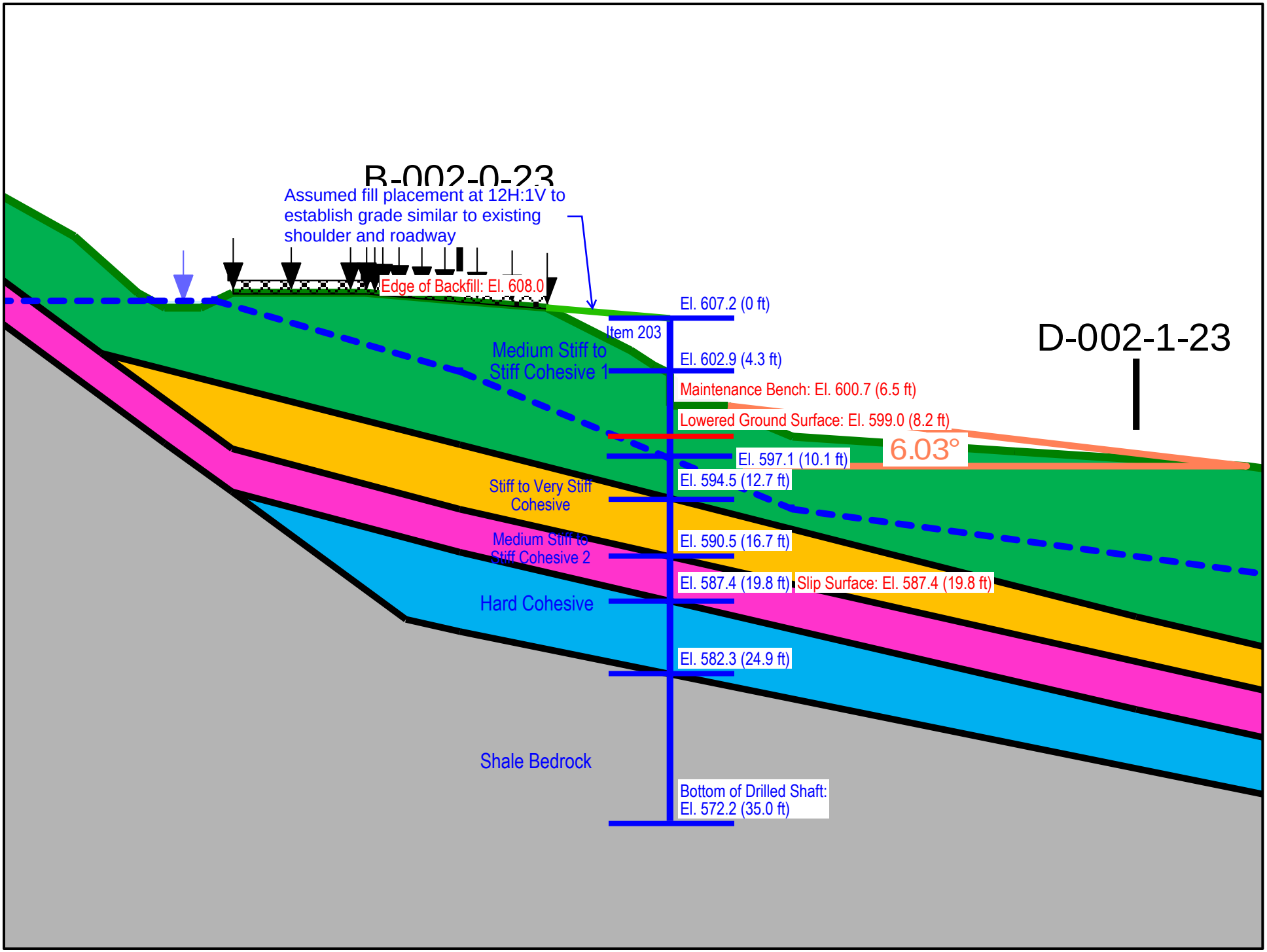
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
X (ft)	-28.50	-16.00	-11.50	5.50	28.50	86.20	110.00
Y (ft)	31.50	31.50	31.50	36.50	46.00	54.00	54.00

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12	Point 13	Point 14
X (ft)	-50.80	-45.84	-38.45	-34.95	-30.65	-28.46	-27.98	-27.17	-25.58	-23.10	-20.35	-15.48	-13.75	-12.00
Y (ft)	15.00	18.65	24.11	26.69	29.86	31.47	31.83	32.42	33.60	35.42	37.45	40.04	40.64	41.25

Wall Calculations

LPILE Analyses


B-002-0-23
Assumed fill placement at 12H:1V to establish grade similar to existing shoulder and roadway
Edge of Backfill: El. 608.0
El. 607.2 (0 ft)
Item 203
Medium Stiff to Stiff Cohesive 1
El. 602.9 (4.3 ft)
Maintenance Bench: El. 600.7 (6.5 ft)
Lowered Ground Surface: El. 599.0 (8.2 ft)
6.03°
El. 597.1 (10.1 ft)
El. 594.5 (12.7 ft)
Stiff to Very Stiff Cohesive
Medium Stiff to Stiff Cohesive 2
El. 590.5 (16.7 ft)
El. 587.4 (19.8 ft)
Slip Surface: El. 587.4 (19.8 ft)
Hard Cohesive
El. 582.3 (24.9 ft)
Shale Bedrock
Bottom of Drilled Shaft: El. 572.2 (35.0 ft)
D-002-1-23

Geometry

	Elevation (ft)	
Top of Backfill =	608.0	*at Outside Edge of Shoulder*
Top of Wall =	607.2	*at C/L of Wall*
Existing Ground Surface =	602.9	*at C/L of Wall*
Maintenance Bench =	600.7	*at C/L of Wall*
Slip Plane =	587.4	*at C/L of Wall*

	Horiz. Distance from C/L (ft)	
Start of Wall Backfill =	11.4	*at Outside Edge of Shoulder*
Wall =	21.0	*at C/L of Wall*
Backfill Slope Angle =	12.0	H:1V

Wall Loading Profile

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Item 203	607.2	4.3	200	28	120
Medium Stiff to Stiff Cohesive 1	602.9	2.2	140	24	120
Bottom of Wall/Maintenance Bench	600.7				
Weighted Value		6.5	180	27	120

Earth Pressure Coefficients

	Deg		
Shear Resistance, Φ =	30		
Wall Friction , δ^A =	0.0		
Wall Slope, θ =	90		
Backfill Slope, β =	4.76		
Revised Backfill Slope, β =	4.76		
Backfill Condition	INFINITE		
Horz. Backslope Dist.	9.6	feet	*(C/L of Wall - Edge of Shoulder)*
Wall Height (H)	6.5	feet	*(Top of Wall - Maintenance Bench)*
Slope Height (h)	0.8	feet	*(Top of Backfill - Top of Wall)*
I =	3.52	degrees	

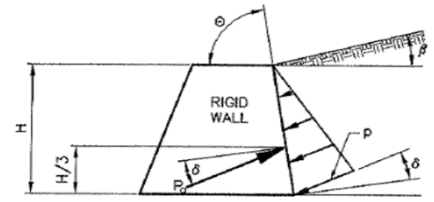


Figure 3.11.5.3-1—Notation for Coulomb Active Earth Pressure

Active Earth Coefficient

$$K_a = \frac{\sin^2(\theta+\Phi)}{(\sin^2(\theta)*\sin(\theta-\delta)*[1+\sqrt{(\sin(\Phi+\delta)*\sin(\Phi-\beta))/(\sin(\theta-\delta)*\sin(\theta+\beta))}]^2)}$$

K_a = **0.356**

At-Rest Earth Coefficient

$K_o = (1- \sin(\phi))*(1+\sin(\beta))$

K_o = **0.547**

Notes:

A. *Wall friction neglected*

B. *Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).*

C. *The wall backfill will consist of proposed fill and cohesive overburden. Using the soil layer thicknesses and respective soil parameters as determined by backcalculation in SlopeW, a weighted average was determined and assumed for the entire backfill (c' = 180 psf and φ' = 27°, per backcalculated UA Slope Values). The parameters were converted to equivalent soil strength parameters c' = 0 psf and φ'= 30° for computing earth pressures based on a 1 degree increase in friction angle for every 50 psf decrease in cohesion up to 150 psf (Ref: Hall's Thesis).*

Soil Lateral Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)	ε50	k
Medium Stiff to Stiff Cohesive 1 (Above GWT)	599.0	8.2	600	0	120	0.01	N/A
Medium Stiff to Stiff Cohesive 1 (Below GWT)	597.1	10.1	600	0	57.6	0.01	N/A
Stiff to Very Stiff Cohesive	594.5	12.7	1500	0	62.6	0.007	N/A
Medium Stiff to Stiff Cohesive 2	590.5	16.7	750	0	67.6	0.01	N/A
Hard Cohesive	587.4	19.8	4000	0	77.6	0.005	N/A
Bedrock	582.3	24.9	N/A	N/A	N/A	N/A	N/A

Depths referenced below the top of wall, starting at the lowered ground surface. ε50 and k values per LPile Technical Manual.

Wall Loading Computations

Earth Pressure Model = CONVENTIONAL *(Conventional or UA SLOPE)* UA SLOPE

1) Soil Unit Weight = 120 pcf *Weighted Average Along Cantilevered Wall Height*

2) Determine Coefficient of Earth Pressure (K)

Restraint Condition = ACTIVE *(Active or At-Rest)*

Ka = 0.356

3) Determine Equivalent Fluid Weight (G_H)

G_H = $(\gamma_m) * (K_a)$

G_H = 43 *For application to CONVENTIONAL Earth Pressure Model*

4) Artificially Lowered Ground Surface (ODOT GDM Section 903.3.2, pg. 9-14) for FS_{dh} < 1.30

Consider Lowered G. S.? YES

Lowered Ground Surface (ft) = 1.4 = dt (tan(β_{dh})

Bench to Breakpoint (ft) = 1.7 = Height difference between bench elevation and slope breakpoint

$GS_{AL\ (ft)}$ = 1.7 = Greater of the above values

β_{dh} = 6.03 = steepness of the slope downhill of the drilled shaft

FS_{dh} = 1.22 = Factor of Safety down slope of the proposed wall

d_t = 13.3 = depth below bench to the shear surface at the location of the drilled shaft

5) Modification of p-y curves (ODOT GDM Section 903.2, pg. 9-13]

P_m = $0.64*(S/D)^{0.34}$ *(Ref: Reese, Isenhower, & Wang - 2006)*

D = 4 feet *(shaft diameter or pile flange width)*

Assumed Shaft Spacing = 6 feet *(center-to-center pile spacing)*

P_m = 0.73 *For retaining wall, applies from top of wall to top of rock/bottom of drilled shafts*

For a row of drilled shafts, applies below shear plane to top of rock/bottom of drilled shafts

Reduce p-multiplier? NO *For application above shear plane if using a row of spaced drilled shafts instead of a retaining wall*

