



# Technical Design Memo

Client: Ohio Department of Transportation, District 10

Project: **WAS-77-9.58 (Task Order 10-EE)**  
**PID 115420**

HDR Project No: 10375564

Rev: 0

Calculation No: 1

Page: 1 of 315

Title: Retaining Wall Analyses and Design

Purpose: Design of a permanent retaining wall to allow access to an existing buried junction chamber and culvert running beneath Interstate 77 (I-77) in Washington County, Ohio.

Originator: AKB

Date: 8/24/2023

Checked by: DCM

Date: 9/5/2023

QC Review by: DMV

Date: 9/8/2023

## Summary

1. An existing 48-inch culvert running beneath I-77 near mile marker 9.58 in Washington County, Ohio is to be lined for approximately 552 feet from its inlet to an existing junction chamber buried beneath approximately 40 feet of embankment fill. This junction chamber, as well as the culvert pipe located downstream of the chamber, are to be removed as part of a culvert repair project. To access and remove the buried junction chamber and pipe, a permanent retaining wall is planned between approximately Sta. 504+50 and Sta. 505+50, at roughly 250 to 280 feet left of the I-77 centerline. The project location is shown on the attached Site Vicinity and Topographic Map.

Based on observations gathered during the site reconnaissance; review of the existing site plans, historic geotechnical explorations, and geophysical study; the depth of the existing junction chamber; and the findings from the recent geotechnical explorations performed between July 12 to 17, 2023, two feasible wall options were considered. Option 1 considers a cantilever tangent drilled shaft wall. Option 2 considers a soldier pile and lagging wall with tiebacks. Presented herein are the discussion and evaluation of both wall designs. These designs assume that the topography

and slope geometry as presented in the site survey are representative of the current field conditions.

2. Washington County lies upon the Marietta Plateau region within the unglaciated Allegheny (Kanawha) Plateaus section of the Appalachian Plateaus province of southeast Ohio. The physiographic features across a majority of the county have been strongly influenced by stream erosion. The impact of numerous drainage routes are distinct and prevalent throughout Washington County, as indicated by the dramatic elevation changes between the rugged, steep slopes and low-lying valleys containing numerous creeks and tributaries. However, these elevation changes are more gradual in and to the southeast of the project area, which is comprised of gently-rolling hillsides and pre-glacial terraces within an ancient valley that was at one time occupied by Whipple Creek, a headwater tributary of the pre-glacial Marietta River within the Teays River System. This northwestern-flowing river system was blocked by ice during the pre-Illinoian glaciation, forming a large lake known as Lake Tight and inundating much of southern Ohio. As such, sediments deposited along the bed of this ancient lake are widely-distributed across southeastern Ohio, including central Washington County. The central portion of Washington County is currently drained by tributaries of the Muskingum River, which in turn flows into the Ohio River near Marietta in the southern portion of the county. The project site is drained directly by an unnamed tributary of Bear Creek, which drains into Bear Creek itself approximately 0.6 mile west of the project site.

The surficial materials within Washington County largely consist of colluvium and residuum derived from the underlying sedimentary bedrock, with some areas of alluvial, glacial outwash, and lacustrine deposits located in areas of historic surface water. The bedrock at the project site is mapped as transitioning between the Permian-Pennsylvanian-age Dunkard Group as mapped along the ridgetops, to the Pennsylvanian-age Monongahela Group within the valleys. The Dunkard Group consists of mudstone, shale, and siltstone, with minor amounts of sandstone, limestone, and coal. The Monongahela Group consists of shale, siltstone, and mudstone, with minor amounts of limestone and coal.

3. The main coal seam of note within the Dunkard Group is the Washington No. 12 coal, while notable seams within the underlying Monongahela Group include the Pittsburgh No. 8, Pomeroy (Redstone) No. 8a, Meigs Creek (Sewickley) No. 9, Uniontown No. 10, and Waynesburg No. 11 coals. Most of the mining in Washington County occurred in the north-central portion of the county; no significant mining activity is mapped at the project site according to information from the Ohio Department of Natural Resources. Several abandoned mine portals with unknown extents and occasional historic surface mines are mapped within about 1 to 2 miles to the north, west, and east of the project site. Where identified, the associated coal seam is identified as the Pittsburgh No. 8 or the Meigs Creek No. 9. Two of the mine points identify coal elevations of the Meigs Creek No. 9 as El. 670 towards the northwest, and El. 762 towards the east. More extensive surface mining is mapped to the northeast, approximately 3 miles or more from the project site. The associated coal seams and elevations are not reported.



4. No base flood elevation has been established based on review of FEMA flood maps for the area to determine the highwater elevation along the slope located below the roadway. The project site is mapped in an area designated as an area of minimal flood hazard (Zone X).
5. Prior geotechnical explorations have been performed at the WAS-77-9.58 project site. ODOT performed four borings in 2022, designated as Borings B-001-0-22 through B-004-0-22, in support of the culvert project. Refraction microtremor (ReMi) and electrical resistivity (ER) surveys were also performed as part of this study on the east embankment face. These borings extended to depths of 30 to 97.5 feet (El. 848.9 to 834.7) below the existing ground surface and generally encountered stiff to hard Sandy Silt (A-4a), Silt and Clay (A-6a), and Silty Clay (A-6b) with intervals of medium dense to very dense Stone Fragments (A-1-a), Stone Fragments with Sand (A-1-b), Stone Fragments with Sand and Silt (A-2-4), and Stone Fragments with Sand, Silt, and Clay (A-2-6), and stiff Clay (A-7-6) encountered to a lesser extent. Intervals of boulders/cobbles were also encountered in Boring B-002-0-22 from 63.5 to 68.5 feet (El. 870.4 to El. 865.4) and Boring B 003 0-22 from 71 to 71.5 feet (El. 862.6 to El. 862.1). A distinction was not made between embankment fill and native soils on the boring logs. However, construction plans for I-77 as developed for the WAS-77-9.12 project indicate embankment fill thicknesses up to approximately 56 feet at Sta. 504+00 and 74 feet at Sta. 505+00. Bedrock was not encountered within the borings to the depths explored, but was observed at the culvert inlet on the east side of the embankment at approximately El. 876, and dropped sharply towards the west based on the geophysical results. The Interoffice Communication presenting the findings from the 2022 study is attached.

A search of the available records on ODOT's Transportation Information Mapping System (TIMS) also reveals two prior projects within the project limits. WAS-77-9.00 (sub-batch 15603) was completed in 1964 for the original construction of I-77. WAS-77-9.45 (sub-batch 15609) was completed in 1969 as an embankment repair between approximately Sta. 501+50 and Sta. 505+00. Five of the historic borings from these two projects, located approximately 50 to 70 feet downstation of the proposed wall at offsets between 140 feet and 260 feet left of centerline, were considered to be relevant. These borings, redesignated as Borings B-004-1-64, B-004-2-64, and B-004-3-64 from the WAS-77-9.00 project and Borings B-002-0-69 and B-003-0-69 from the WAS-77-9.45 project are attached. Reported elevations have been adjusted to the NAVD88 datum, approximately 0.6 feet lower than the original NGVD29 datum. These borings indicate predominantly Sandy Silt (A-4a) and Silt and Clay (A-6a) materials, with Silty Clay (A-6b) and Clay (A-7-6) encountered to a lesser extent. Coring was not performed in the 1964 borings, but "indurated clay" is described in each of the borings starting at depths of 0 to 13 feet below grade (El. 854.4 at 140 feet left of centerline to 821.0 at 250 feet left of centerline), increasing in depth towards the west along Sta. 504+00. Coring was performed in the 1969 borings, extending approximately 27 to 30 feet into bedrock. Top of rock was encountered at 30 to 34 feet below grade (El. 839.8 at 176 feet left of C/L, to 807.8 feet at 256 feet left of C/L) along approximate Sta. 504+00. The encountered rock was described as mudstone. It contained arenaceous intervals and clay seams throughout, as well as interbedded dolomite, chert, and limestone in the mudstone encountered in Boring B-003-0-69.

6. The recent geotechnical exploration program consisted of a series of 3 test borings (designated as Borings B-005-0-23, B-006-0-23, and B-007-0-23) to characterize the subsurface profile in the vicinity of the proposed wall. Two test borings (B-005-0-23 and B-007-0-23) were drilled along the proposed wall alignment, and one boring (B-006-0-23) was drilled approximately 70 feet downslope of the wall as shown on the attached Boring Location Plan. The soil profile, as encountered in the borings, generally consisted of an upper layer of medium stiff to stiff embankment fill to depths of 10 feet to 33.5 feet below existing grade depending upon location. The fill was predominantly comprised of Silt and Clay (A-6a), Silty Clay (A-6b), and Clay (A-7-6). An interval of medium dense Stone Fragments with Sand, Silt, and Clay (A-2-6) was also encountered in Boring B-005-0-23 from a depth of approximately 28.5 feet to 33.5 feet (El. 830.2 to El. 825.2) below existing grade. Below the fill, stiff to hard native cohesive soils comprised of Silt and Clay (A-6a), Silty Clay (A-6b), and Clay (A-7-6) were encountered to the top of bedrock encountered at depths of 35 to 48.5 feet (El. 814.7 to 804.8). The bedrock as encountered in the borings was comprised of predominantly claystone and siltstone, with occasional thin layers of limestone and sandstone.

Free water was recorded in Boring B-006-0-23 at a depth of 23.5 feet (El. 816.3), but was not encountered in the remaining test borings during drilling. As the borings were sealed upon completion, delayed water level readings were not obtained. Typed boring logs and laboratory testing results are included in the attachments.

The generalized soil profile developed for the design section is primarily based on the findings from Boring B-005-0-23, located near the upslope end of the wall. The soil profile is assumed to be depicted as indicated on the attached boring log for Boring B-005-0-23 based on the generalized soil conditions as encountered in the explorations, as well as field observations gathered during the course of our site reconnaissance.

7. In accordance with ODOT Geotechnical Design Manual (GDM) recommendations, an initial set of soil and bedrock 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” and “Rock Strength Parameter Determination”.

Limited groundwater information was available from the borings and published sources. However, the moisture contents encountered in Borings B-001-0-22, B-002-0-22, and B-003-0-22, performed across the top of the I-77 embankment, were generally in the low- to mid-teens, with occasional samples in the high-teens or low-20s. Moisture contents in Borings B-004-0-22, B-005-0-23, B-006-0-23, and B-007-0-23, performed downslope of the roadway embankment, were generally in the high-teens to low-20s to the boring termination depth or top of bedrock. Based on the available information and on-site observations, groundwater was considered to be approximately 7.5 feet below grade based on the elevated moisture contents combined with the lower blow counts and hand penetrometer values in Borings B-005-0-23 and B-007-0-23.

To supplement the limited bedrock testing able to be performed on the rock core obtained in the 2023 borings, additional claystone bedrock testing from the WAS-821-3.68 project site (also referred to as WAS-821-3.79) located approximately 2.9 miles south of the WAS-77-9.58 site, was used in developing the bedrock parameters. Use of these supplemental samples from the WAS-821-3.68 project was limited to red/reddish-brown claystone below about El. 770, where the transition between the Dunkard Group and Monongahela Group is shown on ODNR bedrock mapping, similar to the current WAS-77-9.58 project site.

8. After development of the subsurface profile and strength parameters, wall backslope geometry was determined based on survey information near Boring B-005-0-23 for design. The top of the wall was considered at El. 856 based on existing grades near the proposed wall location. The bottom of the wall was considered at the approximate bottom of the junction box at El. 814. As such, the resulting 42-foot exposed wall height was adopted for design purposes. Once the wall location and geometries were established, an iterative process was undertaken in order to determine a drilled shaft size, spacing, and the horizontal forces acting on the wall. Based on conventional wall loading, the unfactored force per shaft required consideration of a tangent pile wall configuration for this cantilevered wall option. As this wall configuration does not facilitate free-drainage of the supported soils nor the implementation of a drainage layer, hydrostatic loading was also applied to the wall design.

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). Based on a depth to bedrock of 45.8 feet, the allowable pile head deflection is **5.50 inches**. Considering the maximum available beam size, a W 44x408, installed in 4.5-foot diameter tangent shafts, the pile head deflection exceeded this allowable deflection with water at a depth of 7.5 feet below the top of the wall (El. 848.5). Consideration was given to installing drains behind the wall to reduce the hydrostatic loading, but the water table would need to be lowered to El. 823.5, or 32.5 feet below the top of the wall, to reduce the deflection below the allowable. As this approach was not considered feasible, the drilled shaft layout was adjusted to a staggered configuration to allow for closer spacing.

9. At a 3.25-foot staggered center-to-center spacing, the computed unfactored force per shaft is  $P_s + P_w = 108,942 \text{ pounds} + 120,691 \text{ pounds} = \mathbf{229,633 \text{ pounds}}$ . LPILE software was used to determine the pile response to the applied lateral loading. The following were considered relative to LPILE analyses:

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

- Calculate conventional earth pressure wall loading.
  - Equivalent Fluid Weight ( $G_H$ ) = ( $\gamma_{eff}$ ) \* ( $K$ ) = **38 pcf**  
 $\gamma_{eff}$  = soil effective unit weight (see attached calculations)  
 $K_a$  = active earth pressure (see attached calculations)
  - Lateral Thrust ( $P$ ) =  $1/2 * G_H * H^2 = P = \mathbf{33,521 \text{ lbs/ft}}$   
 $H$  = Wall Height

- Horizontal Force Per Shaft ( $P_{SH}$ ) =  $P * (S_{cc}) = \underline{108,942 \text{ lbs/shaft}}$   
 $S_{cc}$  = Center-to-Center Shaft Spacing = 3.25 ft
- Resolve Horizontal Earth Pressure to Distributed Triangular Load  
 $(2 * P_{SH}/H) / (12 \text{ in/ft})$   
 $= \underline{432 \text{ lbs/in per shaft (Service Load)}}$   
 $(432 \text{ lbs/in}) (\gamma_{EH}) = (432 \text{ lbs/in}) (1.5)$   
 $= \underline{648 \text{ lbs/in per shaft (Strength Load)}}$

(b) Hydrostatic Loading

- Calculate conventional earth pressure wall loading.
  - Hydrostatic Loading ( $P_w$ ) =  $1/2 * \gamma_w * H_w^2 = P_w = \underline{37,136 \text{ lbs/ft}}$   
 $H$  = Water Height
  - Horizontal Force Per Shaft ( $P_{SH}$ ) =  $P_w * (S_{cc}) = \underline{120,691 \text{ lbs/shaft}}$   
 $S_{cc}$  = Center-to-Center Shaft Spacing = 3.25 ft
  - Resolve Horizontal Earth Pressure to Distributed Triangular Load  
 $(2 * P_w/H_w) / (12 \text{ in/ft})$   
 $= \underline{583 \text{ lbs/in per shaft (Service Load)}}$   
 $(583 \text{ lbs/in}) (\gamma_{EH}) = (583 \text{ lbs/in}) (1.5)$   
 $= \underline{875 \text{ lbs/in per shaft (Strength Load)}}$

(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).

- $\beta_a = 0.64(S/D)^{0.34}$  applies when  $1 \leq S/D < 3.75$ , where  $0.5 \leq P_m < 1.0$ . As the minimum value of  $P_m$  is 0.5, and the PYWall user's manual by Ensoft indicates "For a continuous diaphragm wall or drilled shaft wall, the p-multiplier of 0.5 has been widely used by engineers." A P-multiplier of 0.5 was adopted.

(d) Pile Head Deflection

1% of the drilled shaft length above bedrock (45.8 feet) = 5.50 inches

Computed Pile Head Deflection (W 44 x 408) = 5.25 inches < 5.50 inches OK  
(See attached calculations)

(e) Pile Length

The "Top Deflection Versus Length" plot produced by the LPILE software was reviewed to determine the recommended rock socket length. Based on the encountered claystone bedrock and our experience with such local bedrock types, a minimum rock socket length of 20 feet is recommended.

(f) Steel Reinforcement and Pile Cross Section Character

Use W 44 x 408 shaft reinforcement

$$A_s = \text{Area of Steel} = 120.5 \text{ in}^2$$

$$I_x = \text{Moment of Inertia around strong axis} = 38,500 \text{ in}^4$$

$$T_w = \text{web thickness} = 1.22 \text{ in}$$

$$E = \text{Modulus of Elasticity of Steel} = 29,000,000 \text{ psi}$$

$$F_y = \text{yield strength of steel} = 50,000 \text{ psi}$$

$$B_f = \text{Flange Width} = 16.1 \text{ in}$$

For the two piles immediately adjacent to the 48-inch culvert, a larger spacing will be required to span across the culvert ( $0.5 * 3.25$  feet drilled shaft spacing +  $2.25$  foot drilled shaft radius +  $0.5 * 4$  foot culvert diameter +  $10$ -inch clearance =  $6.71$  foot spacing). However, as lagging will be required to span across the culvert, a drainage layer will be included, and hydrostatic pressures were not included on these two shafts. The computed unfactored force per shaft is  $P_s = 357,142$  pounds.

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

➤ Calculate conventional earth pressure wall loading.

$$\text{Equivalent Fluid Weight } (G_H) = (\gamma_{\text{eff}}) * (K) = \mathbf{60 \text{ pcf}}$$

$\gamma_{\text{eff}}$  = soil effective unit weight (see attached calculations)

$K_a$  = active earth pressure (see attached calculations)

$$\text{Lateral Thrust } (P) = 1/2 * G_H * H^2 = P = \mathbf{53,239 \text{ lbs/ft}}$$

$H$  = Wall Height

$$\text{Horizontal Force Per Shaft } (P_{SH}) = P * (S_{cc}) = \mathbf{357,142 \text{ lbs/shaft}}$$

$S_{cc}$  = Center-to-Center Shaft Spacing =  $6.71$  ft

$$\text{Resolve Horizontal Earth Pressure to Distributed Triangular Load}$$

$$(2 * P_{SH} / H) / (12 \text{ in/ft})$$

$$= \mathbf{1417 \text{ lbs/in per shaft (Service Load)}}$$

$$(1242 \text{ lbs/in}) (\gamma_{EH}) = (1242 \text{ lbs/in}) (1.5)$$

$$= \mathbf{2126 \text{ lbs/in per shaft (Strength Load)}}$$

(b) 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).

$$\beta_a = 0.64(S/D)^{0.34} = \beta_a = 0.64(4.5/5.88)^{0.34}$$

$$\beta_a = \mathbf{0.73}$$

(c) Pile Head Deflection

1% of the drilled shaft length above bedrock (45.8 feet) = **5.50 inches**

Computed Pile Head Deflection (W 36 x 652) = **5.87 inches** = 1.07% of the shaft length above bedrock. While it exceeds the target deflection of 1%, this deflection is considered to be acceptable. (See the attached calculations)

(d) Pile Length

The “Top Deflection Versus Length” plot produced by the LPILE software was reviewed to determine the recommended rock socket length. Based on the encountered claystone bedrock and our experience with such local bedrock types, **a minimum rock socket length of 20 feet** is recommended.

(e) Steel Reinforcement and Pile Cross Section Character

Use W 36 x 652 shaft reinforcement

$A_s$  = Area of Steel = 192.0 in<sup>2</sup>

$I_x$  = Moment of Inertia around strong axis = 50,600 in<sup>4</sup>

$T_w$  = web thickness = 1.97 in

$E$  = Modulus of Elasticity of Steel = 29,000,000 psi

$F_y$  = yield strength of steel = 50,000 psi

$B_f$  = Flange Width = 17.6 in

**10.** As an alternative to the cantilever wall, a soldier pile and lagging wall with tiebacks was analyzed in accordance with ODOT and AASHTO design requirements using Shoring Suite software. For the soldier pile and lagging wall with tiebacks, a 6-foot center-to-center spacing was used. Earth pressures were developed considering a 2-trapezoid envelope. It is assumed that filter fabric and free draining granular material will be installed behind the lagging panels to facilitate drainage of the encountered ground water. As such, the soldier pile and lagging wall were not designed for hydrostatic pressures. Groundwater was lowered to the ground surface on the passive side of the wall. Rows of tiebacks were spaced 6 feet on center at depths of 10, 20, and 30 feet below the top of the wall, inclined at an angle of 20 degrees below the horizontal.

(a) Steel Reinforcement and Tieback Details

Use HP 14 x 73 shaft reinforcement in a 2.5-foot diameter drilled shaft embedded a minimum of 5 feet into bedrock

$A_s$  = Area of Steel = 21.4 in<sup>2</sup>

$I_x$  = Moment of Inertia around strong axis = 729 in<sup>4</sup>

$T_w$  = web thickness = 0.505 in

$E$  = Modulus of Elasticity of Steel = 29,000,000 psi

$F_y$  = yield strength of steel = 50,000 psi

$B_f$  = Flange Width = 14.6 in



1<sup>st</sup> Row of Tiebacks

Depth below top of wall = 10 ft  
Center-to-center spacing = 6 ft  
Inclination angle below horizontal = 20°  
Tieback drill hole diameter = 9 in  
Unbonded length = 32 ft  
Required bond length = 43 ft  
Total length = 75 ft  
Required Anchor Load = 210.5 kips  
No. of 0.6 in diameter prestressing steel strands: 6

2<sup>nd</sup> Row of Tiebacks

Depth below top of wall = 20 ft  
Center-to-center spacing = 6 ft  
Inclination angle below horizontal = 20°  
Tieback drill hole diameter = 9 in  
Unbonded length = 26 ft  
Required bond length = 28 ft  
Total length = 54 ft  
Required Anchor Load = 135.8 kips  
No. of 0.6 in diameter prestressing steel strands: 4

3<sup>rd</sup> Row of Tiebacks

Depth below top of wall = 30 ft  
Center-to-center spacing = 6 ft  
Inclination angle below horizontal = 20°  
Tieback drill hole diameter = 9 in  
Unbonded length = 21 ft  
Required bond length = 33 ft  
Total length = 55 ft  
Required Anchor Load = 164.6 kips  
No. of 0.6 in diameter prestressing steel strands: 5

A 8.5-foot spacing (2.5-foot diameter drilled shaft + 4-foot diameter culvert + 1-foot clearance on either side of the culvert) was considered for the piles immediately adjacent to either side of the culvert.

(b) Steel Reinforcement and Tieback Details (Span 48 inch Culvert)

Use HP 14 x 73 shaft reinforcement in a 2.5-foot diameter drilled shaft embedded a minimum of 5 feet into bedrock

$A_s$  = Area of Steel = 21.4 in<sup>2</sup>  
 $I_x$  = Moment of Inertia around strong axis = 729 in<sup>4</sup>  
 $T_w$  = web thickness = 0.505 in  
 $E$  = Modulus of Elasticity of Steel = 29,000,000 psi



$F_y$  = yield strength of steel = 50,000 psi

$B_f$  = Flange Width = 14.6 in

1<sup>st</sup> Row of Tiebacks

Depth below top of wall = 10 ft

Center-to-center spacing = 8.5 ft

Inclination angle below horizontal = 20°

Tieback drill hole diameter = 9 in

Unbonded length = 32 ft

Required bond length = 52 ft

Total length = 84 ft

Required Anchor Load = 254.3 kips

No. of 0.6 in diameter prestressing steel strands: 8

2<sup>nd</sup> Row of Tiebacks

Depth below top of wall = 20 ft

Center-to-center spacing = 8.5 ft

Inclination angle below horizontal = 20°

Tieback drill hole diameter = 9 in

Unbonded length = 26 ft

Required bond length = 34 ft

Total length = 60 ft

Required Anchor Load = 164.1 kips

No. of 0.6 in diameter prestressing steel strands: 5

3<sup>rd</sup> Row of Tiebacks

Depth below top of wall = 30 ft

Center-to-center spacing = 6.5 ft

Inclination angle below horizontal = 20°

Tieback drill hole diameter = 9 in

Unbonded length = 21 ft

Required bond length = 41 ft

Total length = 62 ft

Required Anchor Load = 198.4 kips

No. of 0.6 in diameter prestressing steel strands: 6

- 11.** Please refer to the attached sheets for further details on the wall designs themselves. Note that these details are considered to be preliminary and should be revised as the overall project and wall design progresses. For example, it may be decided that temporary hardwood lagging be utilized and a permanent concrete face installed to protect the tiebacks as well as allow for the use of a geocomposite drain strip for constructability. A waler may also be utilized to allow for the placement of the tiebacks between the piles rather than through.



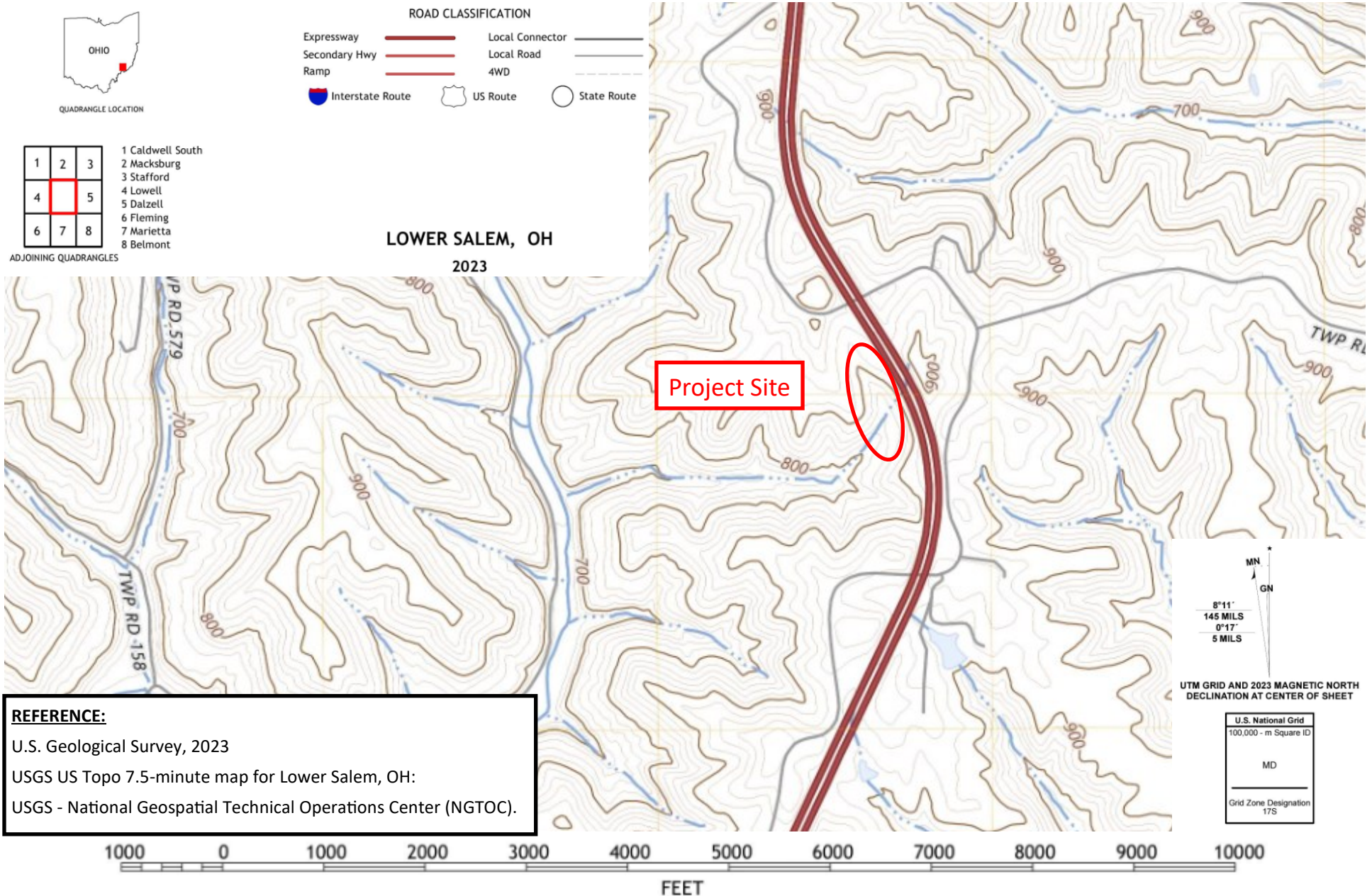


12. The proposed retaining wall is to be located along an existing embankment slope with an exposed height that extends from the current ground surface to the bottom of the buried junction chamber. The adopted design height of 42 feet is substantial, and while a cantilever wall does offer a more simplistic and straight forward construction approach, the required sizing of the drilled shafts and reinforcing steel section could be cost prohibitive and a significant time lag built into any schedule to allow for rolling and delivery of the beams. As an alternative option, smaller drilled shafts and reinforcing steel sections could be utilized by incorporating 3 rows of tieback anchors to a soldier pile and lagging wall. While this option will require a more specialized contractor and testing, the sizing of the drilled shafts is more typical and the reinforcing sections more readily available from multiple steel producers. As such, the soldier pile and lagging wall with 3 rows of tieback supports is the recommended option.



## **Site Vicinity and Topographic Map**

# Site Vicinity and Topographic Map





## **Bedrock Geology Maps**



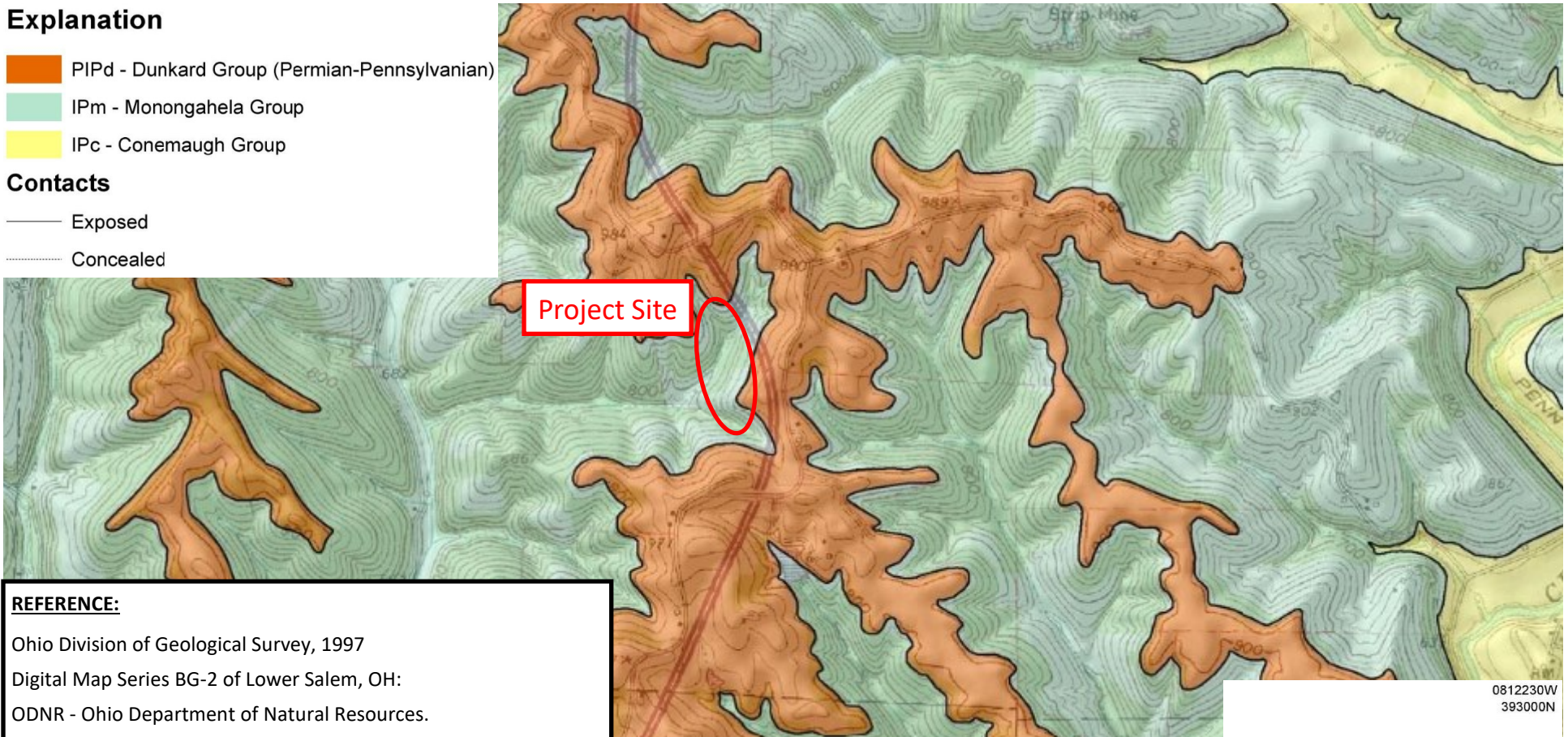
# Bedrock Geology Map

## Explanation

- PIPd - Dunkard Group (Permian-Pennsylvanian)
- IPm - Monongahela Group
- IPc - Conemaugh Group

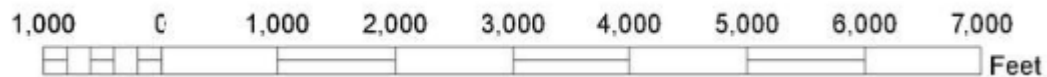
## Contacts

- Exposed
- Concealed



## REFERENCE:

Ohio Division of Geological Survey, 1997  
Digital Map Series BG-2 of Lower Salem, OH:  
ODNR - Ohio Department of Natural Resources.