FS_{UAS} = N/A = Factor of Safety from UASlope including shafts

p-multipler = 0.73 = (P_m - P_m/FS_{UAS}) *From top of wall to bottom of shear plane*

6) Determine Lateral Thrust

Conventional Earth Pressure Theory *UA SLOPE*

Exposed Wall Height (H) = 6.5 feet Depth from T/Wall to Slip Plane = 19.8 feet

Wall Height (H) + GS_{AL} = 8.2

P = $1/2 * G_H * H^2$

P = 1435 lbs/foot

P_{SH} = P*(Shaft Spacing) *(earth loading)*

P_{SH} = 8613 lbs/shaft Force Per Shaft = 156173 lbs/shaft

7) Resolve horizontal earth force to distributed triangular load (for LPILE)

w = $2*P_{SH}/H$

w = 2101 lbs/foot per shaft (Earth - Service Limit) 15775 lbs/foot per shaft

w = 175 lbs/inch per shaft (Earth - Service Limit) 1315 lbs/inch per shaft

γ_E = 1.5 *Earth Load Factor*

w = $(2*P_{SH}/H)*\gamma_E$

w = 263 lbs/inch per shaft (Earth - Strength Limit) 1972 lbs/inch per shaft

8) Determine live-load traffic surcharge force (P_s)

Include traffic surcharge? YES

Surcharge Pressure (q_s) = 250 psf

P_s = Ka * qs * H

P_s = 729 lbs/foot *(surcharge resolved to distributed load)* 1761 lbs/foot

P_s = 4376 lbs/shaft 10568 lbs/shaft

9) Resolve surcharge to distributed rectangular load (for LPILE)

w = P_S/H

w = 534 lbs/foot per shaft (surcharge - unfactored) 534 lbs/foot per shaft

w = 44 lbs/inch per shaft (surcharge - unfactored) 44 lbs/inch per shaft

γ_S = 1.75 *Surcharge Load Factor - Strength I*

w = $(P_S/L)*\gamma_S$

w = 78 lbs/inch per shaft (Surcharge - Strength I) 78 lbs/inch per shaft

Distributed Lateral Loads for LPILE

CONVENTIONAL		
Depth (ft.)	**Service (psi)**	**Strength-I (psi)**
0	44	78
8.2	220	340

Distributed Lateral Loads for LPILE

UA SLOPE		
Depth (ft.)	**Service (psi)**	**Strength-I (psi)**
0	44	78
19.8	1359	2050

Steel Beam and Cross-Section Properties

Assumed Pile Shape W 36x150

Pile Availability

AISC Member Producers	3
Non-Member Producers	1

Shaft Geometry

Shaft Diameter	48	in
Longest Beam Dimension	37.852477	in
Clear Distance	5.0737616	in

Steel Beam Geometry

Beam Depth (D)	35.9	in
Web Thickness (t_w)	0.625	in
Flange Width (B_f)	12.0	in
Flange Thickness (t_f)	0.94	in
Area of Steel (A_s)	44.2	in^2

Steel Properties

Yield Strength of Steel	50	ksi
Moment of Inertia (I_{xx}) of Steel	9040	in^4
Modulus of Elasticity of Steel (E)	29000	ksi
Modulus of Elasticity of Steel (E)	29000000	psi
EI (Steel Only)	2.622E+11	$lb*in^2$
Section Modulus (S_x)	504	in^3
Section Modulus (Z_x)	581	in^3
Shear-Buckling Coefficient (k)	5	
Ratio of Shear-Buckling Resistance (C)	1	
D/t_w	57.44	
$1.12\sqrt{Ek/F_{yw}}$	60.313846	
$1.40\sqrt{Ek/F_{yw}}$	75.392307	

Determined by AASHTO LRFD Bridge Specifications Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, and 6.10.9.3.2-6

Shear Capacity Calculation

$V_u \le \phi V_{cr}$

$\phi_v =$ 1 *AASHTO LRFD Bridge Design Spec's 6.5.4.2*

$V_u =$ *shear in web due to factored permanent and construction loads applied to noncompact section (kips)*

$V_{cr} =$ *shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)*

$V_n = V_{cr} = CV_p$

$V_p = 0.58F_{yw}Dt_w$

$V_p =$ *plastic shear force (kips)*

$C =$ *ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6*

$V_p =$ 0.58 * 50 * 35.9 * 0.625

$V_p =$ 650.7 kips

$\phi V_{cr} = \phi * C * V_p$

$\phi V_{cr} =$ 1 * 1 * 650.7

$\phi V_{cr =}$ 650.7 kips

$V_u =$ 519.97 kips *(from LPILE)*

kips *(from PYWALL)*

$V_u < \phi V_{cr}$ **OK**

Flexure Capacity Calculation

$M_u \le \phi M_n$

$\phi_b =$ 1 *AASHTO LRFD Bridge Design Spec's 6.5.4.2*

$M_u =$ *Moment due to the factored loads*

$M_n =$ *Nominal flexural resistance of a section*

$S_x =$ *Elastic section modulus about the x-axis*

$\phi M_n = \phi * F_y * S_x$

$\phi M_n =$ 1 * 50 * 504

$\phi M_n =$ 25200 in*kips

$M_u =$ 25083 in*kips *(from LPILE)*

$M_u =$ in*kips *(from PYWALL)*

$M_u < \phi M_n$ **OK**

Minimum Pile Length

Top of Wall to Slip Plane =	19.8	ft	
Minimum Pile Length Below Slip Plane =	10	ft	*ODOT Minimum Required Length*
Minimum Required Pile Length =	29.8	ft	

Deflection Criteria

Pile Length Above Rock =	24.9	ft	Exposed Wall Height = 6.5 ft
Pile Length Above Rock =	298.8	in	Exposed Wall Height = 78 in

1.)

Per the ODOT GDM, pile-head deflection in the service limit state limited to 1% or less of the shaft length above bedrock, or 1% of total drilled shaft length if not embedded in bedrock.

2.) *Following industry acceptance criteria, limit wall deflection to 1% of exposed wall height where ODOT landslide criteria does not govern. Alternatively, limit wall deflection to 1.5% of the exposed wall height in accordance with NCDOT guidelines. Use 1.5% wall deflection for PYWALL software.*

ODOT Landslide Criteria Governs YES

1% Wall Height **OR** 2 inches- LPILE	2	in	$\delta =$	2.017	in *(from LPILE)*
1.5% Wall Height - PYWALL		in	$\delta =$		in *(from PYWALL)*

Drilled Shafts Located Within 10 feet of Edge of Pavement YES

Service Limit Analysis

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

                     LPile for Windows, Version 2019-11.002

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

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--------------------------------------------------------------------------------
                              Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\pwworking\east01\d3052807\

Name of input data file:
ATH-144-12.08 Service Case.lp11

Name of output report file:
ATH-144-12.08 Service Case.lp11

Name of plot output file:
ATH-144-12.08 Service Case.lp11

Name of runtime message file:
```

ATH-144-12.08 Service Case.lp11

Date and Time of Analysis

Date: February 24, 2023 Time: 16:05:27

Problem Title

Project Name: ATH-144-12.08

Job Number:

Client: ODOT D10

Engineer: HDR

Description: Service Case

Program Options and Settings

Computational Options:
- Conventional Analysis

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed = 500
 - Deflection tolerance for convergence = 1.0000E-05 in
 - Maximum allowable deflection = 100.0000 in
 - Number of pile increments = 100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Analysis uses p-y modification factors for p-y curves
 - Analysis uses layering correction (Method of Georgiadis)
 - Analysis includes loading by one distributed lateral load acting on pile
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 35.000 ft
Depth of ground surface below top of pile = 8.2000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over

the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	48.0000
2	35.000	48.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	35.000000 ft
Width of top of section	=	48.000000 in
Width of bottom of section	=	48.000000 in
Top Area	=	44.200000 sq. in
Bottom Area	=	44.200000 sq. in
Moment of Inertia at Top	=	9040. in^4
Moment of Inertia at Bottom	=	9040. in^4
Elastic Modulus	=	29000000. psi

Ground Slope and Pile Batter Angles

Ground Slope Angle	=	0.000 degrees
	=	0.000 radians
Pile Batter Angle	=	0.000 degrees
	=	0.000 radians

Soil and Rock Layering Information

The soil profile is modelled using 6 layers

Layer 1 is stiff clay without free water

Distance from top of pile to top of layer	=	8.200000 ft
Distance from top of pile to bottom of layer	=	10.100000 ft
Effective unit weight at top of layer	=	120.000000 pcf
Effective unit weight at bottom of layer	=	120.000000 pcf
Undrained cohesion at top of layer	=	600.000000 psf
Undrained cohesion at bottom of layer	=	600.000000 psf
Epsilon-50 at top of layer	=	0.010000
Epsilon-50 at bottom of layer	=	0.010000

Layer 2 is stiff clay without free water

Distance from top of pile to top of layer	=	10.100000 ft
Distance from top of pile to bottom of layer	=	12.700000 ft
Effective unit weight at top of layer	=	57.600000 pcf
Effective unit weight at bottom of layer	=	57.600000 pcf
Undrained cohesion at top of layer	=	600.000000 psf
Undrained cohesion at bottom of layer	=	600.000000 psf
Epsilon-50 at top of layer	=	0.010000
Epsilon-50 at bottom of layer	=	0.010000

Layer 3 is stiff clay without free water

Distance from top of pile to top of layer	=	12.700000 ft
Distance from top of pile to bottom of layer	=	16.700000 ft
Effective unit weight at top of layer	=	62.600000 pcf
Effective unit weight at bottom of layer	=	62.600000 pcf
Undrained cohesion at top of layer	=	1500. psf
Undrained cohesion at bottom of layer	=	1500. psf
Epsilon-50 at top of layer	=	0.007000
Epsilon-50 at bottom of layer	=	0.007000

Layer 4 is stiff clay without free water

```
   Distance from top of pile to top of layer          =    16.700000 ft
   Distance from top of pile to bottom of layer       =    19.800000 ft
   Effective unit weight at top of layer              =    67.600000 pcf
   Effective unit weight at bottom of layer           =    67.600000 pcf
   Undrained cohesion at top of layer                 =   750.000000 psf
   Undrained cohesion at bottom of layer              =   750.000000 psf
   Epsilon-50 at top of layer                         =     0.010000
   Epsilon-50 at bottom of layer                      =     0.010000


Layer 5 is stiff clay without free water

   Distance from top of pile to top of layer          =    19.800000 ft
   Distance from top of pile to bottom of layer       =    24.900000 ft
   Effective unit weight at top of layer              =    77.600000 pcf
   Effective unit weight at bottom of layer           =    77.600000 pcf
   Undrained cohesion at top of layer                 =        4000. psf
   Undrained cohesion at bottom of layer              =        4000. psf
   Epsilon-50 at top of layer                         =     0.005000
   Epsilon-50 at bottom of layer                      =     0.005000


Layer 6 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer          =    24.900000 ft
   Distance from top of pile to bottom of layer       =    50.000000 ft
   Effective unit weight at top of layer              =   150.000000 pcf
   Effective unit weight at bottom of layer           =   150.000000 pcf
   Uniaxial compressive strength at top of layer      =   400.000000 psi
   Uniaxial compressive strength at bottom of layer   =   400.000000 psi
   Initial modulus of rock at top of layer            =       16400. psi
   Initial modulus of rock at bottom of layer         =       16400. psi
   RQD of rock at top of layer                        =    49.000000 %
   RQD of rock at bottom of layer                     =    49.000000 %
   k rm of rock at top of layer                       =    0.0005000
   k rm of rock at bottom of layer                    =    0.0005000


 (Depth of the lowest soil layer extends 15.000 ft below the pile tip)


**** Warning - Possible Input Data Error ****
```

Values entered for effective unit weight of rock were outside the limits of
50 pcf to 150 pcf.

The maximum input value, in layer 1, for effective unit weight = 150.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	Rock Mass Modulus psi
1	Stiff Clay	8.2000	120.0000	600.0000	--	--	0.01000	--
	w/o Free Water	10.1000	120.0000	600.0000	--	--	0.01000	--
2	Stiff Clay	10.1000	57.6000	600.0000	--	--	0.01000	--
	w/o Free Water	12.7000	57.6000	600.0000	--	--	0.01000	--
3	Stiff Clay	12.7000	62.6000	1500.	--	--	0.00700	--
	w/o Free Water	16.7000	62.6000	1500.	--	--	0.00700	--
4	Stiff Clay	16.7000	67.6000	750.0000	--	--	0.01000	--
	w/o Free Water	19.8000	67.6000	750.0000	--	--	0.01000	--
5	Stiff Clay	19.8000	77.6000	4000.	--	--	0.00500	--
	w/o Free Water	24.9000	77.6000	4000.	--	--	0.00500	--

6	Weak	24.9000	150.0000	--	400.0000	49.0000	5.00E-04	16400.
	Rock	50.0000	150.0000	--	400.0000	49.0000	5.00E-04	16400.

---

p-y Modification Factors for Group Action

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

Point No.	Depth X ft	p-mult	y-mult
1	8.200	0.7300	1.0000
2	24.900	0.7300	1.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading Used For All Load Cases

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lb/in
1	0.000	45.000
2	237.600	1359.000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

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Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

---

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	8.2000	0.00	N.A.	No	0.00	15088.
2	10.1000	1.9000	Yes	No	15088.	24422.
3	12.7000	2.0662	Yes	No	39509.	89060.
4	16.7000	10.3187	Yes	No	128570.	52812.
5	19.8000	3.4886	Yes	No	181382.	323016.
6	24.9000	16.7000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	2.0174	-1.06E-04	7.86E-07	-0.00785	2.80E-07	2.62E+11	0.00	0.00	50.8068
0.3500	1.9844	448.1162	249.9716	-0.00785	1.1897	2.62E+11	0.00	0.00	68.2273
0.7000	1.9514	2100.	585.3034	-0.00785	5.5746	2.62E+11	0.00	0.00	91.4545
1.0500	1.9185	5365.	1018.	-0.00785	14.2425	2.62E+11	0.00	0.00	114.6818
1.4000	1.8855	10653.	1549.	-0.00785	28.2811	2.62E+11	0.00	0.00	137.9091

1.7500	1.8525	18373.	2177.	-0.00785	48.7783	2.62E+11	0.00	0.00	161.1364
2.1000	1.8195	28936.	2902.	-0.00785	76.8218	2.62E+11	0.00	0.00	184.3636
2.4500	1.7865	42751.	3725.	-0.00785	113.4994	2.62E+11	0.00	0.00	207.5909
2.8000	1.7536	60229.	4646.	-0.00785	159.8989	2.62E+11	0.00	0.00	230.8182
3.1500	1.7206	81777.	5664.	-0.00785	217.1080	2.62E+11	0.00	0.00	254.0455
3.5000	1.6876	107807.	6780.	-0.00785	286.2145	2.62E+11	0.00	0.00	277.2727
3.8500	1.6547	138729.	7993.	-0.00785	368.3062	2.62E+11	0.00	0.00	300.5000
4.2000	1.6217	174951.	9304.	-0.00784	464.4709	2.62E+11	0.00	0.00	323.7273
4.5500	1.5888	216883.	10713.	-0.00784	575.7964	2.62E+11	0.00	0.00	346.9545
4.9000	1.5559	264936.	12219.	-0.00784	703.3703	2.62E+11	0.00	0.00	370.1818
5.2500	1.5230	319519.	13822.	-0.00783	848.2806	2.62E+11	0.00	0.00	393.4091
5.6000	1.4901	381042.	15523.	-0.00783	1012.	2.62E+11	0.00	0.00	416.6364
5.9500	1.4572	449914.	17322.	-0.00782	1194.	2.62E+11	0.00	0.00	439.8636
6.3000	1.4244	526545.	19218.	-0.00781	1398.	2.62E+11	0.00	0.00	463.0909
6.6500	1.3916	611345.	21212.	-0.00780	1623.	2.62E+11	0.00	0.00	486.3182
7.0000	1.3589	704724.	23303.	-0.00779	1871.	2.62E+11	0.00	0.00	509.5455
7.3500	1.3262	807091.	25492.	-0.00778	2143.	2.62E+11	0.00	0.00	532.7727
7.7000	1.2935	918857.	27778.	-0.00777	2439.	2.62E+11	0.00	0.00	556.0000
8.0500	1.2609	1040430.	30162.	-0.00775	2762.	2.62E+11	0.00	0.00	579.2273
8.4000	1.2284	1172220.	32171.	-0.00773	3112.	2.62E+11	-225.0587	769.4829	602.4545
8.7500	1.1960	1310669.	33791.	-0.00771	3480.	2.62E+11	-231.8549	814.2191	625.6818
9.1000	1.1636	1456064.	35480.	-0.00769	3866.	2.62E+11	-238.5110	860.8790	648.9091
9.4500	1.1314	1608698.	37238.	-0.00767	4271.	2.62E+11	-245.0234	909.5945	672.1364
9.8000	1.0992	1768867.	39068.	-0.00764	4696.	2.62E+11	-251.3880	960.5096	695.3636
10.1500	1.0672	1936868.	40969.	-0.00761	5142.	2.62E+11	-257.2319	1012.	718.5909
10.5000	1.0353	2113006.	42948.	-0.00758	5610.	2.62E+11	-260.7302	1058.	741.8182
10.8500	1.0036	2297632.	45010.	-0.00754	6100.	2.62E+11	-264.1076	1105.	765.0455
11.2000	0.9720	2491094.	47156.	-0.00750	6614.	2.62E+11	-267.3605	1155.	788.2727
11.5500	0.9405	2693744.	49386.	-0.00746	7152.	2.62E+11	-270.4855	1208.	811.5000
11.9000	0.9093	2905939.	51701.	-0.00742	7715.	2.62E+11	-273.4787	1263.	834.7273
12.2500	0.8782	3128033.	54101.	-0.00737	8305.	2.62E+11	-276.3361	1322.	857.9545
12.6000	0.8474	3360388.	56587.	-0.00732	8921.	2.62E+11	-279.0536	1383.	881.1818
12.9500	0.8168	3603364.	58450.	-0.00726	9566.	2.62E+11	-619.3268	3185.	904.4091
13.3000	0.7864	3851368.	59686.	-0.00720	10225.	2.62E+11	-624.3676	3335.	927.6364
13.6500	0.7563	4104723.	60998.	-0.00714	10897.	2.62E+11	-629.0259	3493.	950.8636
14.0000	0.7265	4363755.	62390.	-0.00707	11585.	2.62E+11	-633.3021	3661.	974.0909
14.3500	0.6969	4628798.	63862.	-0.00700	12289.	2.62E+11	-637.1935	3840.	997.3182
14.7000	0.6677	4900194.	65416.	-0.00692	13009.	2.62E+11	-640.6952	4030.	1021.
15.0500	0.6388	5178290.	67053.	-0.00684	13748.	2.62E+11	-643.8005	4233.	1044.
15.4000	0.6102	5463442.	68776.	-0.00675	14505.	2.62E+11	-646.5008	4450.	1067.
15.7500	0.5820	5756011.	70586.	-0.00667	15281.	2.62E+11	-648.7864	4682.	1090.
16.1000	0.5542	6056368.	72485.	-0.00657	16079.	2.62E+11	-650.6460	4931.	1113.

16.4500	0.5269	6364888.	74475.	-0.00647	16898.	2.62E+11	-652.0673	5198.	1137.