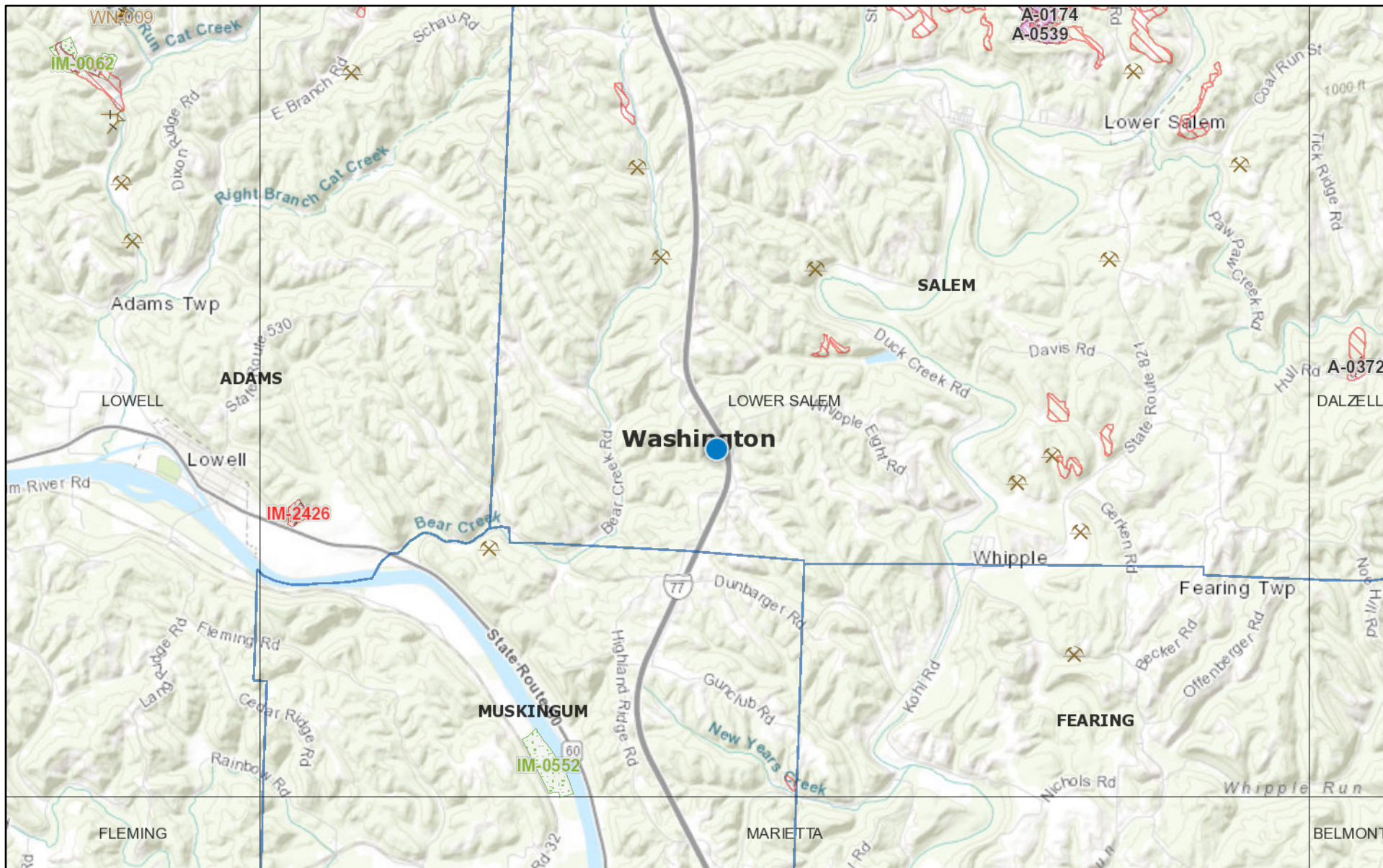
LOCATION MAP



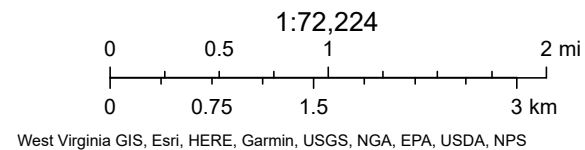
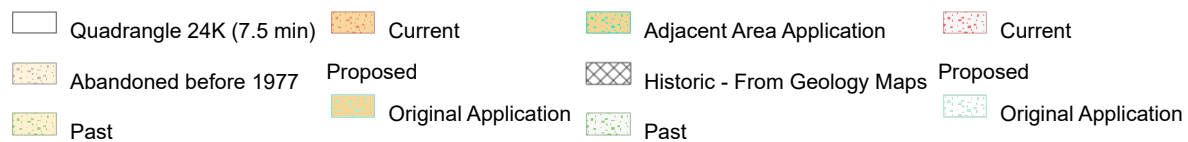
## **Mine Map**



# WAS-77-9.58 Mine Map



August 22, 2023





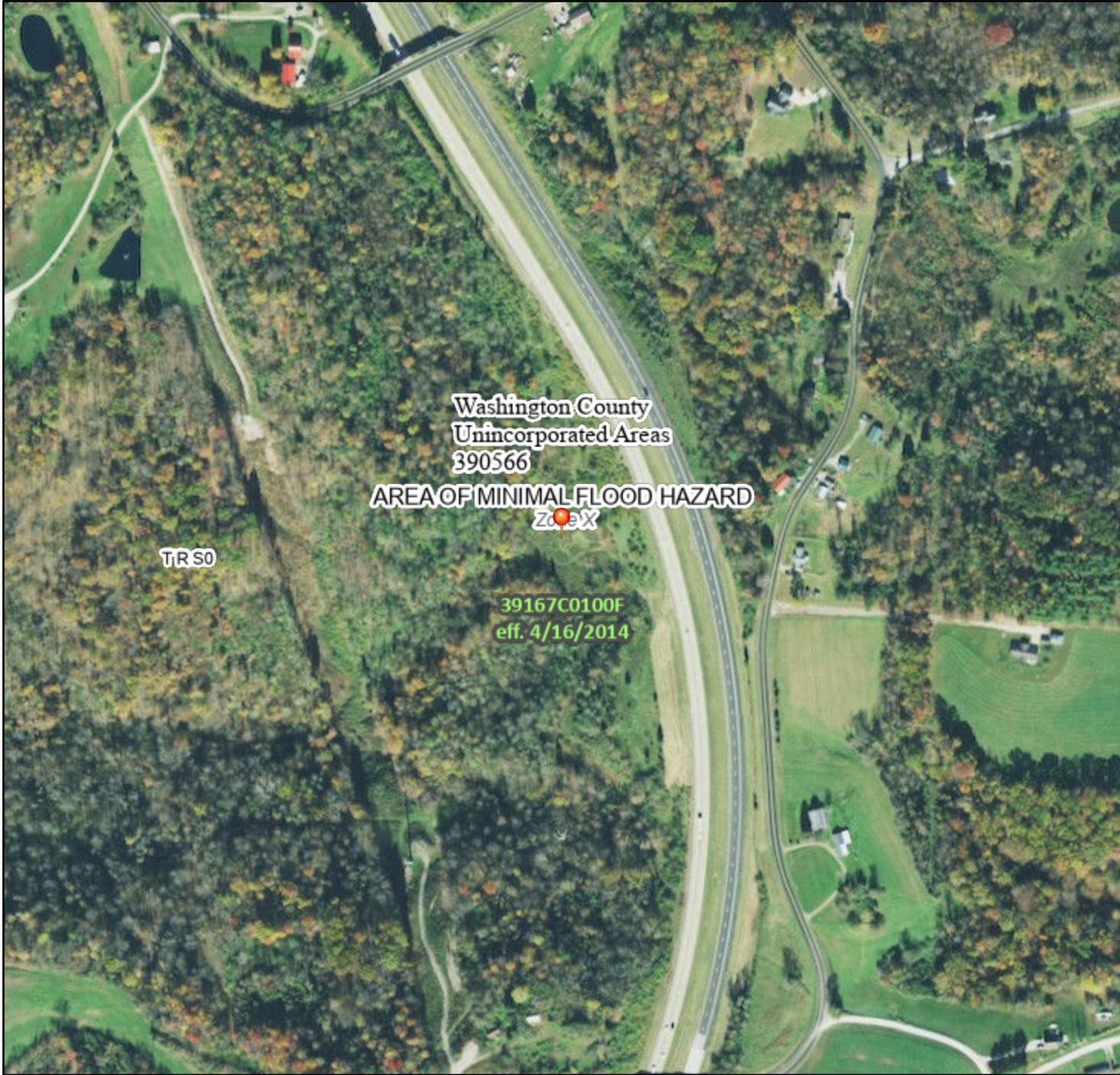
## **FEMA Flood Map**



# National Flood Hazard Layer FIRMMette



81°27'3"W 39°32'9"N



1:6,000

81°26'25"W 39°31'41"N

Basemap Imagery Source: USGS National Map 2023

## 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 Water Surface Elevation
		17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
		Coastal Transect
		Base Flood Elevation Line (BFE)
		Limit of Study
		Jurisdiction Boundary
		Coastal Transect Baseline
MAP PANELS		Digital Data Available
		No Digital Data Available
		Unmapped



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 **8/23/2023 at 1:38 PM** 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.



## **Historical Records**

WAS-77-9.58 (2022)



# INTEROFFICE COMMUNICATION

**TO:** Andrew Moreland, P.E., District Geotechnical Engineer, District 10  
**FROM:** Andrew Jalbrzikowski, Office of Geotechnical Engineering  
Paul Painter, Office of Geotechnical Engineering  
**DATE:** January 10, 2023  
**SUBJECT:** WAS-77-9.58 PID 113235 Geophysical Exploration Summary

---

Pursuant to your request, the Office of Geotechnical Engineering (OGE) has completed four geotechnical borings and two geophysical surveys to determine the bedrock elevation along a proposed jack and bore culvert alignment. The borings were completed from November 22 to December 12, 2022. Bedrock was not encountered in the borings, though boring B-002-0-22 encountered cobbles and boulders from a depth of 63.5' to 68.5'. Sandstone and shale bedrock is exposed in the stream channel near the proposed inlet at an approximate elevation of 876. During the geophysical survey a bulk sample of the sandstone was collected at the location indicated on the attached exploration plan.

To further characterize the soil bedrock interface along the proposed culvert alignment, two geophysical methods; refraction microtremor (ReMi) and electric resistivity (ER) were utilized. Traffic on I-77 creates excessive seismic noise and prevented the collection of a seismic refraction survey. The following is a discussion of the field exploration and results of the geophysical exploration. The latitude, longitude, and elevation values used to create the seismic and resistivity sections were from a Trimble Geo7x GPS unit utilizing the ODOT VRS network. The geophysical field work was completed on December 13, 2023.

The ReMi survey line was completed along the east side of the I-77 embankment, along the anticipated culvert alignment. The geophones were planted into the embankment soil, starting near the proposed culvert inlet, and extending up the embankment slope. The ReMi data was collected with a SeismicSource DAQlink III 24 channel seismograph along one survey line using 24 geophones spaced approximately 6 feet apart. The ReMi data consisted of ten 30 second records using a 2-millisecond sampling interval. Data was recorded with a laptop computer using SeismicSource Vibroscope software. The data was processed, and surface elevation corrected by SubTerraSeis using Vibroscope, Geogiga Seismic Pro, and Golden Surfer software packages.

The ReMi 2D profile indicates the top of rock is at an approximate shear wave velocity of 1,800 to 2,000 feet per second as indicated by the green to yellow transition on the figure. It appears that the bedrock elevation decreases rapidly along the culvert alignment, falling below elevation 860 approximately 55 feet from the first geophone.

The ER data was collected with an Advanced Geosciences Inc. (AGI) SuperSting R8 control unit. For the ER survey, thirty-one electrodes were spaced approximately 6 feet apart. The survey line started near the proposed culvert inlet and terminated on the northbound shoulder. The electrodes were used to measure the potential field with Dipole-Dipole and Strong Gradient Arrays. The data was processed, and surface elevation corrected using AGI's EarthImager 2D software.

The ER survey indicates a resistivity contrast at elevations and distances similar to the velocity contrast encountered in the ReMi survey.

Based on field reconnaissance, the results of the borings, and the geophysical surveys, rock will be encountered at the inlet. Sandstone bedrock may be encountered within the first fifty-five linear feet

of the culvert alignment, though the bedrock surface drops sharply. Cobbles and boulders may be also present along the proposed culvert alignment.

Attached are a site plan, seismic profile, resistivity sections, and borings logs to aid you in your design.

If you have any questions, please feel free to contact me at 614-275-1305.

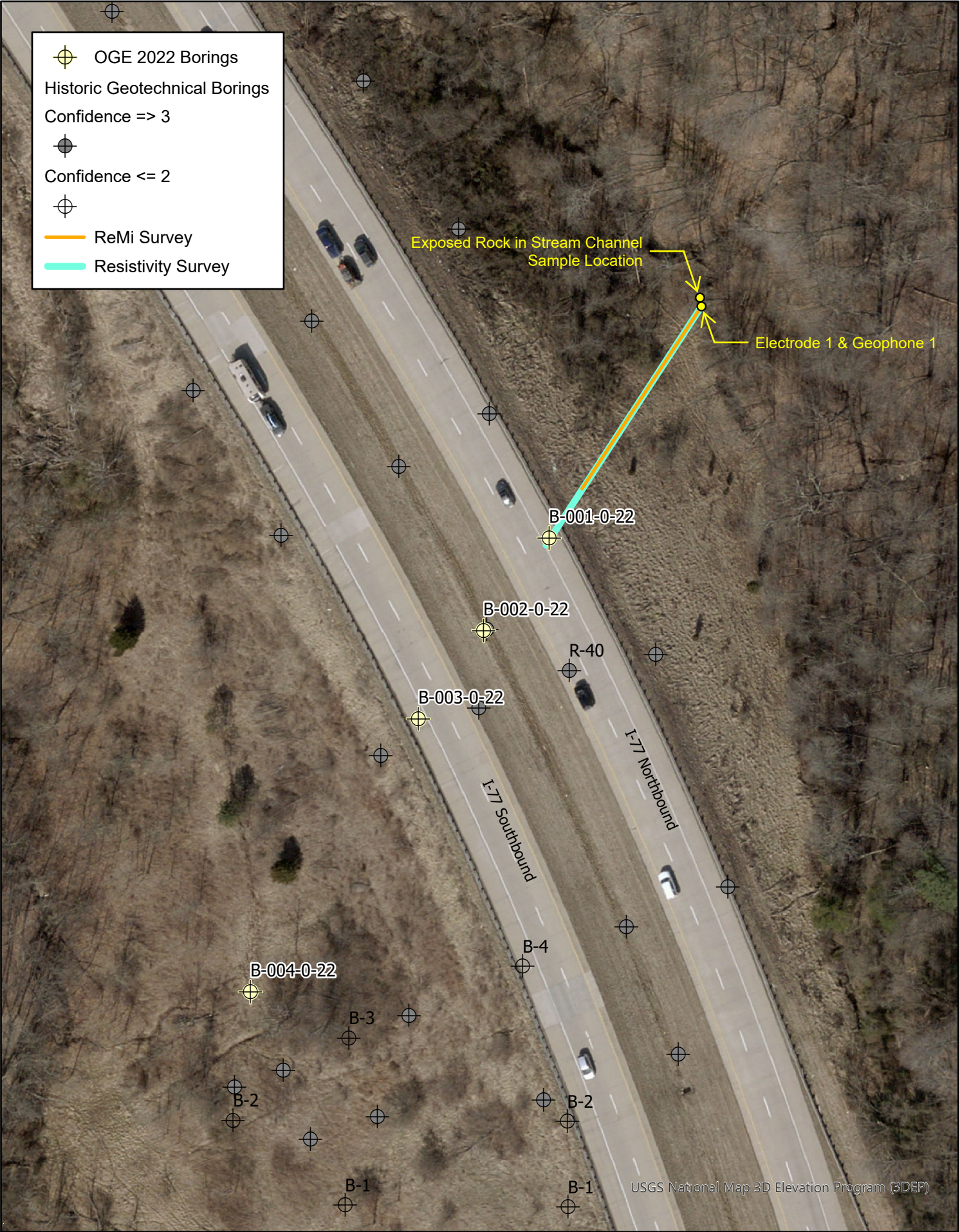
Thank you,

AMJ

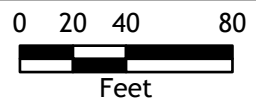
PC: Reading File, File

Attachments: Site plan, geophysical exploration results, boring logs.