16.8000	0.4999	6681957.	77108.	-0.00637	17740.	2.62E+11	-390.5852	3282.	1160.
17.1500	0.4734	7012597.	80388.	-0.00626	18618.	2.62E+11	-390.7024	3466.	1183.
17.5000	0.4473	7357216.	83765.	-0.00614	19532.	2.62E+11	-390.5442	3667.	1206.
17.8500	0.4218	7716225.	87241.	-0.00602	20486.	2.62E+11	-390.0995	3884.	1230.
18.2000	0.3968	8090043.	90818.	-0.00589	21478.	2.62E+11	-389.3568	4122.	1253.
18.5500	0.3723	8479093.	94495.	-0.00576	22511.	2.62E+11	-388.3038	4381.	1276.
18.9000	0.3484	8883802.	98275.	-0.00562	23585.	2.62E+11	-386.9281	4665.	1299.
19.2500	0.3250	9304605.	102160.	-0.00548	24702.	2.62E+11	-385.2164	4977.	1322.
19.6000	0.3024	9741942.	106149.	-0.00532	25864.	2.62E+11	-383.1553	5322.	1346.
19.9500	0.2803	1.02E+07	105400.	-0.00516	27070.	2.62E+11	-1417.	21223.	97.0122
20.3000	0.2590	1.06E+07	99671.	-0.00500	28214.	2.62E+11	-1409.	22844.	0.00
20.6500	0.2383	1.10E+07	93775.	-0.00482	29292.	2.62E+11	-1399.	24653.	0.00
21.0000	0.2185	1.14E+07	87922.	-0.00464	30305.	2.62E+11	-1388.	26684.	0.00
21.3500	0.1993	1.18E+07	82120.	-0.00446	31253.	2.62E+11	-1375.	28973.	0.00
21.7000	0.1810	1.21E+07	76375.	-0.00427	32137.	2.62E+11	-1360.	31567.	0.00
22.0500	0.1635	1.24E+07	70696.	-0.00407	32956.	2.62E+11	-1344.	34526.	0.00
22.4000	0.1468	1.27E+07	65090.	-0.00387	33713.	2.62E+11	-1325.	37921.	0.00
22.7500	0.1310	1.30E+07	59566.	-0.00366	34408.	2.62E+11	-1305.	41844.	0.00
23.1000	0.1160	1.32E+07	54133.	-0.00345	35042.	2.62E+11	-1282.	46415.	0.00
23.4500	0.1020	1.34E+07	48800.	-0.00324	35615.	2.62E+11	-1257.	51787.	0.00
23.8000	0.08880	1.36E+07	43578.	-0.00302	36130.	2.62E+11	-1230.	58162.	0.00
24.1500	0.07655	1.38E+07	38476.	-0.00281	36587.	2.62E+11	-1200.	65814.	0.00
24.5000	0.06523	1.39E+07	33507.	-0.00258	36988.	2.62E+11	-1167.	75112.	0.00
24.8500	0.05485	1.41E+07	28683.	-0.00236	37334.	2.62E+11	-1131.	86573.	0.00
25.2000	0.04542	1.42E+07	8716.	-0.00213	37628.	2.62E+11	-8378.	774755.	0.00
25.5500	0.03693	1.41E+07	-27436.	-0.00191	37529.	2.62E+11	-8837.	1005000.	0.00
25.9000	0.02940	1.39E+07	-65274.	-0.00168	37016.	2.62E+11	-9181.	1311478.	0.00
26.2500	0.02281	1.36E+07	-104290.	-0.00146	36073.	2.62E+11	-9398.	1730573.	0.00
26.6000	0.01713	1.31E+07	-143926.	-0.00125	34690.	2.62E+11	-9477.	2323585.	0.00
26.9500	0.01233	1.24E+07	-183566.	-0.00104	32863.	2.62E+11	-9399.	3201744.	0.00
27.3000	0.00836	1.15E+07	-222495.	-8.52E-04	30596.	2.62E+11	-9138.	4589364.	0.00
27.6500	0.00517	1.05E+07	-259836.	-6.76E-04	27901.	2.62E+11	-8643.	7019257.	0.00
28.0000	0.00269	9342007.	-294361.	-5.17E-04	24802.	2.62E+11	-7797.	1.22E+07	0.00
28.3500	8.32E-04	8036922.	-316897.	-3.77E-04	21337.	2.62E+11	-2934.	1.48E+07	0.00
28.7000	-4.83E-04	6680076.	-319291.	-2.60E-04	17735.	2.62E+11	1794.	1.56E+07	0.00
29.0500	-0.00135	5354874.	-304461.	-1.63E-04	14216.	2.62E+11	5268.	1.64E+07	0.00
29.4000	-0.00185	4122602.	-277446.	-8.72E-05	10945.	2.62E+11	7596.	1.72E+07	0.00
29.7500	-0.00208	3024330.	-242746.	-3.00E-05	8029.	2.62E+11	8927.	1.80E+07	0.00
30.1000	-0.00210	2083534.	-204189.	1.10E-05	5532.	2.62E+11	9433.	1.88E+07	0.00
30.4500	-0.00199	1309139.	-164865.	3.81E-05	3476.	2.62E+11	9293.	1.96E+07	0.00
30.8000	-0.00178	698668.	-127123.	5.42E-05	1855.	2.62E+11	8680.	2.04E+07	0.00

31.1500	-0.00153	241306.	-92620.	6.18E-05	640.6342	2.62E+11	7750.	2.12E+07	0.00
31.5000	-0.00127	-79340.	-62401.	6.31E-05	210.6385	2.62E+11	6640.	2.20E+07	0.00
31.8500	-0.00100	-282859.	-36999.	6.02E-05	750.9534	2.62E+11	5456.	2.28E+07	0.00
32.2000	-7.60E-04	-390133.	-16555.	5.48E-05	1036.	2.62E+11	4279.	2.36E+07	0.00
32.5500	-5.43E-04	-421925.	-929.4597	4.83E-05	1120.	2.62E+11	3162.	2.45E+07	0.00
32.9000	-3.55E-04	-397941.	10189.	4.17E-05	1056.	2.62E+11	2132.	2.53E+07	0.00
33.2500	-1.93E-04	-336341.	17180.	3.58E-05	892.9397	2.62E+11	1197.	2.61E+07	0.00
33.6000	-5.39E-05	-253626.	20417.	3.11E-05	673.3425	2.62E+11	344.4310	2.69E+07	0.00
33.9500	6.82E-05	-164835.	20198.	2.77E-05	437.6149	2.62E+11	-448.9284	2.77E+07	0.00
34.3000	1.79E-04	-83963.	16706.	2.57E-05	222.9115	2.62E+11	-1214.	2.85E+07	0.00
34.6500	2.84E-04	-24503.	9996.	2.49E-05	65.0521	2.62E+11	-1982.	2.93E+07	0.00
35.0000	3.88E-04	0.00	0.00	2.47E-05	0.00	2.62E+11	-2778.	1.50E+07	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

Pile-head deflection = 2.01740164 inches
Computed slope at pile head = -0.00785260 radians
Maximum bending moment = 14173076. inch-lbs
Maximum shear force = -319291. lbs
Depth of maximum bending moment = 25.20000000 feet below pile head
Depth of maximum shear force = 28.70000000 feet below pile head
Number of iterations = 23
Number of zero deflection points = 2

Pile-head Deflection vs. Pile Length for Load Case 1

Boundary Condition Type 1, Shear and Moment

Shear = 0. lbs
Moment = 0. in-lbs
Axial Load = 0. lbs

Pile Length	Pile Head Deflection	Maximum Moment	Maximum Shear

feet	inches	ln-lbs	lbs
35.00000	2.01740164	14173076.	-319291.
33.25000	1.98152446	14095361.	-314392.
31.50000	2.02283187	14067151.	-330526.
29.75000	2.81672686	12555119.	-387379.
28.00000	9.80255445	9052146.	-339325.
26.25000	50.64756625	6155548.	-190194.

Summary of Pile-head Responses for Conventional Analyses

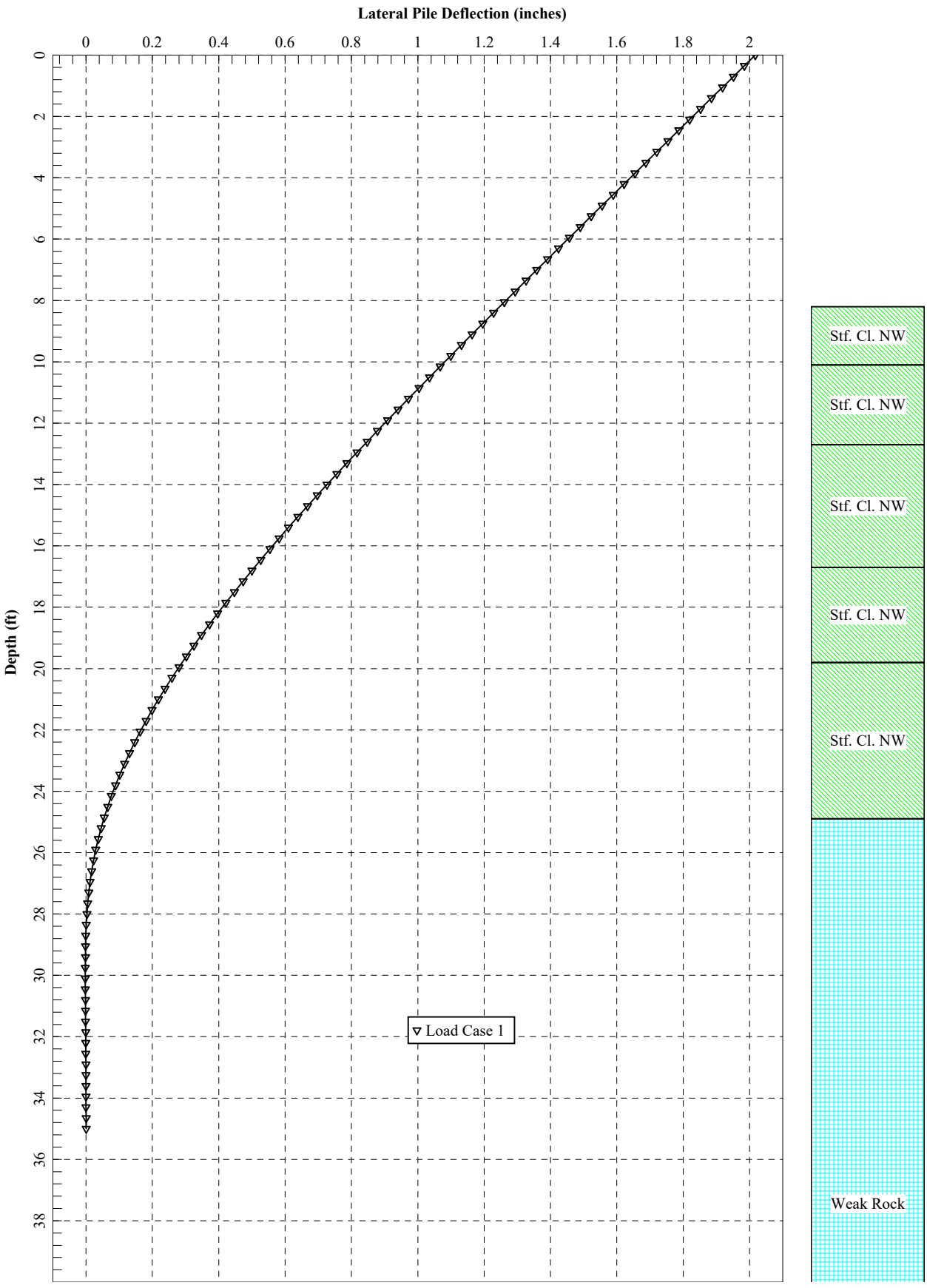
Definitions of Pile-head Loading Conditions:

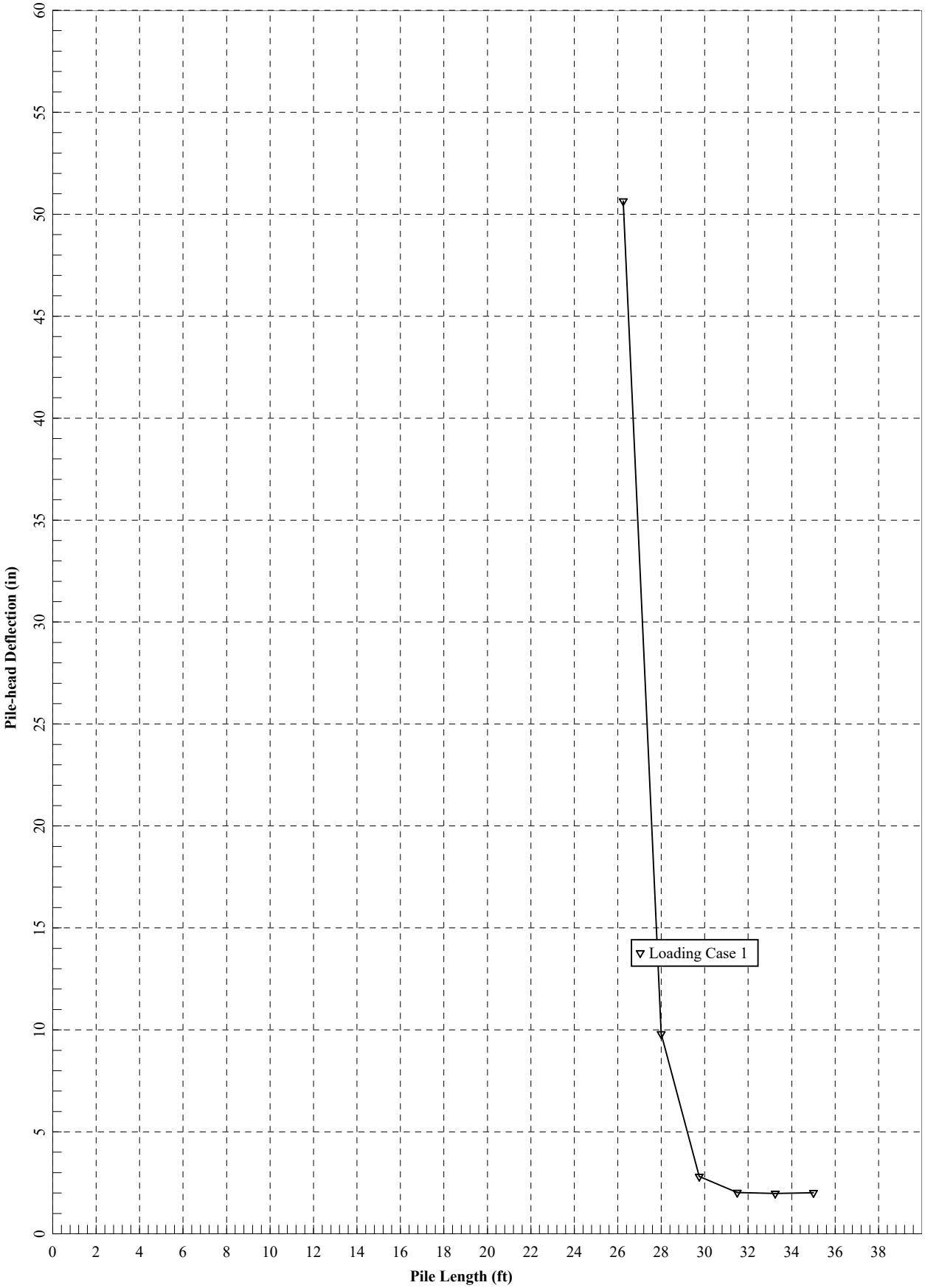
Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	2.0174	-0.00785	-319291.	1.42E+07

Maximum pile-head deflection = 2.0174016370 inches
Maximum pile-head rotation = -0.0078526042 radians = -0.449921 deg.

The analysis ended normally.


Lateral Pile Deflection (inches)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Load Case 1
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Weak Rock


Pile-head Deflection (in)
0
5
10
15
20
25
30
35
40
45
50
55
60
Pile Length (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Loading Case 1

Strength Limit Analysis

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

                     LPile for Windows, Version 2019-11.002

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

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--------------------------------------------------------------------------------
                              Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\pwworking\east01\d3052807\

Name of input data file:
ATH-144-12.08 Strength Case.lp11

Name of output report file:
ATH-144-12.08 Strength Case.lp11

Name of plot output file:
ATH-144-12.08 Strength Case.lp11

Name of runtime message file:
```

ATH-144-12.08 Strength Case.lp11

Date and Time of Analysis

Date: February 24, 2023 Time: 16:09:44

Problem Title

Project Name: ATH-144-12.08

Job Number:

Client: ODOT D10

Engineer: HDR

Description: Strength Case

Program Options and Settings

Computational Options:
- Conventional Analysis

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed = 500
 - Deflection tolerance for convergence = 1.0000E-05 in
 - Maximum allowable deflection = 100.0000 in
 - Number of pile increments = 100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Analysis uses p-y modification factors for p-y curves
 - Analysis uses layering correction (Method of Georgiadis)
 - Analysis includes loading by one distributed lateral load acting on pile
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 35.000 ft
Depth of ground surface below top of pile = 8.2000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over

the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	48.0000
2	35.000	48.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	35.000000 ft
Width of top of section	=	48.000000 in
Width of bottom of section	=	48.000000 in
Top Area	=	44.200000 sq. in
Bottom Area	=	44.200000 sq. in
Moment of Inertia at Top	=	9040. in^4
Moment of Inertia at Bottom	=	9040. in^4
Elastic Modulus	=	29000000. psi

Ground Slope and Pile Batter Angles

Ground Slope Angle	=	0.000 degrees
	=	0.000 radians
Pile Batter Angle	=	0.000 degrees
	=	0.000 radians

Soil and Rock Layering Information

The soil profile is modelled using 6 layers

Layer 1 is stiff clay without free water

Distance from top of pile to top of layer	=	8.200000 ft
Distance from top of pile to bottom of layer	=	10.100000 ft
Effective unit weight at top of layer	=	120.000000 pcf
Effective unit weight at bottom of layer	=	120.000000 pcf
Undrained cohesion at top of layer	=	600.000000 psf
Undrained cohesion at bottom of layer	=	600.000000 psf
Epsilon-50 at top of layer	=	0.010000
Epsilon-50 at bottom of layer	=	0.010000

Layer 2 is stiff clay without free water

Distance from top of pile to top of layer	=	10.100000 ft
Distance from top of pile to bottom of layer	=	12.700000 ft
Effective unit weight at top of layer	=	57.600000 pcf
Effective unit weight at bottom of layer	=	57.600000 pcf
Undrained cohesion at top of layer	=	600.000000 psf
Undrained cohesion at bottom of layer	=	600.000000 psf
Epsilon-50 at top of layer	=	0.010000
Epsilon-50 at bottom of layer	=	0.010000

Layer 3 is stiff clay without free water

Distance from top of pile to top of layer	=	12.700000 ft
Distance from top of pile to bottom of layer	=	16.700000 ft
Effective unit weight at top of layer	=	62.600000 pcf
Effective unit weight at bottom of layer	=	62.600000 pcf
Undrained cohesion at top of layer	=	1500. psf
Undrained cohesion at bottom of layer	=	1500. psf
Epsilon-50 at top of layer	=	0.007000
Epsilon-50 at bottom of layer	=	0.007000

Layer 4 is stiff clay without free water

```
   Distance from top of pile to top of layer          =    16.700000 ft
   Distance from top of pile to bottom of layer       =    19.800000 ft
   Effective unit weight at top of layer              =    67.600000 pcf
   Effective unit weight at bottom of layer           =    67.600000 pcf
   Undrained cohesion at top of layer                 =   750.000000 psf
   Undrained cohesion at bottom of layer              =   750.000000 psf
   Epsilon-50 at top of layer                         =     0.010000
   Epsilon-50 at bottom of layer                      =     0.010000


Layer 5 is stiff clay without free water

   Distance from top of pile to top of layer          =    19.800000 ft
   Distance from top of pile to bottom of layer       =    24.900000 ft
   Effective unit weight at top of layer              =    77.600000 pcf
   Effective unit weight at bottom of layer           =    77.600000 pcf
   Undrained cohesion at top of layer                 =        4000. psf
   Undrained cohesion at bottom of layer              =        4000. psf
   Epsilon-50 at top of layer                         =     0.005000
   Epsilon-50 at bottom of layer                      =     0.005000


Layer 6 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer          =    24.900000 ft
   Distance from top of pile to bottom of layer       =    50.000000 ft
   Effective unit weight at top of layer              =   150.000000 pcf
   Effective unit weight at bottom of layer           =   150.000000 pcf
   Uniaxial compressive strength at top of layer      =   400.000000 psi
   Uniaxial compressive strength at bottom of layer   =   400.000000 psi
   Initial modulus of rock at top of layer            =       16400. psi
   Initial modulus of rock at bottom of layer         =       16400. psi
   RQD of rock at top of layer                        =    49.000000 %
   RQD of rock at bottom of layer                     =    49.000000 %
   k rm of rock at top of layer                       =    0.0005000
   k rm of rock at bottom of layer                    =    0.0005000


 (Depth of the lowest soil layer extends 15.000 ft below the pile tip)


**** Warning - Possible Input Data Error ****
```

Values entered for effective unit weight of rock were outside the limits of
50 pcf to 150 pcf.

The maximum input value, in layer 1, for effective unit weight = 150.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	Rock Mass Modulus psi
1	Stiff Clay	8.2000	120.0000	600.0000	--	--	0.01000	--
	w/o Free Water	10.1000	120.0000	600.0000	--	--	0.01000	--
2	Stiff Clay	10.1000	57.6000	600.0000	--	--	0.01000	--
	w/o Free Water	12.7000	57.6000	600.0000	--	--	0.01000	--
3	Stiff Clay	12.7000	62.6000	1500.	--	--	0.00700	--
	w/o Free Water	16.7000	62.6000	1500.	--	--	0.00700	--
4	Stiff Clay	16.7000	67.6000	750.0000	--	--	0.01000	--
	w/o Free Water	19.8000	67.6000	750.0000	--	--	0.01000	--
5	Stiff Clay	19.8000	77.6000	4000.	--	--	0.00500	--
	w/o Free Water	24.9000	77.6000	4000.	--	--	0.00500	--

6	Weak	24.9000	150.0000	--	400.0000	49.0000	5.00E-04	16400.
	Rock	50.0000	150.0000	--	400.0000	49.0000	5.00E-04	16400.

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p-y Modification Factors for Group Action

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

Point No.	Depth X ft	p-mult	y-mult
1	8.200	0.7300	1.0000
2	24.900	0.7300	1.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading Used For All Load Cases

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lb/in
1	0.000	79.000
2	237.600	2050.000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

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Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	8.2000	0.00	N.A.	No	0.00	15088.
2	10.1000	1.9000	Yes	No	15088.	24422.
3	12.7000	2.0662	Yes	No	39509.	89060.
4	16.7000	10.3187	Yes	No	128570.	52812.
5	19.8000	3.4886	Yes	No	181382.	323016.
6	24.9000	16.7000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	3.7444	1.85E-04	0.00	-0.01413	4.91E-07	2.62E+11	0.00	0.00	87.7102
0.3500	3.6850	773.6043	423.2574	-0.01413	2.0538	2.62E+11	0.00	0.00	113.8409
0.7000	3.6257	3555.	974.5551	-0.01413	9.4390	2.62E+11	0.00	0.00	148.6818
1.0500	3.5663	8960.	1672.	-0.01413	23.7873	2.62E+11	0.00	0.00	183.5227
1.4000	3.5070	17602.	2516.	-0.01413	46.7302	2.62E+11	0.00	0.00	218.3636