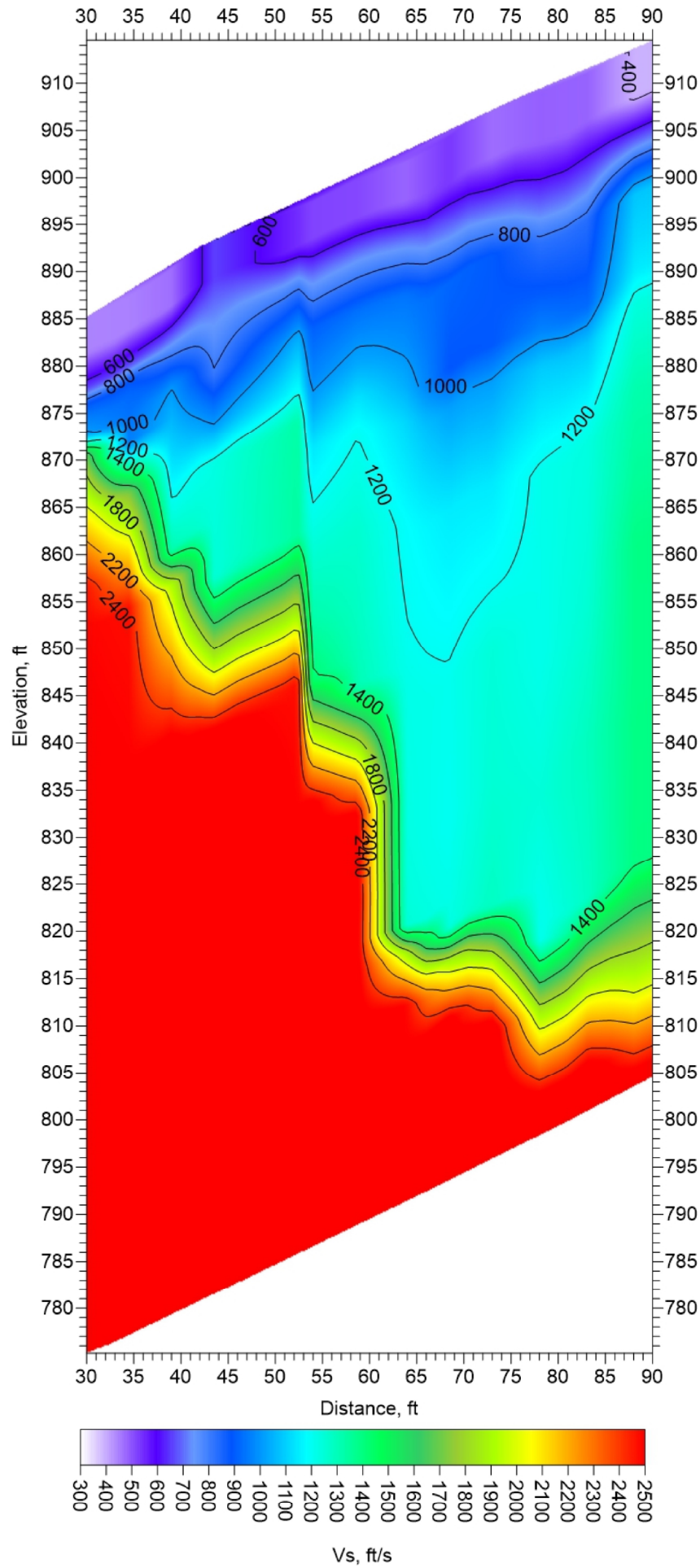


WAS-77-9.58  
Exploration Plan

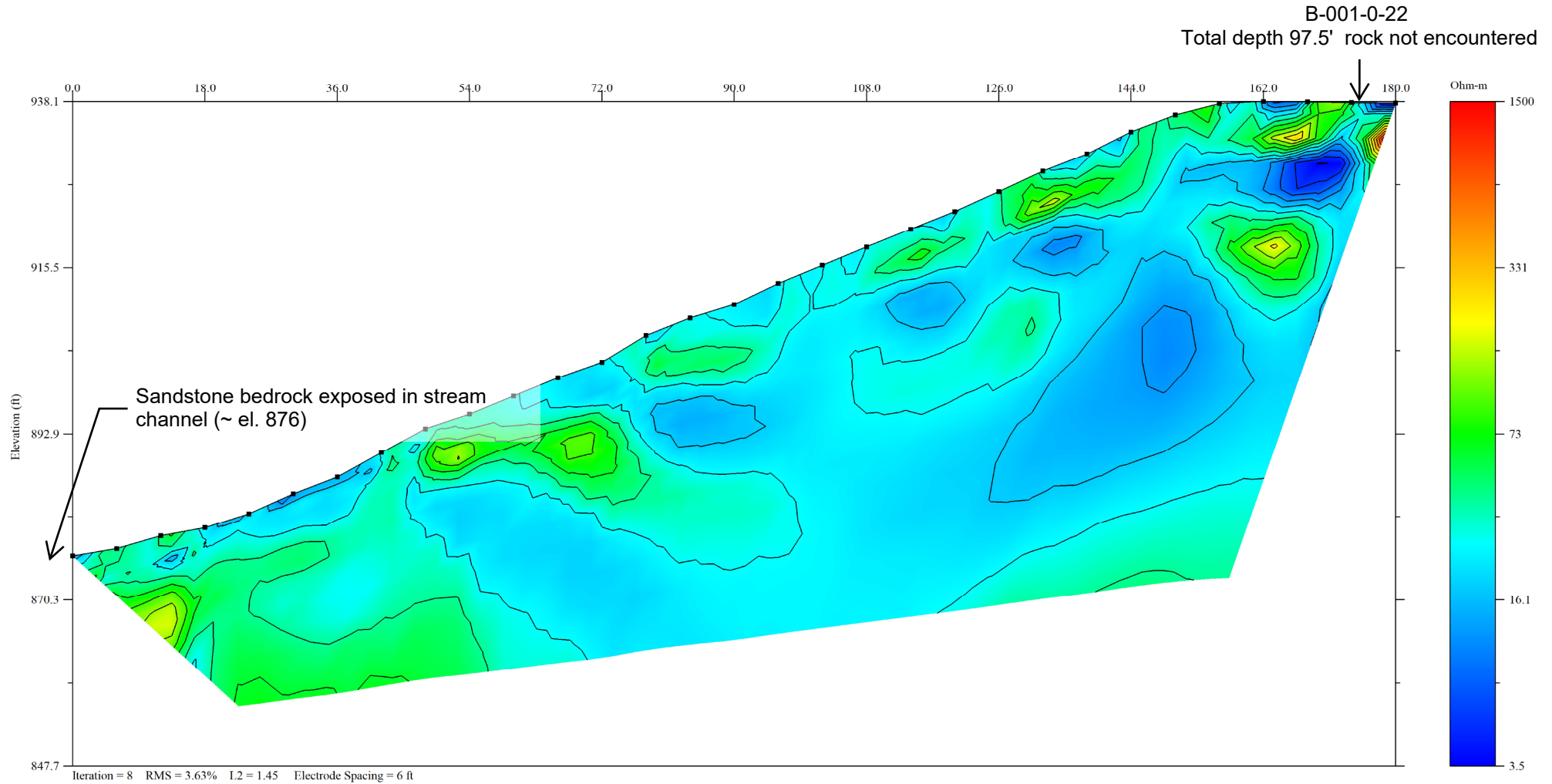




# WAS-77-9.58 Refraction Microtremor Section



# WAS-77-9.58 Inverted Resistivity Section









PROJECT: WAS-77-9.58		DRILLING FIRM / OPERATOR: ODOT / MCINTOSH		DRILL RIG: CME 850R TRACKED		STATION / OFFSET:		EXPLORATION ID											
TYPE: CULVERT		SAMPLING FIRM / LOGGER: ODOT / LEWIS		HAMMER: CME AUTOMATIC		ALIGNMENT: CL IR 77		B-002-0-22											
PID: 115420 SFN:		DRILLING METHOD: 3.75" HSA / NQ2		CALIBRATION DATE: 4/19/21		ELEVATION: 933.9 (MSL) EOB: 85.0 ft.		PAGE											
START: 12/6/22 END: 12/7/22		SAMPLING METHOD: SPT / NQ2		ENERGY RATIO (%): 90*		LAT / LONG: 39.532929, -81.445005		1 OF 2											
MATERIAL DESCRIPTION AND NOTES		ELEV.	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
		933.9							GR	CS	FS	SI	CL	LL	PL	PI			
TOPSOIL (5")		933.4																	
VERY STIFF, REDDISH BROWN AND GRAY, SILT AND CLAY, SOME STONE FRAGMENTS, LITTLE SAND, DAMP			1																
			2	5	6	18	72	SS-1	2.50	33	6	8	30	23	33	21	12	12	A-6a (4)
			3		6														
			4	3	5	15	61	SS-2	2.00	-	-	-	-	-	-	-	-	16	A-6a (V)
			5		5														
@3.5'; STIFF			6																
			7																
			8																
STIFF, REDDISH BROWN AND GRAY, SANDY SILT, "AND" STONE FRAGMENTS, LITTLE CLAY, DAMP		925.4																	
			9	5	4	12	78	SS-3	2.00	42	2	13	25	18	26	16	10	11	A-4a (2)
			10		4														
			11																
			12																
			13																
			14	4	4	14	50	SS-4	2.00	-	-	-	-	-	-	-	-	14	A-4a (V)
			15		5														
			16																
			17																
VERY STIFF, REDDISH BROWN AND GRAY, SILTY CLAY, SOME STONE FRAGMENTS, LITTLE SAND, DAMP			18																
			19	3	3	11	67	SS-5	2.00	-	-	-	-	-	-	-	-	21	A-4a (V)
			20		4														
			21																
			22																
			23																
			24	5	7	33	83	SS-6	3.50	35	2	8	28	27	34	18	16	18	A-6b (6)
			25		15														
			26																
			27																
HARD, RED AND GRAY, SILT AND CLAY, "AND" STONE FRAGMENTS, TRACE SAND, DAMP		910.4																	
			28																
			29	8	5	18	50	SS-7	3.00	-	-	-	-	-	-	-	-	10	A-6b (V)
			30		7														
			31																
			32																
			33																
			34	4	7	23	78	SS-8	3.00	-	-	-	-	-	-	-	-	12	A-6b (V)
			35		8														
			36																
@43.5'; VERY STIFF			37																
			38																
			39	7	14	41	89	SS-9	4.00	46	1	2	26	25	34	19	15	12	A-6a (5)
			40		13														
			41																
			42																
			43																
			44	7	9	30	83	SS-10	3.50	-	-	-	-	-	-	-	-	14	A-6a (V)
			45		11														
			46																
@58.5'; BROWN AND RED, SOME STONE FRAGMENTS, LITTLE SAND			47																
			48																
			49	10	11	33	78	SS-11	3.00	-	-	-	-	-	-	-	-	13	A-6a (V)
			50		11														
			51																
			52	10	12	41	72	SS-12	3.50	-	-	-	-	-	-	-	-	12	A-6a (V)
			53		15														
			54	6	6	24	89	SS-13	3.00	47	2	8	27	16	31	18	13	12	A-6a (2)
			55		10														
			56																

PID: 115420	SFN:	PROJECT: WAS-77-9.58	STATION / OFFSET:					START: 12/6/22	END: 12/7/22	PG 2 OF 2		B-002-0-22								
MATERIAL DESCRIPTION AND NOTES			ELEV. 873.9	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
HARD, RED AND GRAY, <b>SILT AND CLAY</b> , "AND" STONE FRAGMENTS, TRACE SAND, DAMP (continued) @61.0'; RED AND BROWN  @63.5' - 68.5'; ENCOUNTERED BOULDERS/COBBLES  @68.5'; VERY STIFF  @71.0'; TRACE SAND			873.9	61	14	80	89	SS-16	4.50	47	4	7	27	15	33	20	13	12	A-6a (2)	
				62	24 29															
				63																
				64																
				65																
				66	0		78	NQ2-1											CORE	
				67																
				68																
				69	8 10 11	32	67	SS-17	2.50	-	-	-	-	-	-	-	-	14	A-6a (V)	
				70																
				71	18															
				72	17 25	63	89	SS-18	3.00	37	2	5	31	25	35	20	15	17	A-6a (6)	
				73																
				74	13 15 23	57	89	SS-19	3.50	-	-	-	-	-	-	-	-	16	A-6a (V)	
				75																
				76	18															
				77	22 26	72	83	SS-20	3.50	-	-	-	-	-	-	-	-	21	A-6a (V)	
				VERY STIFF, RED AND BROWN, <b>SILTY CLAY</b> , SOME STONE FRAGMENTS, TRACE SAND, DAMP  @83.5'; MOIST			855.4	78												
79	11 12 17	44	89					SS-21	3.50	26	1	8	30	35	37	20	17	18	A-6b (9)	
80																				
81	17																			
82	22 24	69	72					SS-22	3.50	-	-	-	-	-	-	-	-	16	A-6b (V)	
83																				
			848.9	84	10 12 18	45	89	SS-23	3.00	-	-	-	-	-	-	-	21	A-6b (V)		
				85																

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 120 GAL. BENTONITE GROUT

[illegible]



PROJECT: <u>WAS-77-9.58</u>	DRILLING FIRM / OPERATOR: <u>ODOT / MCINTOSH</u>	DRILL RIG: <u>CME 850R TRACKED</u>	STATION / OFFSET: _____	EXPLORATION ID: <u>B-004-0-22</u>
TYPE: <u>CULVERT</u>	SAMPLING FIRM / LOGGER: <u>ODOT / LEWIS</u>	HAMMER: <u>CME AUTOMATIC</u>	ALIGNMENT: <u>CL IR 77</u>	PAGE 1 OF 1
PID: <u>115420</u> SFN: _____	DRILLING METHOD: <u>3.75" HSA</u>	CALIBRATION DATE: <u>4/19/21</u>	ELEVATION: <u>864.7 (MSL)</u> EOB: <u>30.0 ft.</u>	
START: <u>12/8/22</u> END: <u>12/12/22</u>	SAMPLING METHOD: <u>SPT</u>	ENERGY RATIO (%): <u>90*</u>	LAT / LONG: <u>39.532353, -81.445497</u>	

MATERIAL DESCRIPTION AND NOTES	ELEV. 864.7	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL	
								GR	CS	FS	SI	CL	LL	PL	PI				
TOPSOIL (2") STIFF, RED, <b>SILTY CLAY</b> , SOME STONE FRAGMENTS, TRACE SAND, MOIST	864.5	1																	
		2	3	2	8	67	SS-1	2.00	30	2	7	28	33	37	19	18	21	A-6b (8)	
		3	1	2	8	44	SS-2	1.50	-	-	-	-	-	-	-	-	20	A-6b (V)	
@4.5'; MEDIUM STIFF		4	2	3															
		5	2	2	8	33	SS-3	1.00	-	-	-	-	-	-	-	-	24	A-6b (V)	
@6.0'; DAMP		6	3	3															
		7	3	3	9	61	SS-4	1.00	-	-	-	-	-	-	-	-	17	A-6b (V)	
@7.5'; LITTLE STONE FRAGMENTS, LITTLE SAND		8	2	3															
		9	3	6	14	67	SS-5	2.00	13	3	9	36	39	36	18	18	17	A-6b (11)	
@9.0'; VERY STIFF		10	2	3															
		11	3	5	12	72	SS-6	2.50	-	-	-	-	-	-	-	-	18	A-6b (V)	
@10.5'; STIFF		12	4	3															
		13	3	4	11	78	SS-7	2.00	-	-	-	-	-	-	-	-	18	A-6b (V)	
@12.0'; MOIST		14	2	4															
		15	4	5	14	61	SS-8	2.00	-	-	-	-	-	-	-	-	23	A-6b (V)	
STIFF, RED, <b>CLAY</b> , SOME SILT, LITTLE STONE FRAGMENTS, TRACE SAND, MOIST	851.2	16	1	4															
		17	3	5	12	89	SS-9	1.50	11	1	6	33	49	43	20	23	25	A-7-6 (14)	
STIFF, RED AND OLIVE BROWN, <b>SILT AND CLAY</b> , LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP	849.7	18	3	5															
		19	5	5	15	22	SS-10	1.75	-	-	-	-	-	-	-	-	19	A-6a (V)	
@16.5'; VERY STIFF		20	3	6															
		21	6	5	17	78	SS-11	2.00	20	2	8	34	36	39	24	15	21	A-6a (9)	
VERY STIFF, DARK RED, <b>SILT AND CLAY</b> , SOME STONE FFRAGMENTS, TRACE SAND, DAMP	846.7	22	3	5															
		23	5	11	24	89	SS-12	2.00	32	2	5	29	32	38	23	15	17	A-6a (7)	
@19.5'; STIFF, MOIST		24	2	3															
		25	3	4	11	22	SS-13	1.00	-	-	-	-	-	-	-	-	24	A-6a (V)	
@21.0'; VERY STIFF, RED		26	4	5															
		27	5	7	18	100	SS-14	2.00	-	-	-	-	-	-	-	-	21	A-6a (V)	
@22.5'; STIFF		28	3	4															
		29	4	4	12	89	SS-15	1.50	22	1	6	36	35	34	21	13	22	A-6a (8)	
@24.0'; VERY STIFF, DAMP		30	2	7															
		31	7	5	18	94	SS-16	2.50	-	-	-	-	-	-	-	-	18	A-6a (V)	
		32	2	5															
		33	5	6	17	100	SS-17	2.00	-	-	-	-	-	-	-	-	19	A-6a (V)	
		34	3	11															
		35	11	10	32	56	SS-18	2.50	-	-	-	-	-	-	-	-	19	A-6a (V)	
@28.5'; LITTLE SAND		36	4	14															
		37	14	18	48	72	SS-19	2.50	30	2	9	29	30	34	21	13	18	A-6a (6)	

NOTES: HOLE DRY UPON COMPLETION. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE.



# The Ohio Department of Transportation

## Office of Geotechnical Engineering

PROJECT:	<b>WAS-77-9.58</b>	DISTRICT No.:	10	PID No.:	115420	Tech:	PPP
Point Load Strength Calc*: $I_s = P / (D_e^2)$ $D_e^2 = 4A/\pi$ $A = (WD')$ $F = (D_e/50)^{0.45}$ Strength = $I_s * K$ K = <span style="border: 1px solid black; padding: 2px 10px;">24</span>							

Sample #	Approx. El. (Ft.)	Material Type	D (mm) Initial	D (mm) Final	D' (mm) Avg	L (mm)	W (mm)	$D_e^2$	F	$D_e^2_{(50)}$	Failure Load (kN)	$I_{s50}$ (MPa)	$I_{s50}$ (psi)	Strength $S_c$ (MPa)	Strength $S_c$ (psi)
1		Sandstone	29.00	25.50	27.250	54.38	42.05	1458.96	4.56	6657.72	3.487	0.41	60	10	1432
			31.00	27.50	29.250	59.34	41.02	1527.68	4.66	7117.21	4.366	0.48	70	12	<del>1677</del>
			31.00	27.00	29.000	55.77	38.32	1414.93	4.50	6368.36	2.827	0.35	51	8	1213
			41.00	37.00	39.000	76.13	23.02	1143.09	4.09	4673.91	8.661	1.46	211	35	<del>5065</del>
			29.00	28.00	28.500	48.12	42.58	1545.12	4.68	7235.31	2.211	0.24	35	6	<del>835</del>
			46.00	43.50	44.750	47.62	43.74	2492.20	5.81	14471.31	8.029	0.44	63	10	1516
			43.00	39.50	41.250	46.69	45.36	2382.36	5.69	13555.77	3.705	0.21	31	5	<del>747</del>
			42.00	38.00	40.000	43.30	23.06	1174.44	4.14	4860.90	2.681	0.43	63	10	1507
			44.00	40.00	42.000	41.88	27.87	1490.38	4.61	6866.63	3.712	0.42	62	10	1478
			43.00	36.00	39.500	41.30	29.49	1483.14	4.60	6818.33	2.817	0.32	47	8	1129
												<b>Average Strength (Sc)</b>		<b>1379</b>	

Comments: Point Load sample collected from exposed bedrock cut and prepared as Block samples.  
 Highlighted Sc values excluded in Average Strength Sc calculation.