1.7500	3.4476	30095.	3506.	-0.01413	79.8995	2.62E+11	0.00	0.00	253.2045
2.1000	3.3883	47056.	4643.	-0.01413	124.9269	2.62E+11	0.00	0.00	288.0455
2.4500	3.3289	69097.	5926.	-0.01413	183.4440	2.62E+11	0.00	0.00	322.8864
2.8000	3.2696	96834.	7355.	-0.01413	257.0824	2.62E+11	0.00	0.00	357.7273
3.1500	3.2103	130882.	8931.	-0.01412	347.4739	2.62E+11	0.00	0.00	392.5682
3.5000	3.1510	171854.	10653.	-0.01412	456.2501	2.62E+11	0.00	0.00	427.4091
3.8500	3.0917	220366.	12521.	-0.01412	585.0426	2.62E+11	0.00	0.00	462.2500
4.2000	3.0324	277032.	14536.	-0.01412	735.4832	2.62E+11	0.00	0.00	497.0909
4.5500	2.9731	342467.	16697.	-0.01411	909.2034	2.62E+11	0.00	0.00	531.9318
4.9000	2.9138	417285.	19004.	-0.01410	1108.	2.62E+11	0.00	0.00	566.7727
5.2500	2.8546	502100.	21458.	-0.01410	1333.	2.62E+11	0.00	0.00	601.6136
5.6000	2.7954	597529.	24058.	-0.01409	1586.	2.62E+11	0.00	0.00	636.4545
5.9500	2.7363	704184.	26804.	-0.01408	1870.	2.62E+11	0.00	0.00	671.2955
6.3000	2.6772	822681.	29696.	-0.01407	2184.	2.62E+11	0.00	0.00	706.1364
6.6500	2.6181	953634.	32735.	-0.01405	2532.	2.62E+11	0.00	0.00	740.9773
7.0000	2.5592	1097658.	35921.	-0.01403	2914.	2.62E+11	0.00	0.00	775.8182
7.3500	2.5002	1255367.	39252.	-0.01402	3333.	2.62E+11	0.00	0.00	810.6591
7.7000	2.4414	1427377.	42730.	-0.01399	3789.	2.62E+11	0.00	0.00	845.5000
8.0500	2.3827	1614301.	46354.	-0.01397	4286.	2.62E+11	0.00	0.00	880.3409
8.4000	2.3241	1816754.	49571.	-0.01394	4823.	2.62E+11	-263.9498	477.0024	915.1818
8.7500	2.2656	2030695.	52362.	-0.01391	5391.	2.62E+11	-272.0066	504.2545	950.0227
9.1000	2.2072	2256597.	55266.	-0.01388	5991.	2.62E+11	-279.9081	532.6225	984.8636
9.4500	2.1490	2494933.	58284.	-0.01384	6624.	2.62E+11	-287.6500	562.1799	1020.
9.8000	2.0910	2746184.	61416.	-0.01380	7291.	2.62E+11	-295.2283	593.0065	1055.
10.1500	2.0331	3010828.	64664.	-0.01375	7993.	2.62E+11	-302.2051	624.2941	1089.
10.5000	1.9755	3289358.	68034.	-0.01370	8733.	2.62E+11	-306.4355	651.5080	1124.
10.8500	1.9180	3582315.	71533.	-0.01365	9511.	2.62E+11	-310.5325	679.9876	1159.
11.2000	1.8608	3890239.	75162.	-0.01359	10328.	2.62E+11	-314.4925	709.8238	1194.
11.5500	1.8039	4213676.	78921.	-0.01352	11187.	2.62E+11	-318.3114	741.1163	1229.
11.9000	1.7473	4553174.	82810.	-0.01345	12088.	2.62E+11	-321.9853	773.9738	1264.
12.2500	1.6909	4909281.	86831.	-0.01337	13033.	2.62E+11	-325.5098	808.5157	1298.
12.6000	1.6349	5282551.	90983.	-0.01329	14024.	2.62E+11	-328.8807	844.8730	1333.
12.9500	1.5793	5673538.	94432.	-0.01321	15062.	2.62E+11	-730.3072	1942.	1368.
13.3000	1.5240	6075776.	97170.	-0.01311	16130.	2.62E+11	-736.6691	2030.	1403.
13.6500	1.4691	6489767.	100029.	-0.01301	17229.	2.62E+11	-742.6073	2123.	1438.
14.0000	1.4147	6916022.	103011.	-0.01290	18361.	2.62E+11	-748.1233	2221.	1473.
14.3500	1.3607	7355057.	106116.	-0.01279	19527.	2.62E+11	-753.2151	2325.	1507.
14.7000	1.3073	7807397.	109347.	-0.01267	20728.	2.62E+11	-757.8784	2435.	1542.
15.0500	1.2543	8273574.	112706.	-0.01254	21965.	2.62E+11	-762.1065	2552.	1577.
15.4000	1.2020	8754129.	116195.	-0.01240	23241.	2.62E+11	-765.8910	2676.	1612.
15.7500	1.1502	9249610.	119815.	-0.01226	24556.	2.62E+11	-769.2220	2809.	1647.
16.1000	1.0990	9760571.	123568.	-0.01211	25913.	2.62E+11	-772.0884	2951.	1682.

16.4500	1.0485	1.03E+07	127456.	-0.01195	27312.	2.62E+11	-774.4775	3102.	1717.
16.8000	0.9987	1.08E+07	132137.	-0.01178	28755.	2.62E+11	-464.3550	1953.	1751.
17.1500	0.9496	1.14E+07	137614.	-0.01160	30259.	2.62E+11	-464.9692	2057.	1786.
17.5000	0.9012	1.20E+07	143236.	-0.01141	31824.	2.62E+11	-465.2865	2168.	1821.
17.8500	0.8537	1.26E+07	149003.	-0.01121	33453.	2.62E+11	-465.2957	2289.	1856.
18.2000	0.8070	1.32E+07	154918.	-0.01101	35147.	2.62E+11	-464.9847	2420.	1891.
18.5500	0.7613	1.39E+07	160980.	-0.01079	36908.	2.62E+11	-464.3414	2562.	1926.
18.9000	0.7164	1.46E+07	167193.	-0.01056	38737.	2.62E+11	-463.3528	2716.	1960.
19.2500	0.6725	1.53E+07	173556.	-0.01032	40637.	2.62E+11	-462.0059	2885.	1995.
19.6000	0.6297	1.60E+07	180073.	-0.01007	42608.	2.62E+11	-460.2869	3070.	2030.
19.9500	0.5880	1.68E+07	180097.	-0.00981	44652.	2.62E+11	-1705.	12177.	146.3397
20.3000	0.5473	1.76E+07	173258.	-0.00953	46624.	2.62E+11	-1698.	13032.	0.00
20.6500	0.5079	1.83E+07	166142.	-0.00924	48516.	2.62E+11	-1690.	13978.	0.00
21.0000	0.4697	1.90E+07	159063.	-0.00895	50329.	2.62E+11	-1681.	15029.	0.00
21.3500	0.4327	1.96E+07	152028.	-0.00864	52063.	2.62E+11	-1669.	16199.	0.00
21.7000	0.3971	2.02E+07	145046.	-0.00832	53719.	2.62E+11	-1656.	17511.	0.00
22.0500	0.3629	2.08E+07	138124.	-0.00799	55298.	2.62E+11	-1640.	18986.	0.00
22.4000	0.3300	2.14E+07	131271.	-0.00765	56800.	2.62E+11	-1623.	20655.	0.00
22.7500	0.2986	2.19E+07	124496.	-0.00730	58226.	2.62E+11	-1603.	22554.	0.00
23.1000	0.2687	2.24E+07	117807.	-0.00695	59576.	2.62E+11	-1582.	24727.	0.00
23.4500	0.2402	2.29E+07	111214.	-0.00659	60853.	2.62E+11	-1558.	27232.	0.00
23.8000	0.2133	2.34E+07	104728.	-0.00621	62056.	2.62E+11	-1531.	30139.	0.00
24.1500	0.1880	2.38E+07	98359.	-0.00584	63188.	2.62E+11	-1502.	33543.	0.00
24.5000	0.1643	2.42E+07	92119.	-0.00545	64250.	2.62E+11	-1470.	37565.	0.00
24.8500	0.1422	2.46E+07	86020.	-0.00506	65243.	2.62E+11	-1435.	42365.	0.00
25.2000	0.1218	2.49E+07	60493.	-0.00466	66168.	2.62E+11	-10721.	369659.	0.00
25.5500	0.1031	2.51E+07	13992.	-0.00426	66592.	2.62E+11	-11422.	465494.	0.00
25.9000	0.08599	2.50E+07	-35207.	-0.00386	66480.	2.62E+11	-12006.	586398.	0.00
26.2500	0.07061	2.48E+07	-86598.	-0.00346	65806.	2.62E+11	-12466.	741482.	0.00
26.6000	0.05690	2.43E+07	-139643.	-0.00307	64549.	2.62E+11	-12794.	944352.	0.00
26.9500	0.04482	2.36E+07	-193764.	-0.00269	62692.	2.62E+11	-12979.	1216121.	0.00
27.3000	0.03434	2.27E+07	-248336.	-0.00232	60228.	2.62E+11	-13008.	1591175.	0.00
27.6500	0.02537	2.15E+07	-302666.	-0.00196	57154.	2.62E+11	-12864.	2129230.	0.00
28.0000	0.01786	2.01E+07	-355968.	-0.00163	53478.	2.62E+11	-12518.	2943566.	0.00
28.3500	0.01170	1.85E+07	-407298.	-0.00132	49216.	2.62E+11	-11925.	4279053.	0.00
28.7000	0.00679	1.67E+07	-455412.	-0.00104	44395.	2.62E+11	-10987.	6791158.	0.00
29.0500	0.00301	1.47E+07	-498297.	-7.83E-04	39060.	2.62E+11	-9435.	1.32E+07	0.00
29.4000	2.16E-04	1.25E+07	-519966.	-5.65E-04	33283.	2.62E+11	-883.7491	1.72E+07	0.00
29.7500	-0.00174	1.03E+07	-506182.	-3.82E-04	27464.	2.62E+11	7448.	1.80E+07	0.00
30.1000	-0.00299	8284499.	-467800.	-2.32E-04	21994.	2.62E+11	10830.	1.52E+07	0.00
30.4500	-0.00369	6415257.	-420050.	-1.15E-04	17032.	2.62E+11	11908.	1.36E+07	0.00
30.8000	-0.00395	4756079.	-368536.	-2.52E-05	12627.	2.62E+11	12622.	1.34E+07	0.00