## Historical Records

WAS-77-9.12 Construction Plans (1964)



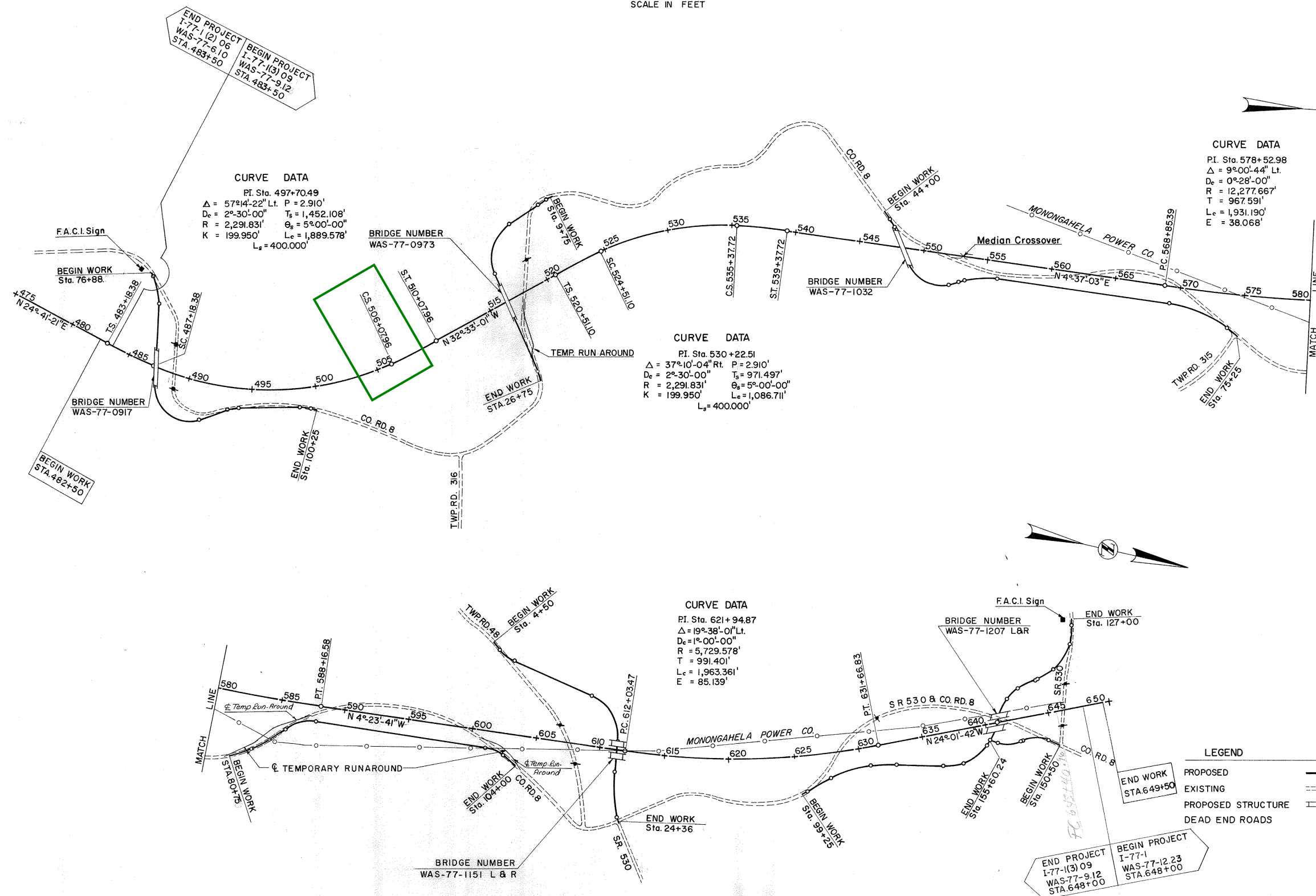
MICROFILMED  
OCT 17 1985

# LOCATION PLAN SALEM TOWNSHIP

FED. RD. DIVISION	STATE	PROJECT
2	OHIO	

WASHINGTON COUNTY  
WAS-77-9.12

2  
263



LOCATION PLAN

Existing culvert to be modified.



\* To Be Shop Elongated & Strutted

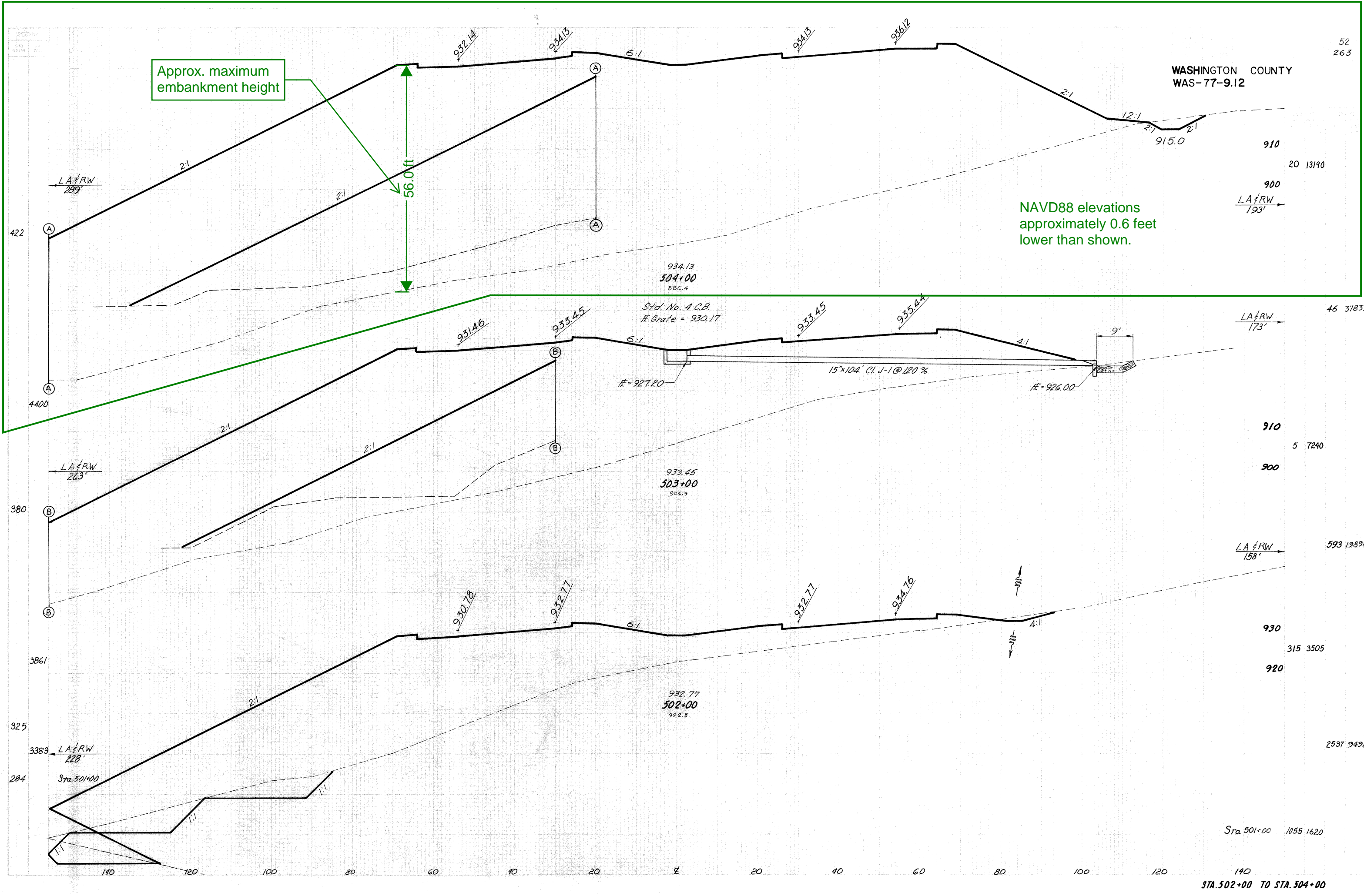
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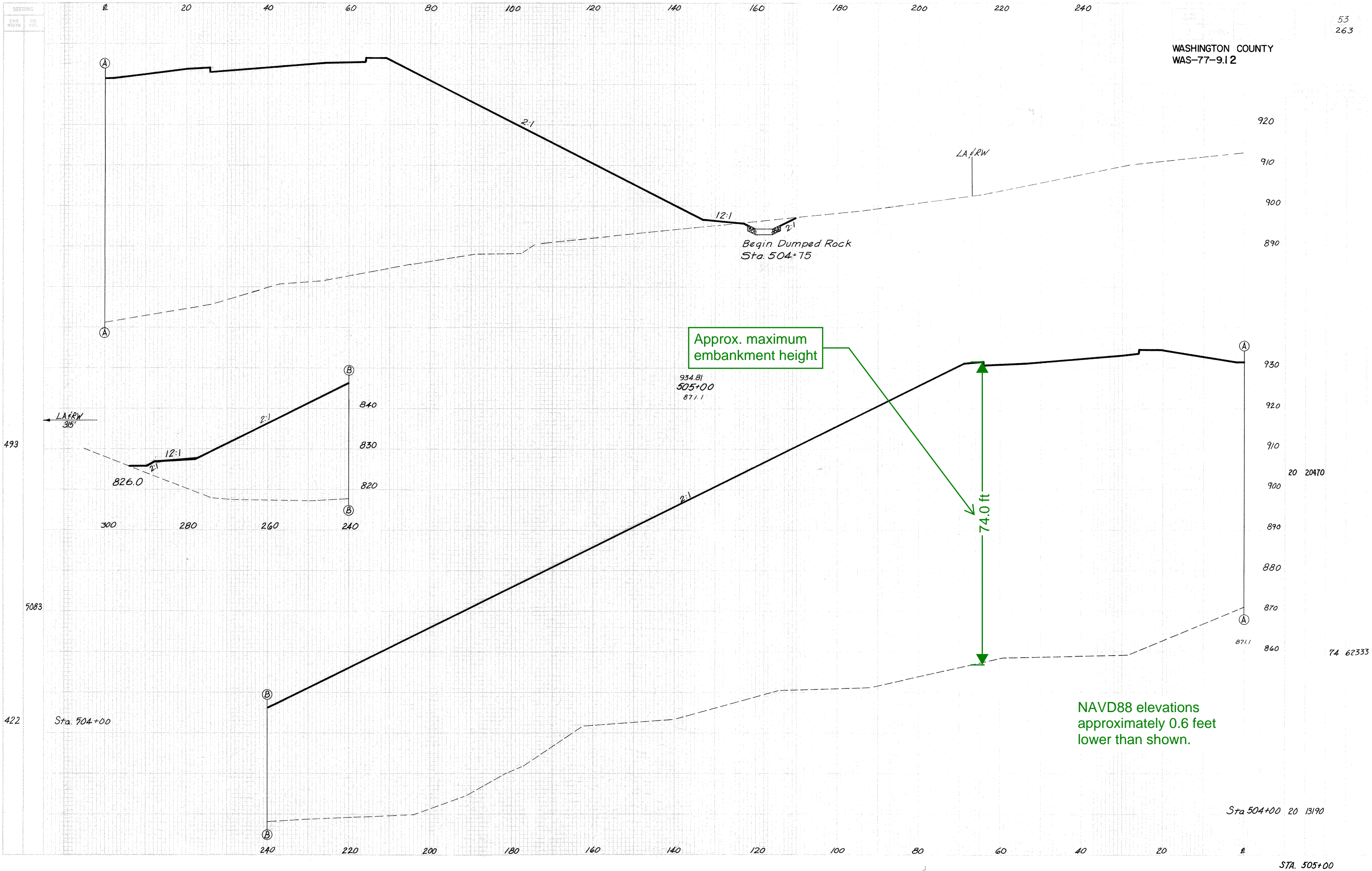
**STA. 500+00 TO STA. 510+00**

**SUB-TOTAL**

1675	552	104	30	15	1686	422
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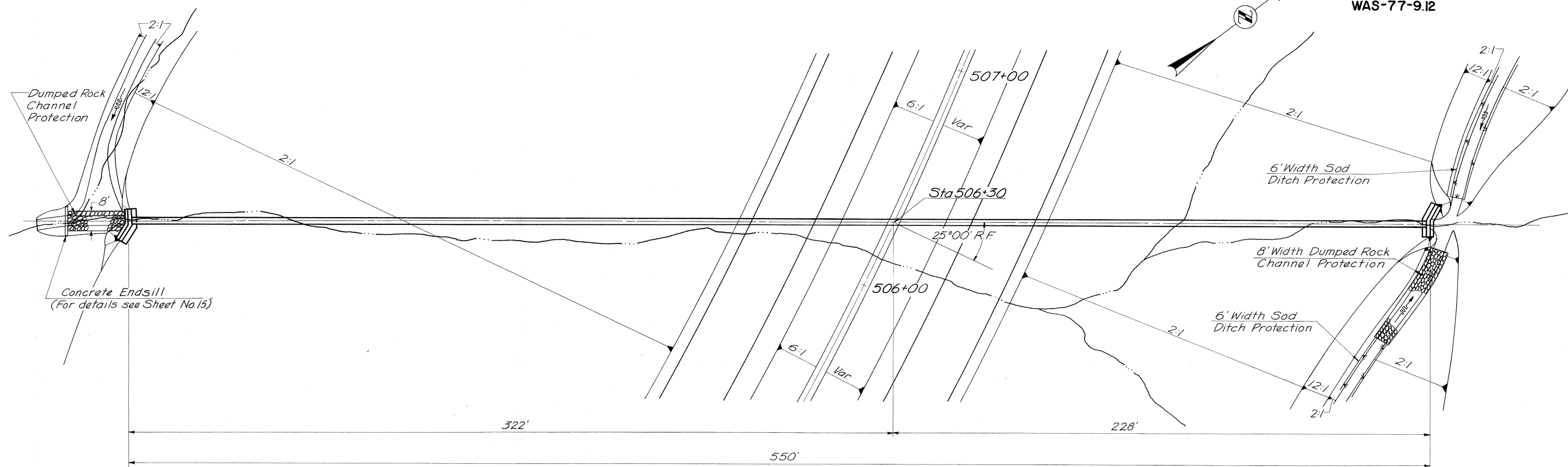






WASHINGTON COUNTY  
WAS-77-9.12

Existing culvert profile



PLAN

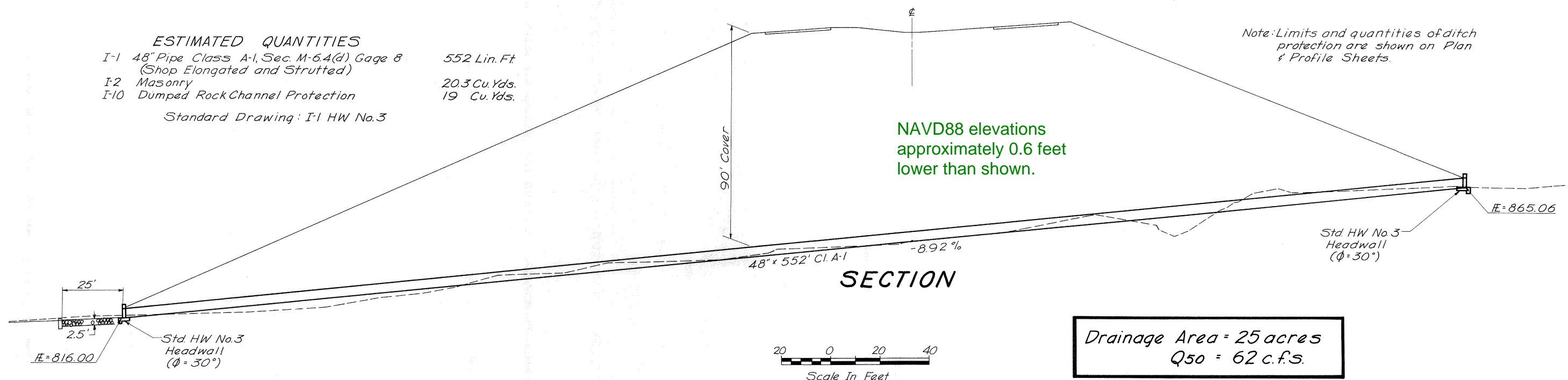
**ESTIMATED QUANTITIES**

I-1 48" Pipe Class A-1, Sec. M-6.4(d) Gage 8 (Shop Elongated and Strutted)	552 Lin. Ft.
I-2 Masonry	20.3 Cu. Yds.
I-10 Dumped Rock Channel Protection	19 Cu. Yds.

Standard Drawing: I-1 HW No. 3

Note: Limits and quantities of ditch protection are shown on Plan & Profile Sheets.

NAVD88 elevations approximately 0.6 feet lower than shown.



Drainage Area = 25 acres  
Q<sub>50</sub> = 62 c.f.s.

Struct. No. WAS-77-0951

CULVERT DETAIL I.R. 77 STA. 506+30



## Historical Records

WAS-77-9.00 (1964)

# GENERAL INFORMATION

## INTRODUCTION

The project consists of the construction of a 3.2-mile section of proposed relocated USR 21 (Proposed IR 77), beginning 0.3 mile north of Twp. Rd. 318, 400 feet east of Co. Rd. B, extending northward, and terminating 200 feet north of SR 530, 300 feet west of Co. Rd. B.

Proposed grade indicates cuts, maximum 70 feet in depth; fill embankments, maximum 91 feet in height.

## GEOLOGY AND OBSERVATIONS OF THE PROJECT

The project is located on an unglaciated portion of the Allegheny Plateau between Duck Creek and the Muskingum River. The alignment traverses a portion of the highly dissected upland portion and crosses tributaries of Duck Creek. Shallow to moderately deep residual soils, overlie bedrock of the Dunkard Series, Permian age, and the Monongahela Series, Pennsylvanian age. Several rock outcrops were noted and measured along the project.

## EXPLORATION

Exploratory borings were made by means of truck-mounted mechanical soil auger, hand auger (in areas of difficult access), and rotary-type drill rig, during October and November, 1963, and April 1964. Included in this report is a log of a boring from Project WAS-77-6.12.

## INVESTIGATIONAL FINDINGS

Materials occurring at proposed grade consist predominantly of clay, shale, indurated clay, sandstone, and limestone bedrock, with some coal, silt clays (A-6a), and clays (A-7-6), having moisture contents generally below the plastic range.

Bedrock is anticipated in the excavations at the following locations:

Stations 478+00 to 482+25 - indurated clay and shale at grades, in the ditches, and lower portions of the back slopes; sandstone in the upper portions of the back slopes.

Stations 482+25 to 482+75 - shale at left grade, in the left ditch, and lower portion of the left back slope.

Stations 485+50 to 487+00 - sandstone and indurated clay at left grade and in the ditches; shale and indurated clay in the left back slope.

Stations 487+00 to 490+25 - indurated clay at grades, in the ditches, and lower portion of the back slopes.

Stations 490+25 to 490+50 - indurated clay at left grade, in the left ditch, and back slope.

Stations 490+50 to 490+80 - indurated clay in left ditch and back slope.

Stations 494+00 to 495+00 - shale in the right ditch and back slope.

Stations 495+00 to 495+25 - shale at right grade, in the right ditch, and back slope.

Stations 495+25 to 499+75 - shale at grades, in the ditches and back slopes.

Stations 499+75 to 500+50 - shale at right grade, in the right ditch, and back slope.

Stations 500+50 to 501+50 - indurated clay in the right ditch and lower portion of the right back slope.

Stations 510+00 to 510+50 - shale at left grade and in the left ditch.

Stations 510+50 to 513+00 - indurated clay at grades and in the ditches; with coal and underlay in the lower portion of the back slopes; shale in the upper portion of the back slopes.

Stations 513+00 to 521+50 - indurated clay at grades and in the ditches, with shale and coal in the lower portions of the back slopes; sandstone and some shale in the upper portions of the back slopes.

Stations 527+50 to 528+00 - shale in the left ditch and lower portions of the left back slope.

Stations 528+00 to 528+75 - shale at left grade, in the left ditch, and back slope.

Stations 528+75 to 530+00 - shale at grades, in the left ditch, and back slope.

Stations 530+00 to 531+25 - shale at left grade, in the left ditch, and back slope.

Stations 531+25 to 531+80 - shale in the left ditch and back slope.

Stations 539+50 to 540+00 - shale or sandstone in the right ditch and back slope.

Stations 540+00 to 541+00 - shale or sandstone at right grade, in the right ditch, and back slope.

Stations 541+00 to 551+75 - shale and sandstone at grade, in the ditches; indurated clay and shale in the back slopes; sandstone in the upper portions of the left back slope, between approximate stations 544+00 and 546+00.

Stations 551+75 to 552+50 - sandstone and shale at grades and in the ditches.

Stations 552+50 to 553+50 - shale and sandstone at right grade.

Stations 555+50 to 556+00 - sandstone at right grade and in the right ditch.

Stations 556+00 to 559+50 - sandstone at grades, in the ditches, and lower portions of the back slopes; indurated clay in the upper portions of the back slopes.

Stations 559+50 to 560+75 - sandstone and shale at grades, in the right ditch, and back slope.

Stations 560+75 to 562+50 - sandstone at grades and right ditch.

Stations 562+50 to 564+00 - sandstone at grades, in the left ditch, and lower portion of the left back slope; shale in the upper portions of the left back slope.

Stations 564+00 to 573+25 - sandstone and shale at grades, in the ditches, and lower portions of the back slopes; shale and indurated clay in the upper portions of back slopes.

Stations 573+25 to 573+50 - sandstone and shale at grades, in the right ditch, and lower portions of the right back slope; shale and indurated clay in the upper portions of the right back slope.

Stations 573+50 to 574+50 - sandstone and shale at right grade, in the right ditch and back slope.

Stations 574+50 to 575+00 - sandstone and shale in the right ditch.

Stations 580+00 to 582+25 - shale and indurated clay at grades, in the ditches, and lower-most portion of the back slopes; sandstone and indurated clay in the upper portion of the back slopes.

391											
Stone fragments with sand, silt, and clay	A-2-7(2)	A-2-7	59	1	6	15	19	41	21	22	1
Sandy silt	A-4(4)	A-4a	13	2	31	28	26	27	3	13	3
Silt	A-4(8)	A-4b	0	1	6	57	36	32	8	23	5
Silt and clay	A-6(9)	A-6a	17	2	6	34	41	35	13	18	70
Silt clay	A-6(11)	A-6b	11	1	7	35	46	38	17	20	13
Elastic clay	A-7-5(19)	A-7-5	11	1	2	26	60	59	28	24	4
Clay	A-7-6(13)	A-7-6	17	2	3	28	50	45	20	19	39
Underclay											
Coal											
Coal blossom											
Clay bedrock											
Indurated clay											
Weathered indurated clay											
Shale											
Weathered shale											
Sandstone											
Weathered sandstone											
Limestone											
Various other materials											
Sod = X' = Approximate depth.											
Auger boring - plan view.											
Drive sample and/or core boring - plan view.											
Auger boring plotted to vertical scale only											
Drive sample and/or core boring plotted to vertical scale only											
NOTE: Figures beside borings indicate water content in percent. e.g. 15											
<div> <div>•</div> <div>Water content nearly equal to or greater than liquid limit.</div> </div> <div> <div>—w</div> <div>Free water.</div> </div> <div> <div>—v</div> <div>Static water level.</div> </div> <div> <div>⊕</div> <div>Number of blows for "Standard Penetration" test.</div> </div> <div> <div>⊕</div> <div>Number of blows for first 6 inches.</div> </div> <div> <div>⊕</div> <div>Number of blows for second 6 inches.</div> </div> <div> <div>B</div> <div>Indicates broken rock interval.</div> </div>											

Stations 582+25 to 583+00 - sandstone at grades and in the right ditch, and with indurated clay in the right back slope.

Stations 583+00 to 586+25 - sandstone and indurated clay at right grade, in the right ditch, and back slope.

Stations 586+25 to 591+75 - sandstone and shale at grades and in the ditches, and alternating intervals of indurated clay and shale in back slopes.

Stations 591+75 to 592+10 - shale at grades, in the left ditch, and back slope.

Stations 592+10 to 593+75 - shale at left grade, in the left ditch and back slope.

Stations 597+50 to 598+50 - shale and indurated clay at grades, in the ditches, and back slopes.

Stations 602+50 to 602+80 - shale at right grade, in the right ditch and back slope.

Stations 604+50 to 606+50 - shale in the right ditch and back slope.

Stations 611+75 to 612+00 - indurated clay and shale in the left ditch.

Stations 612+00 to 612+25 - shale and indurated clay at left grade, in the left ditch and back slope.

Stations 612+25 to 621+75 - shale and sandstone at grades and in the ditches; shale in the back slopes.

Stations 632+50 to 632+75 - limestone with some shale at right grade and in the right ditch.

Stations 632+75 to 637+25 - limestone with some shale at grade, in the ditches, and lower-most portion of the back slopes; shale and little sandstone in the mid- and upper portions of the back slopes.

Stations 637+25 to 637+50 - limestone at grades and in the left ditch; shale and little sandstone in the left back slope.

Stations 637+50 to 640+30 - limestone and/or shale at left grade and in the left ditch; shale with little limestone in left back slope.

Stations 640+30 to 643+50 - indurated clay at grades, in the ditches, and lower portion of the back slopes; sandstone in upper portion of the back slopes.

Stations 643+50 to 643+60 - indurated clay at grades, in the right ditch, and back slopes; sandstone in upper portion of right back slope.

Stations 643+60 to 643+70 - indurated clay at right grade, in the right ditch, and back slope.

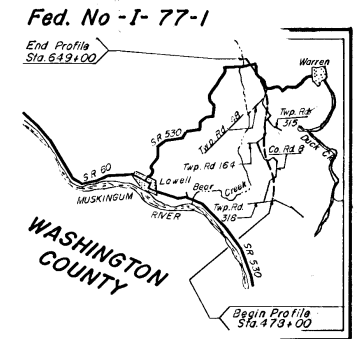
Stations 646+00 to 647+80 - shale and indurated clay in the right ditch.

Stations 647+80 to 648+50 - shale and indurated clay at right grade and in the right ditch.

Frost-susceptible sandy silt was encountered within three feet below proposed grade at station 482+50. Elastic clay (A-7-5) was encountered at grade at station 622+00.

In the embankment foundations, materials are predominantly comprised of (in) to (sh) low silt clays (A-6a) and clays (A-7-6), underlain throughout most of the project by sloping bedrock surface.

## WASHINGTON COUNTY 32 WAS-77-9.00



Recon. J.S.M. 10/11/63  
Drilling Auger - T.R.S. - 10/14/63 to 11/5/63  
and 4/9/64 to 4/20/64  
J.A.G. - 10/14/63 to 10/17/63  
Core - W.L.T. - 10/30/63 to 11/5/63  
J.R.V. - 10/30/63 to 11/6/63  
and 4/21/64 to 4/23/64  
J.H.S. - 10/31/64  
Drafting - R.C.B., T.A.K., A.F. 5/27/64



# SOIL PROFILE WASHINGTON COUNTY WAS-77-9.00

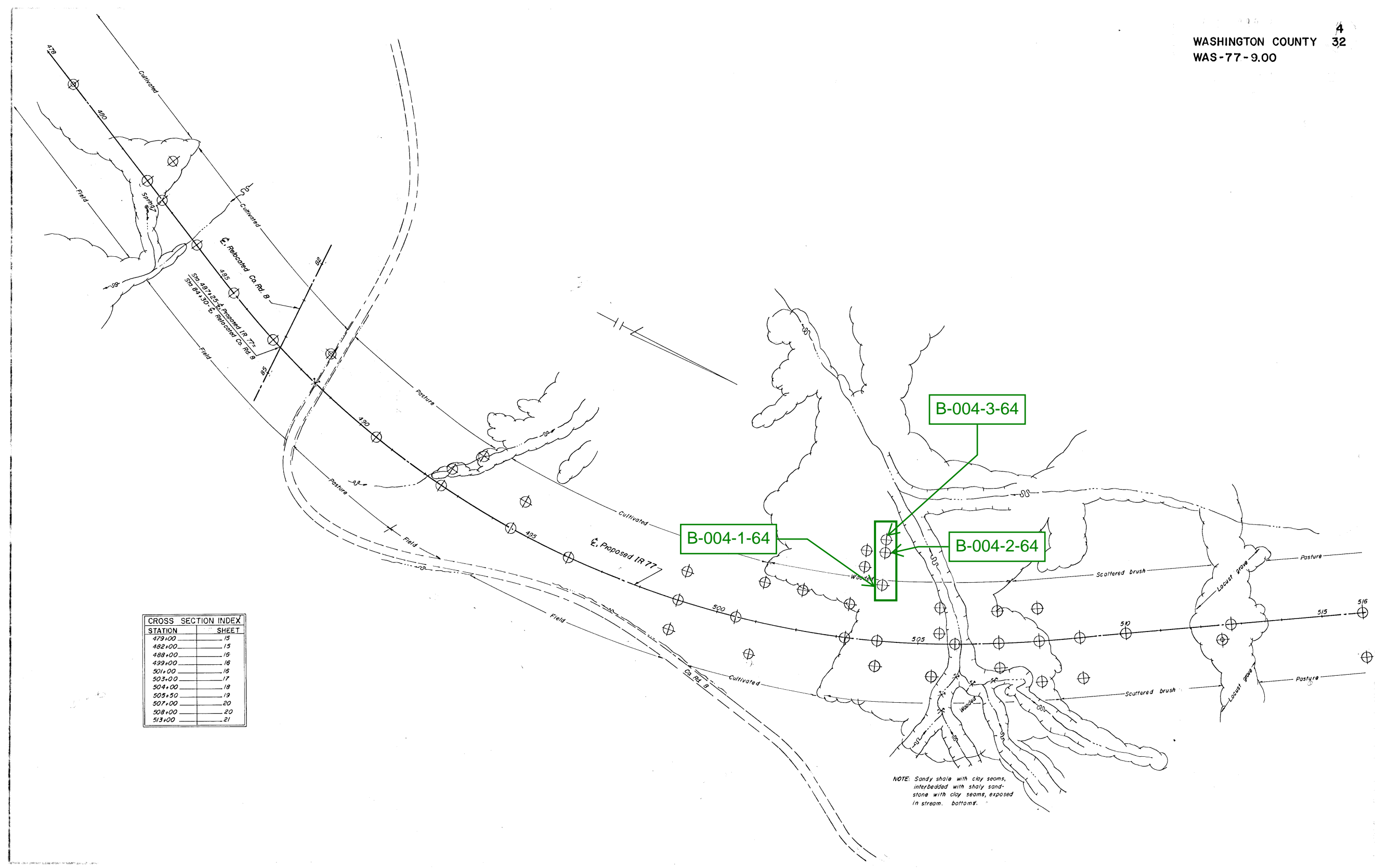
OHIO STATE HIGHWAY TESTING LABORATORY  
1620 W. BROAD ST. COLUMBUS 23, OHIO

2  
32

SUMMARY OF SOIL TEST DATA  
NOTE: NP shown in Liquid Limit and Plasticity Index columns indicates that the material is non-plastic.  
Denotes sample taken at or near grade.