31.1500	-0.00390	3319552.	-314559.	3.95E-05	8813.	2.62E+11	13081.	1.41E+07	0.00
31.5000	-0.00362	2113779.	-259084.	8.30E-05	5612.	2.62E+11	13336.	1.55E+07	0.00
31.8500	-0.00320	1143248.	-202918.	1.09E-04	3035.	2.62E+11	13410.	1.76E+07	0.00
32.2000	-0.00271	409269.	-146794.	1.22E-04	1087.	2.62E+11	13316.	2.07E+07	0.00
32.5500	-0.00218	-89823.	-92158.	1.24E-04	238.4689	2.62E+11	12702.	2.45E+07	0.00
32.9000	-0.00166	-364861.	-44479.	1.20E-04	968.6567	2.62E+11	10003.	2.53E+07	0.00
33.2500	-0.00117	-463444.	-8229.	1.14E-04	1230.	2.62E+11	7259.	2.61E+07	0.00
33.6000	-7.07E-04	-433984.	16516.	1.07E-04	1152.	2.62E+11	4525.	2.69E+07	0.00
33.9500	-2.74E-04	-324706.	29812.	1.01E-04	862.0514	2.62E+11	1806.	2.77E+07	0.00
34.3000	1.37E-04	-183563.	31653.	9.65E-05	487.3354	2.62E+11	-929.7014	2.85E+07	0.00
34.6500	5.36E-04	-58820.	21853.	9.45E-05	156.1591	2.62E+11	-3737.	2.93E+07	0.00
35.0000	9.31E-04	0.00	0.00	9.41E-05	0.00	2.62E+11	-6669.	1.50E+07	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     3.74435155 inches
Computed slope at pile head      =    -0.01413000 radians
Maximum bending moment           =      25082837. inch-lbs
Maximum shear force              =       -519966. lbs
Depth of maximum bending moment  =    25.55000000 feet below pile head
Depth of maximum shear force     =    29.40000000 feet below pile head
Number of iterations             =             25
Number of zero deflection points =              2
```

Pile-head Deflection vs. Pile Length for Load Case 1

Boundary Condition Type 1, Shear and Moment