STATION & OFFSET	DEPTH	Agg.	C.S.	F.S.	SILT	CLAY	L.L.	P.I.	W.C.	CLASS.	SHTL	STATION & OFFSET	DEPTH	Agg.	C.S.	F.S.	SILT	CLAY	L.L.	P.I.	W.C.	CLASS.	SHTL	STATION & OFFSET	DEPTH	Agg.	C.S.	F.S.	SILT	CLAY	L.L.	P.I.	W.C.	CLASS.	SHTL														
482+00	80' Lt	0.0-5.0	Brown Weathered Sandstone						10	Visual		505+50	25' Lt	0.0-5.0	Brown Weathered Indurated Clay						13	Visual		531+05	CL	0.0-3.0	Brown Broken Sandstone						10	Visual		564+00	CL	0.0-1.5	Red Broken Clay Shale						10	Visual			
		5.0-10.0	Brown Weathered Sandstone						8	Visual				0.0-5.0	0 3 14 35 48 37 17	16	A-6b				13	Visual		532+00	CL	0.0-3.0	Red Weathered Shale						10	Visual				1.5-5.0	Reddish-Gray Broken Clay Shale						13	Visual			
		10.0-14.0	Brown Weathered Sandstone						6	Visual				5.0-7.5	0 3 14 35 48 37 17	16	A-6b				13	Visual		532+00	100' Rt	0.0-3.0	Red Weathered Indurated Clay						15	Visual				5.0-8.0	Reddish-Gray Broken Clay Shale						13	Visual			
482+00	CL	0.0-5.0	Reddish-Brown Broken Clay Shale						12	Visual		505+90	CL	0.0-5.0	Brown Weathered Indurated Clay						16	Visual		532+00	180' Rt	0.0-2.5	Reddish-Brown Extremely Weathered Shale						17	Visual				5.0-10.0	Brown and Gray Indurated Clay						10	Visual			
		5.0-10.0	Reddish-Brown Broken Clay Shale						9	Visual				0.0-5.0	25 0 9 32 33 34 15	14	A-6a				14	Visual		533+00	100' Rt	0.0-6.0	Red Broken Clay Shale						19	Visual				7.0-10.5	Reddish-Gray Broken Clay Shale						10	Visual			
482+60	CL	0.0-5.0	0 3 14 31 22 NP NP						12	A-11a		507+00	80' Lt	0.0-5.0	25 0 9 32 33 34 15	14	A-6a				14	Visual		533+25	CL	0.0-5.0	Red Broken Clay Shale						16	Visual				0.0-1.5	0 3 8 42 47 33 11	17	A-6a					17	Visual		
		5.0-10.0	Reddish-Brown Broken Clay Shale						12	A-6a				0.0-1.5	27 1 2 34 36 34 13	10	A-6a				10	Visual		534+00	120' Rt	0.0-4.0	Red Broken Clay Shale						16	Visual				1.5-4.0	25 1 1 31 67 50 25	17	A-7-6					17	Visual		
484+00	CL	0.0-6.0	0 1 4 42 48 34 13						18	A-6a		507+00	CL	0.3-4.0	25 1 3 25 46 41 18	17	A-7-6				17	Visual		534+00	120' Rt	0.0-4.0	Red Broken Clay Shale						16	Visual				4.0-6.5	25 1 1 31 67 50 25	17	A-7-6					17	Visual		
		6.0-10.0	0 1 4 39 56 40 18						18	A-6b				6.5-7.0	25 1 3 25 46 41 18	17	A-7-6				17	Visual		534+00	120' Rt	0.0-4.0	Brown Weathered Shale						14	Visual				7.0-8.0	25 1 1 31 67 50 25	17	A-7-6					17	Visual		
485+50	CL	0.0-5.0	Brown Weathered Sandstone						14	Visual		507+00	60' Rt	0.0-1.5	5 3 4 52 36 40 15	23	A-6a				23	Visual		536+00	CL	0.0-4.0	38 3 13 19 27 33 11	19	A-6a					19	Visual				8.0-9.5	25 1 1 31 67 50 25	17	A-7-6					17	Visual	
		5.0-8.0	Red Broken Clay Shale						10	Visual				1.5-4.0	5 3 4 52 36 40 15	23	A-6a				23	Visual		536+00	CL	0.0-4.0	41 2 3 19 39 40 18	29	A-6b					19	Visual				9.5-10.0	25 1 1 31 67 50 25	17	A-7-6					17	Visual	
487+00	CL	0.0-5.0	0 3 9 32 56 40 14						22	A-6a		508+00	80' Lt	0.6-2.0	Brown Weathered Sandstone						9	Visual		537+00	CL	0.0-4.0	38 3 13 19 27 33 11	19	A-6a					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		5.0-8.0	0 3 9 33 47 33 11						15	A-6a				0.6-2.0	Brown Weathered Sandstone						9	Visual		537+00	CL	0.0-4.0	41 2 3 19 39 40 18	29	A-6b					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		8.0-9.0	Brown Weathered Shale						5	Visual		508+00	CL	0.3-3.0	Reddish-Brown Broken Clay Shale						13	Visual		537+00	CL	0.0-4.0	38 3 13 19 27 33 11	19	A-6a					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
490+50	CL	0.0-3.0	0 1 2 36 61 45 21						19	A-7-6				0.3-3.0	Reddish-Brown Broken Clay Shale						13	Visual		537+00	CL	0.0-4.0	41 2 3 19 39 40 18	29	A-6b					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		3.0-7.0	Red Broken Clay Shale						13	Visual				3.0-4.0	Brownish-Gray Broken Clay Shale						15	Visual		537+00	CL	0.0-4.0	38 3 13 19 27 33 11	19	A-6a					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		7.0-8.0	Red Broken Siliceous Shale						9	Visual		508+00	100' Rt	0.3-3.0	39 3 3 28 27 35 13	13	A-6a				13	Visual		537+00	CL	0.0-4.0	41 2 3 19 39 40 18	29	A-6b					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
492+50	50' Lt	0.3-4.0	0 2 19 17 62 31 11						41	A-6a				3.0-4.0	Brownish-Gray Broken Clay Shale						15	Visual		537+00	CL	0.0-4.0	38 3 13 19 27 33 11	19	A-6a					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		0.3-4.0	Reddish-Brown Weathered Siliceous Shale						8	Visual		508+00	100' Rt	3.0-7.0	0 2 1 2 41 54 43 17	17	A-6a				17	Visual		537+00	CL	0.0-4.0	41 2 3 19 39 40 18	29	A-6b					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
493+00	120' Lt	0.0-2.0	42 3 6 20 29 34 13						24	A-6a				7.0-11.5	0 1 2 42 55 38 13	13	A-6a				13	Visual		537+00	CL	0.0-4.0	38 3 13 19 27 33 11	19	A-6a					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
494+50	75' Lt	0.3-1.5	Reddish-Brown Broken Clay Shale						11	Visual		509+00	CL	0.3-4.0	30 2 1 22 77 67 43	23	A-7-6				23	Visual		537+00	CL	0.0-4.0	41 2 3 19 39 40 18	29	A-6b					19	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		1.5-3.0	Brown Weathered Siliceous Shale						7	Visual				4.0-6.0	Gray Extremely Weathered Shale						16	Visual		539+90	CL	0.2-1.5	40 1 1 33 25 41 14	14	A-7-6					14	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
494+50	CL	0.3-1.0	Red Broken Clay Shale						16	Visual				6.0-7.0	Light Brown Weathered Indurated Clay						16	Visual		539+90	CL	0.2-1.5	40 1 1 33 25 41 14	14	A-7-6					14	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		1.0-2.0	Red Broken Clay Shale						19	Visual		509+00	100' Rt	7.0-7.5	Brown Weathered Siliceous Shale						7	Visual		539+90	CL	0.2-1.5	40 1 1 33 25 41 14	14	A-7-6					14	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		2.0-7.0	Purple Clay Bedrock						12	Visual		509+00	100' Rt	0.3-2.0	Brownish-Gray Weathered Siliceous Shale						9	Visual		540+00	90' Rt	0.0-5.0	19 2 0 25 94 47 23	18	A-7-6					18	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		7.0-9.0	Gray Weathered Indurated Clay						12	Visual		510+15	CL	0.3-3.0	Red Broken Clay Shale						16	Visual		540+00	90' Rt	0.0-5.0	19 2 0 25 94 47 23	18	A-7-6					18	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
496+10	CL	0.3-3.0	29 1 3 34 33 37 13						15	A-6a				3.0-6.0	Brown Broken Siliceous Clay Shale						10	Visual		543+00	CL	0.0-4.0	43 3 5 12 37 55 24	22	A-7-5					22	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		3.0-6.0	Red Broken Clay Shale						13	Visual		512+75	CL	0.3-6.0	Brown Weathered Siliceous Shale						5	Visual		543+00	CL	0.0-4.0	43 3 5 12 37 55 24	22	A-7-5					22	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		6.0-7.5	Brown Weathered Siliceous Shale						10	Visual		516+00	CL	0.0-3.0	Brown Weathered Indurated Clay						9	Visual		543+00	CL	0.0-4.0	43 3 5 12 37 55 24	22	A-7-5					22	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		7.5-10.0	Red Broken Clay Shale						11	Visual		516+00	110' Rt	0.0-5.0	Brown Weathered Siliceous Shale						10	Visual		543+00	CL	0.0-4.0	43 3 5 12 37 55 24	22	A-7-5					22	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
499+00	75' Lt	0.0-5.0	0 1 7 55 37 39 17						15	A-6b		518+00	CL	0.0-5.0	40 2 18 23 17 NP NP	16	A-11a				16	Visual		544+50	65' Rt	0.0-3.0	24 5 9 12 50 50 24	30	A-7-6					30	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		5.0-10.0	Red Broken Clay Shale						15	Visual				5.0-9.5	11 2 17 39 31 28 11	19	A-6a				19	Visual		544+50	65' Rt	0.0-3.0	24 5 9 12 50 50 24	30	A-7-6					30	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		10.0-16.0	Gray Broken Clay Shale						11	Visual				9.5-10.5	0 0 1 22 77 67 43	23	A-7-6				23	Visual		544+72	CL	0.0-5.0	19 2 0 25 94 47 23	18	A-7-6					18	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual	
		16.0-17.0	Red and Gray Clay Bedrock						9	Visual		518+00	CL	10.5-15.0	Brown Weathered Siliceous Shale						15	Visual		544+72	CL	0.0-5.0	19 2 0 25 94 47 23	18	A-7-6					18	Visual				0.0-2.0	0 1 1 31 67 50 25	17	A-7-6					17	Visual</	

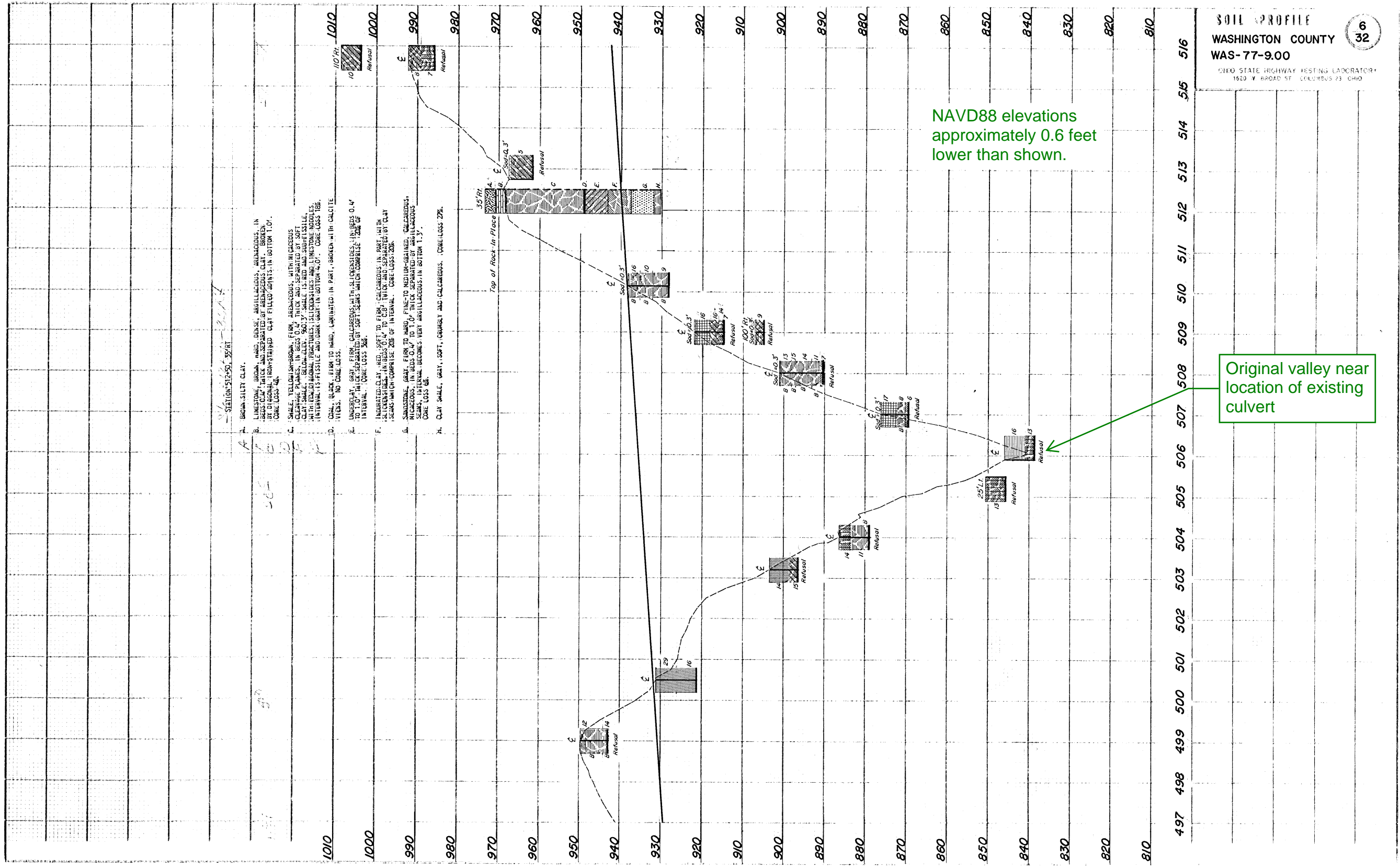


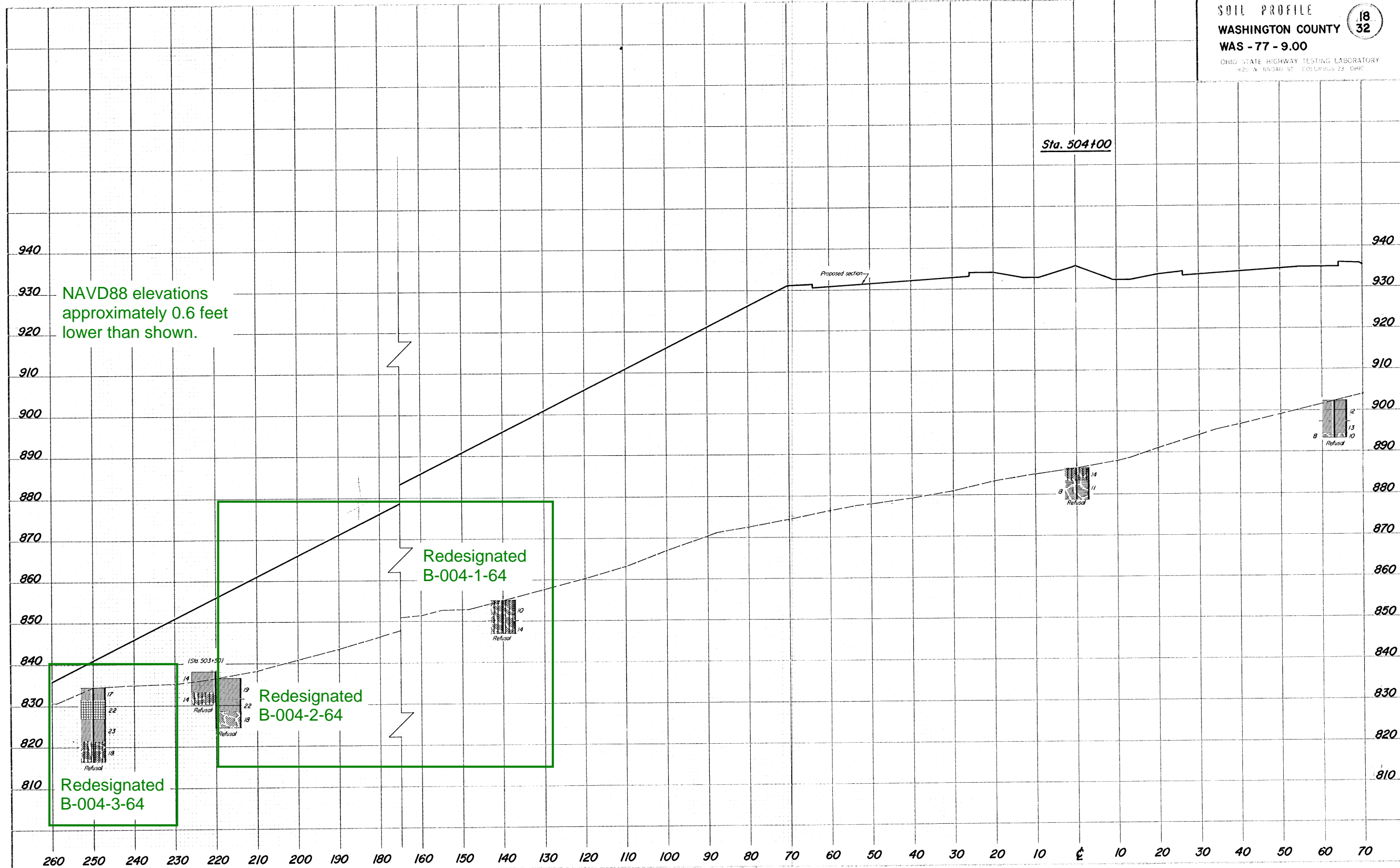


CROSS SECTION INDEX	
STATION	SHEET
479+00	15
482+00	15
488+00	15
499+00	16
501+00	16
503+00	17
504+00	18
505+50	19
507+00	20
508+00	20
513+00	21

NOTE: Sandy shale with clay seams, interbedded with shaly sandstone with clay seams, exposed in stream bottoms.

Profile along I-77 C/L





## SUMMARY OF TESTS ON SOIL PROFILE SAMPLES

26

County, Rt. No., & Section W. 77 - 9.00

Lab. No. So.-	Sample No.	Station	Depth in Feet	Mechanical Analysis					Physical Charact.		Density		SHTL Class	Remarks
				Agg. %	C Sand %	F Sand %	Silt %	Clay %	L.L.	P.I.	Water Cont. %	Opt.	Max. Dry Wt.	
37940	95-S	503+50	180 Lf	2-10'	Br	MC	siliceous	Shale			10			Visual
1	6	504+0	220 Lf	0-5'	23	3	11	32	31	30	11	19		0-60
2	7	"		5-8	39	1	4	15	41	40	15	22		0-60
3	8	"		8'-12'	Red-Gr	IC					18			Visual
4	9	503+50	220 Lf	0-5'	32	2	8	25	33	32	11	14		0-60
5	100-S			5-8	Red	Unk	IC				14			Visual
6	1	504+0	140 Lf	0-5'			Unk				10			Visual
7	2	"		5-8			Unk				14			Visual
8	3	"	250 Lf	0-3'	24	2	9	26	39	32	11	17		0-60
9	4	"		3'-8'	24	1	4	27	44	41	16	22		0-7-6
37950	5	"		8-13	30	1	13	22	29	31	11	23		0-60
1	6	"		13-18	Red-Br	Unk	IC				18			Visual
2	7	"		0-3	Br	Unk	IC				14			Visual



## Historical Records

WAS-77-9.45 (1969)

State of Ohio  
Department of Highways  
Testing Laboratory

LOG OF BORING

Redesignated B-002-0-69

2  
9

Elevation adjustments shown in NAVD88  
datum (approximately 0.6 feet lower).

Date Started 2-17-69 Sampler Type SS Dia. 1 3/8" Water Elev. \_\_\_\_\_  
Date Completed 2-19-69 Casing Length \_\_\_\_\_ Dia. \_\_\_\_\_

Project Identification WASHINGTON

WAB-77-9.45

Embankment Failure

841.8

Surface Elev. 842.4'

Boring No. 2 Station & Offset 503+85, 256' Lt.