```
Shear      =              0. lbs
Moment     =              0. in-lbs
Axial Load =              0. lbs
```

Pile Length	Pile Head Deflection	Maximum Moment	Maximum Shear

feet	inches	ln-lbs	lbs
35.00000	3.74435155	25082837.	-519966.
33.25000	3.67833169	24881586.	-509852.
31.50000	4.38923260	24050682.	-603454.
29.75000	12.18414600	19117413.	-606762.

Summary of Pile-head Responses for Conventional Analyses

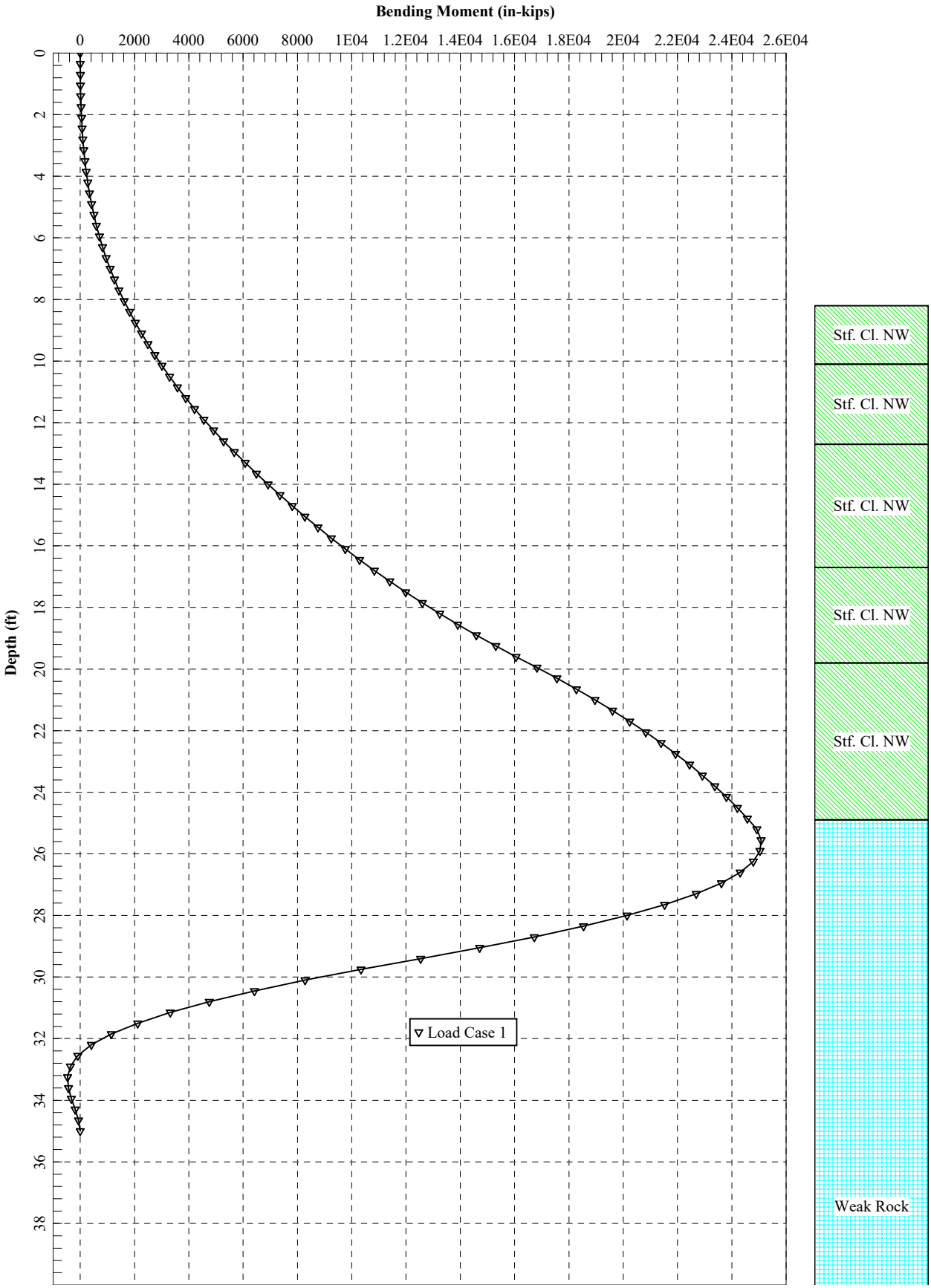
Definitions of Pile-head Loading Conditions:

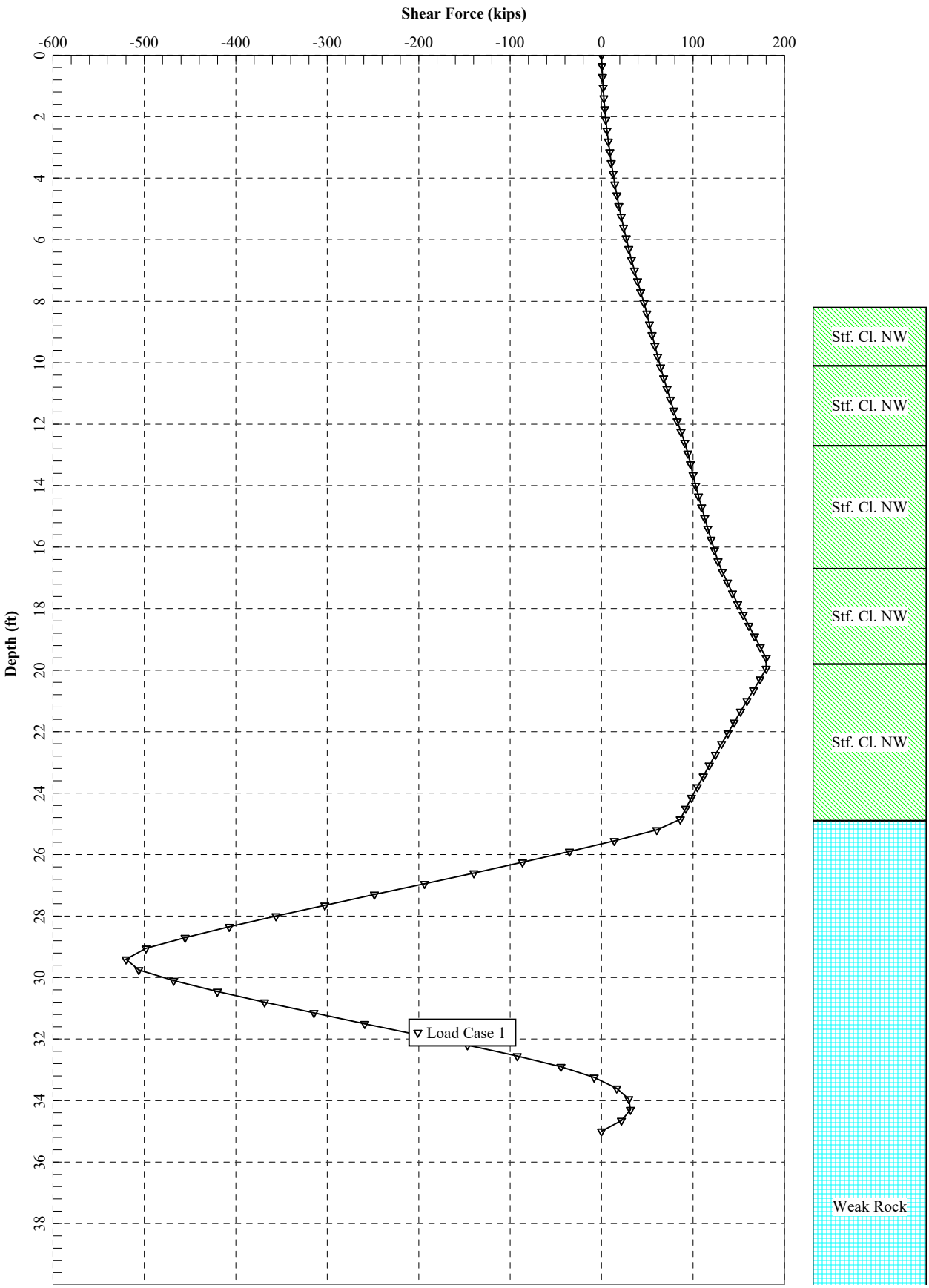
Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

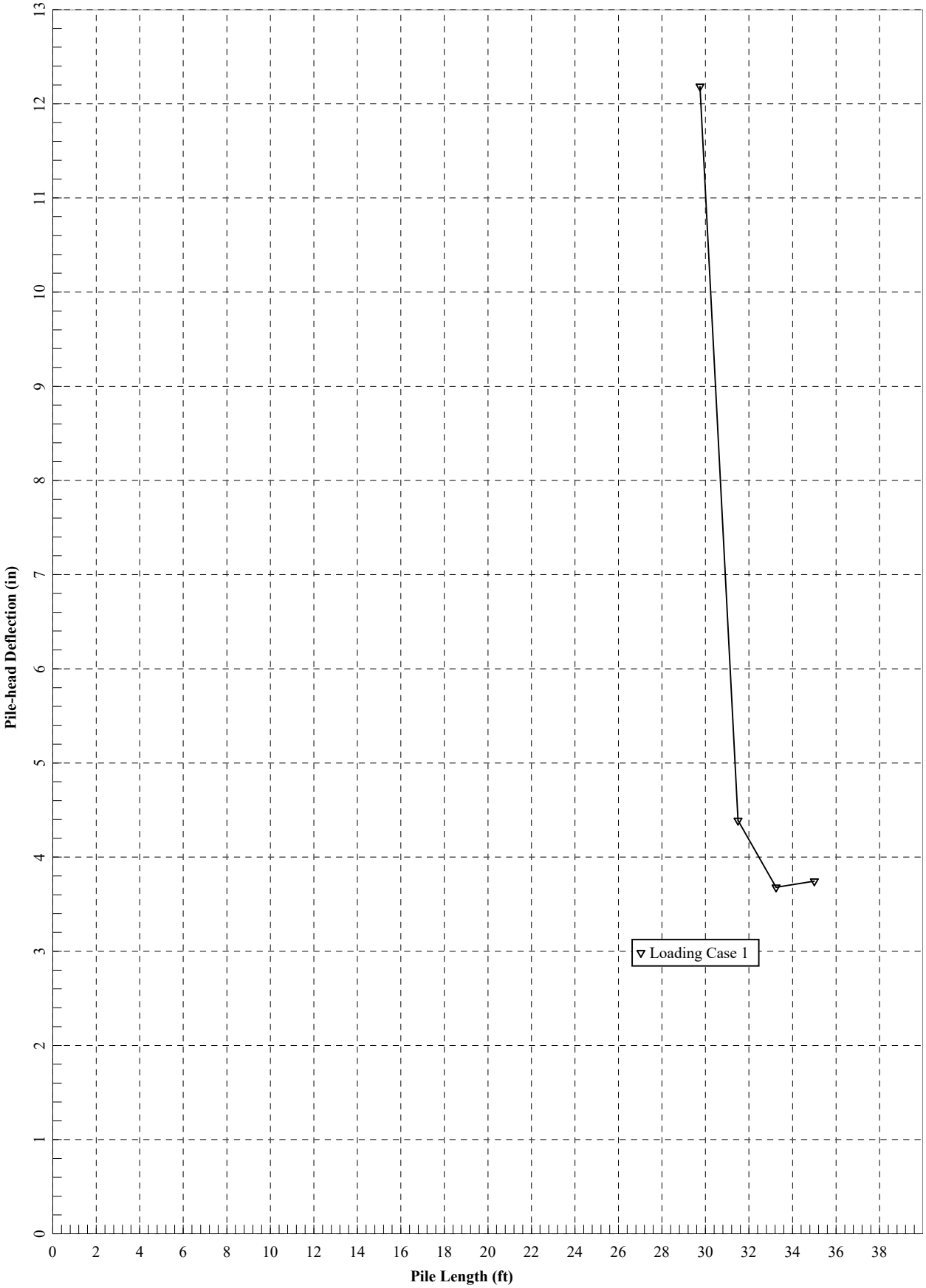
Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	3.7444	-0.01413	-519966.	2.51E+07

Maximum pile-head deflection = 3.7443515510 inches
Maximum pile-head rotation = -0.0141299973 radians = -0.809589 deg.

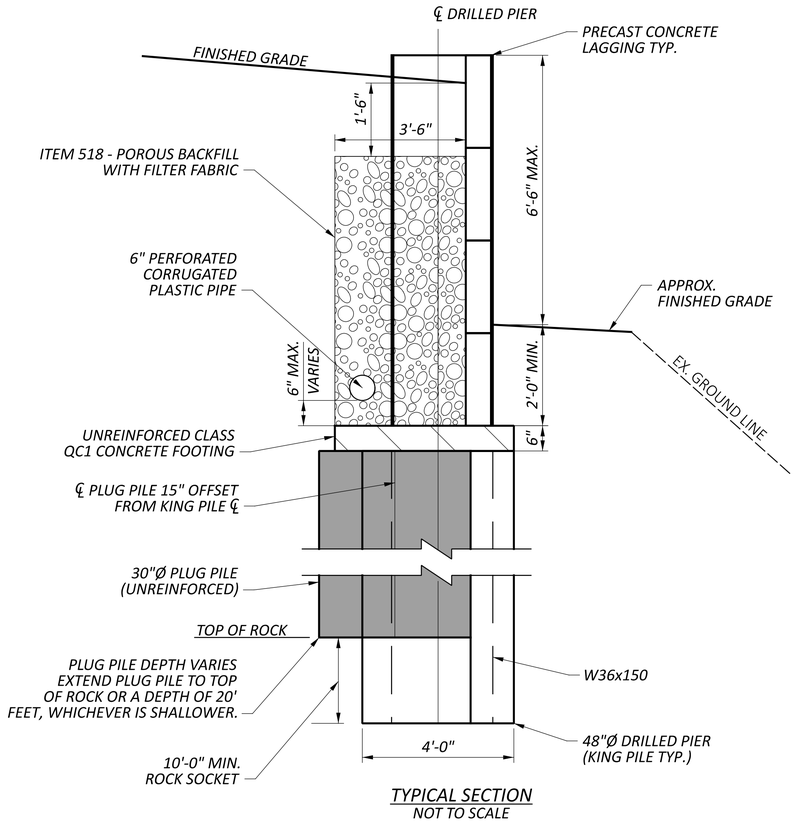
The analysis ended normally.


Bending Moment (in-kips)
0
2000
4000
6000
8000
1E04
1.2E04
1.4E04
1.6E04
1.8E04
2E04
2.2E04
2.4E04
2.6E04
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Load Case 1
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Weak Rock

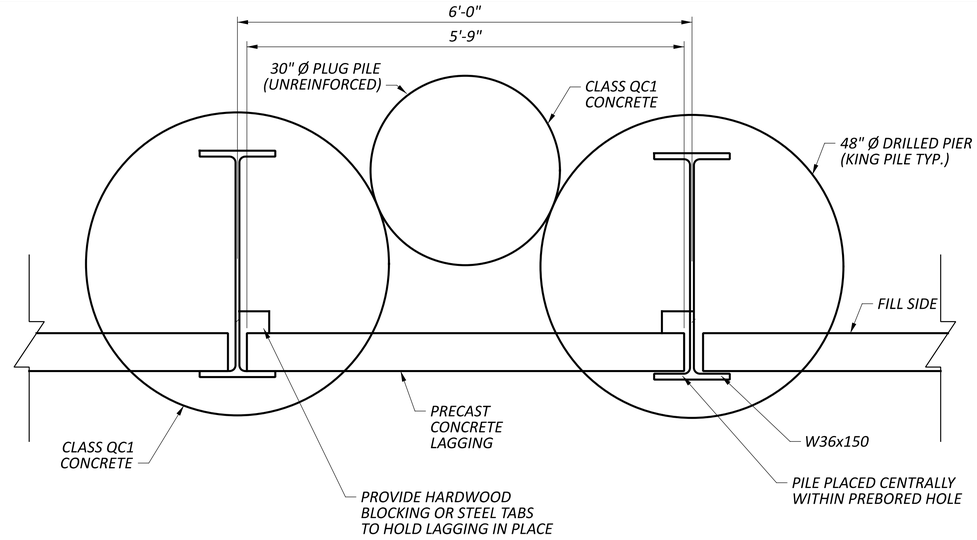

Shear Force (kips)
-600
-500
-400
-300
-200
-100
0
100
200
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Load Case 1
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Stf. Cl. NW
Weak Rock


Pile-head Deflection (in)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Pile Length (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Loading Case 1

Soldier Pile Lagging Wall Detail

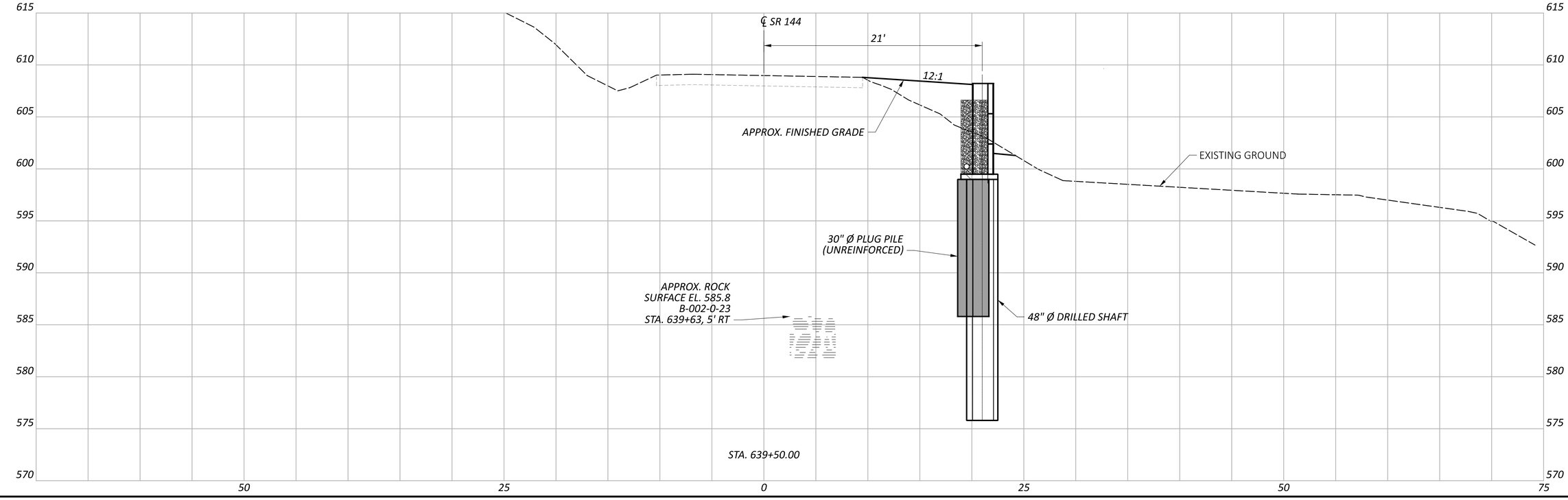


TYPICAL SECTION
NOT TO SCALE



PLAN - RETAINING WALL
NOT TO SCALE

BORING	STATION	OFFSET	APPROX. SURFACE ELEVATION	APPROX. ROCK SURFACE ELEVATION
B-001-0-23	638+35	5' RT	609.3	584.3
B-002-0-23	639+63	5' RT	608.8	585.8
B-003-0-23	640+81	5' RT	611.6	587.1



HORIZONTAL SCALE IN FEET
0 5 10 20

SOLDIER PILE AND LAGGING WALL DETAIL
CRITICAL SECTION STA. 639+50

DESIGN AGENCY
HDR

DESIGNER AKB
REVIEWER DMV 02/24/23
PROJECT ID 116165
SHEET 1 TOTAL 1

ATH-144-12.08