Boring No.		Station & Offset			Physical Characteristics													SHTL
Elev.	Depth	Std Pen. (N)	Rec. ft.	Loss ft.	Description	Field No.	Lab Nos. Sa	% Agg	% C.S.	% F.S.	% Silt	% Clay	LL	P.I.	W.C.	Class		
842.4	0																	
839.9	2																	
	4	1/2			Red Silt and Clay With Little Shale Fragments	1	84956	-	-	-	-	-	33	13	16	Visual		
837.4	6	2/2			Red Silt and Clay With Little Shale Fragments	2	84957	-	-	-	-	-	35	12	19	Visual		
834.9	8	3/4			Red Silt and Clay With Little Shale Fragments	3	84958	18	1	4	27	50	36	14	19	A-6a		
832.4	10																	
	12	3/3			Brown Silt and Clay With Little Shale Fragments	4	84959	11	3	11	30	45	32	11	22	A-6a		
829.9	14	4/5			Brown Silt and Clay , Trace of Wood Fragments	5	84960	6	2	11	41	40	31	13	25	A-6a		
827.4	16	6/8			Brown Silt and Clay, Trace of Shale Fragments	6	84961	4	2	13	34	47	32	11	20	A-6a		
824.9	18																	
	20	12/15			Brown Silt and Clay, Trace of Shale Fragments	7	84962	11	1	2	42	44	38	15	17	A-6a		
822.4	22	8/10			Red Sandy Silt and Clay	8	84963	4	3	16	31	46	31	11	20	A-6a		
819.9	24	7/12			Red Sandy Silt and Clay	9	84964	0	3	12	33	52	37	15	19	A-6a		
817.4	26	10/17			Red Clay	10	84965	2	2	5	18	73	45	18	23	A-7-6		
814.9	28	6/11			Brown Sandy Silt, Trace of Shale Fragments	11	84966	9	2	34	20	35	NP	NP	18	A-4a		
812.4	30																	
	32	19/31			Red Silty Clay, Trace of Shale Fragments	12	84967	4	1	5	25	65	37	13	20	A-6a		
808.4	34																	
	36																	
807.8			1.0	2.0	TOP OF ROCK													

Particle Sizes: Agg. >2.00mm, Coarse Sand = 2.00 - 0.42mm, Fine Sand = 0.42 - 0.074 mm, Silt = 0.074 - 0.005 mm, Clay = <0.005 mm



Boring No. 2 Station B Offset 503+85, 256' Lt.

Surface Elev. 842.4'

Project WAS-77-9.45

3  
9

Elev	Depth	Rec. ft.	Loss ft.	Description
	38	3.8	1.2	Mudstone, brownish-red, soft and crumbly to medium-firm, arenaceous in lower interval, mottled, ferruginous, conglomeratic, interbedded with large clay seam (comprising 7% of the interval). Core loss 25%
	40			
	42			
	44	4.1	0.9	
	46			
	48			
	50	2.3	2.7	
	52			
	54			
	56	4.6	0.4	
	58			
	60			
781.4	62			
	64	5.0	0.0	
	66			
	68			
	70			
	72			
	74			
	76			
	78			
	80			
	62			BOTTOM OF BORING
	64			
	66			
	68			
	70			
	72			
	74			
	76			
	78			
	80			

SHEET of sheets



State of Ohio  
Department of Highways  
Testing Laboratory

LOG OF BORING

Date Started 2-19-69 Sampler Type SS Dia 1 3/8" Water Elev. \_\_\_\_\_  
Date Completed 2-27-69 Casing Length 20.0' Dia 3 1/2"

Redesignated B-003-0-69

4  
9

Elevation adjustments shown in NAVD88  
datum (approximately 0.6 feet lower).

Project Identification: WASHINGTON

WAS-77-9.45

Embankment Failure

Boring No. 3 Station & Offset 504+00, 176' Lt. Surface Elev. 869.8  
870.4'

Boring No. 3			Station B Offset		504+00, 176 Lb.		Surface Elev. 125.5		Physical Characteristics										SHTL
Elev.	Depth	Std Pen (N)	Rec. ft.	Loss ft.	Description	Field No	Lab Nos. Ss	% Agg	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	Class			
870.4	0	3/4			Brown Sandy Silt and Shale Fragments	1	85294	35	4	13	25	23	27	2	11	A-4a			
867.9	2																		
865.4	4																		
	6				Boulders	0													
862.9	8	4/5			Red Sandy Silt With Some Shale Fragments	2	85295	26	4	7	35	28	31	4	14	A-4a			
860.4	10	2/3			Red Clayey Silt With Some Shale Fragments	3	85296	21	4	6	33	36	32	10	16	A-4a			
857.9	12	7/7			Red Silt and Clay With Some Shale Fragments	4	85297	20	2	5	30	43	36	11	26	A-6a			
	14																		
855.4	16	6/10			Brown Silt and Clay With Some Shale Fragments	5	85298	-	-	-	-	-	32	12	19	A-6a			
852.9	18	3/5			Brown Sandy Silt With Little Shale Fragments	6	85299	-	-	-	-	-	NP	NP	14	Visual			
850.4	20	10/13			Red Silty Clay	7	85300	2	3	6	39	50	37	17	20	A-6b			
847.9	22	9/12			Red Sandy Silt and Clay	8	85301	3	3	14	35	45	34	14	20	A-6a			
	24																		
845.4	26	13/17			Red Sandy Silt and Clay With Little Shale Fragments	9	85302	12	7	15	29	37	34	15	22	A-6a			
842.9	28	50* (0.9)			Brownish-Gray Silty Clay	10	85303	0	1	6	40	53	41	18	23	A-7-6			
840.4	30				TOP OF ROCK														
					Brown Weathered Shale	11	85304	12	2	5	41	40	-	-	14	Visual			
839.8	32	50* (0.5)	2.3	2.7	Mudstone, reddish-brown-yellow, medium-firm to firm, slightly arenaceous, highly broken, interbedded with dolomite, with chert, brown, hard (comprising 9% of the interval), limestone, gray, hard, broken (comprising 4% of the interval), thin clay lenses. Core loss 57%														
	34																		
	36					1.5	3.5												

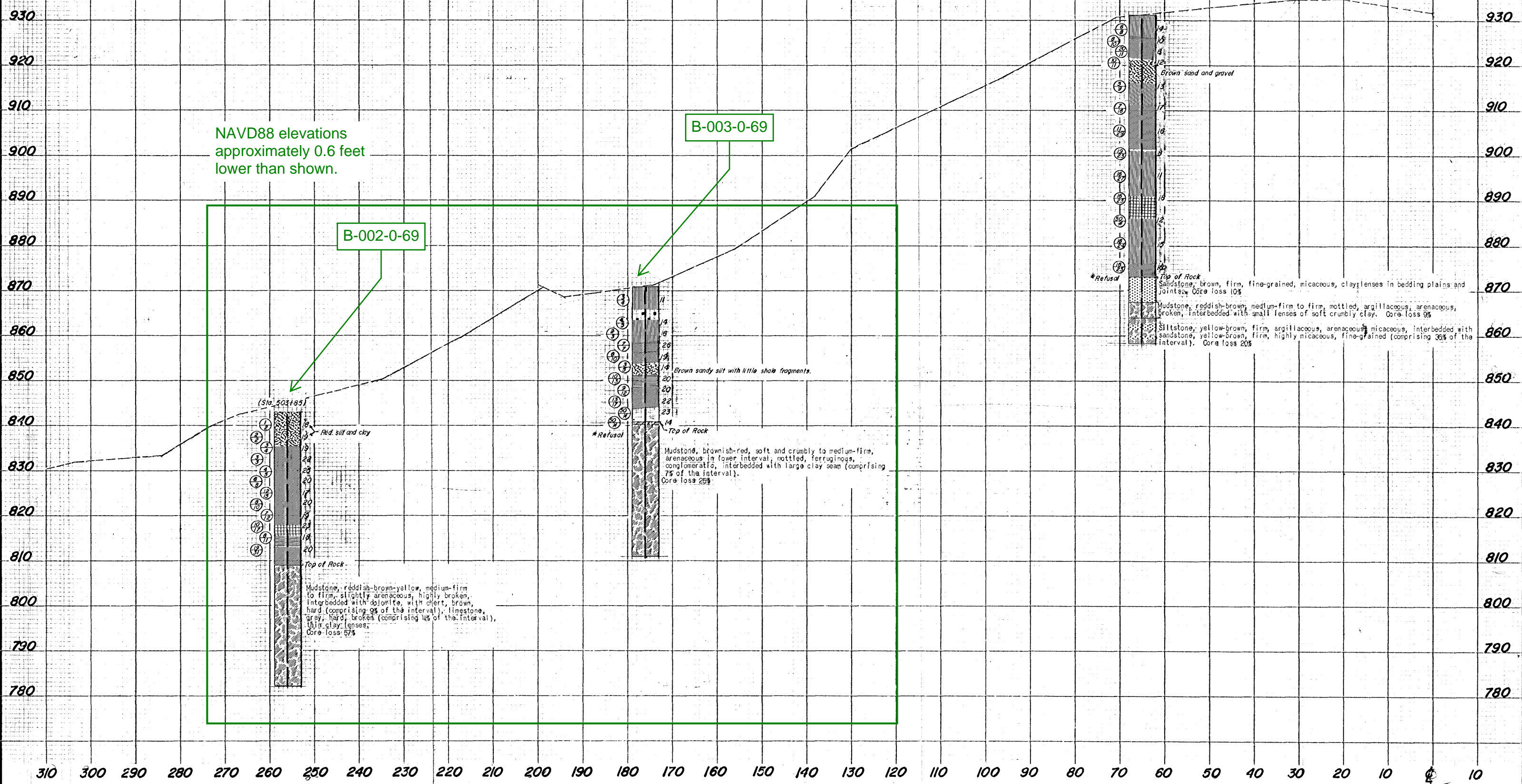
Particle Sizes Agg >2.00mm, Coarse Sand = 2.00 - 0.42mm, Fine Sand = 0.42 - 0.074 mm, Silt = 0.074 - 0.005 mm, Clay = <0.005 mm

Boring No. 3 Station & Offset 504+00, 176'lt. Surface Elev. \_\_\_\_\_ Project: WAS-77-9.45

Boring No.	Station & Offset	Surface Elev.	Project:	Physical Characteristics										SHTL Class			
Elev	Depth	Std. Pen (N)	Rec. ft	Loss ft	Description	Field No.	Lab. Nos. So.	% Agg	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	SHTL Class	
	38		1.5	3.5	Mudstone, reddish-brown-yellow, medium-firm to firm, alightly arenaceous, highly broken, interbedded with dolomite, with chert, brown, hard (comprising 9% of the interval), limestone, gray, hard, broken (comprising 4% of the interval), thin clay lenses. Core loss 57%												
	40																
	42																
	44		2.2	2.8													
	46																
	48		3.0	2.0													
	50																
	52																
	54		1.8	3.2													
	56																
	58		1.8	3.2													
810.4	60																
	62		*Refusal														
	64																
	66																
	68																
	70																
	72																
	74																
	76																
	78																
	80																

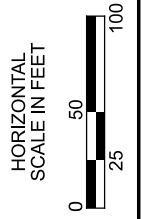
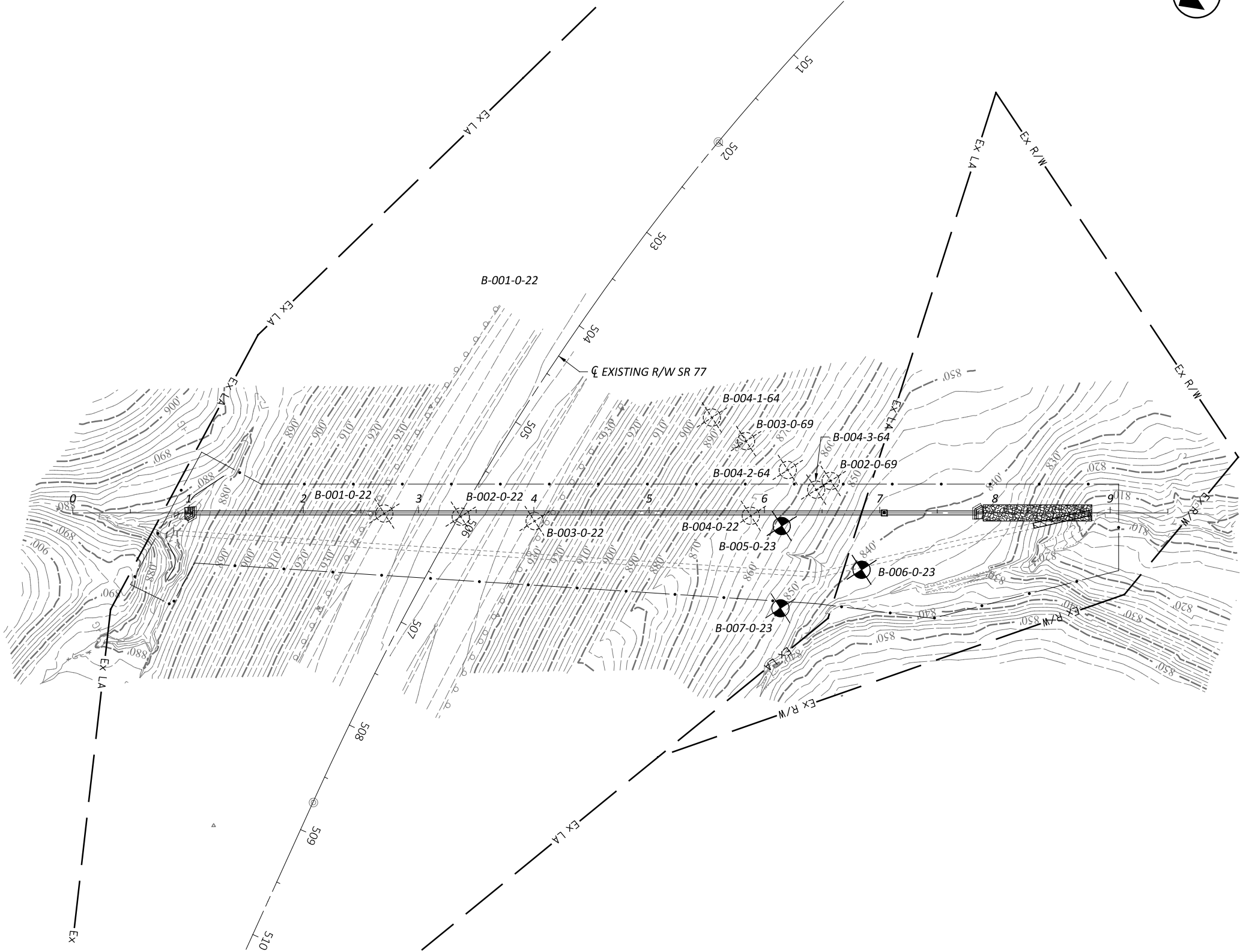
↑  
BOTTOM OF BORING

Sta. 504+00





## **Boring Location Plan**



BORING LOCATION PLAN

DESIGN AGENCY



DESIGNER  
AKB

REVIEWER  
DMV 08/23/23

PROJECT ID  
115420

SHEET	TOTAL
1	0



**Boring Logs  
and  
Rock Core Photos  
WAS-77-9.58 (2023)**

PROJECT: <u>WAS-77-09.58</u>	DRILLING FIRM / OPERATOR: <u>CENTRAL STAR / T.S.</u>	DRILL RIG: <u>DIEDRICH D-50</u>	STATION / OFFSET: <u>504+48, 243' LT.</u>	EXPLORATION ID <u>B-005-0-23</u>
TYPE: <u>RETAINING WALL</u>	SAMPLING FIRM / LOGGER: <u>HDR / A.K.B.</u>	HAMMER: <u>DIEDRICH AUTOMATIC</u>	ALIGNMENT: <u>I-77</u>	
PID: <u>115420</u> SFN: <u></u>	DRILLING METHOD: <u>3.25" HSA / NQ2</u>	CALIBRATION DATE: <u>3/7/22</u>	ELEVATION: <u>858.7 (MSL)</u> EOB: <u>69.1 ft.</u>	PAGE <u>1 OF 3</u>
START: <u>7/17/23</u> END: <u>7/17/23</u>	SAMPLING METHOD: <u>SPT / ST / NQ2</u>	ENERGY RATIO (%): <u>86.8</u>	LAT / LONG: <u>39.532305, -81.445576</u>	

[illegible]



[illegible]

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/7/23 10:15 - C:\P\WORKING\EAST01\D338664\WAS-77-9.58 BORING LOGS.GPJ

SLIGHTLY STRONG, VERY THIN TO THIN BEDDED;  
**CLAYSTONE**, RED-BROWN TO GRAY, SEVERELY TO  
 HIGHLY WEATHERED, VERY WEAK, LAMINATED TO VERY  
 THIN BEDDED.

**CLAYSTONE**, PURPLE, GREEN, AND BROWN, SEVERELY  
 TO HIGHLY WEATHERED, VERY WEAK, VERY THIN BEDDED,  
 JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO  
 HIGHLY FRACTURED, OPEN APERTURE WIDTH,  
 SLICKENSIDED TO SLIGHTLY ROUGH SURFACE,  
 BLOCKY/DISTURBED/SEAMY STRUCTURE, VERY POOR  
 SURFACE; RQD 17%, REC 66%. *(continued)*

**CLAYSTONE**, RED-BROWN, MODERATELY WEATHERED,  
 VERY WEAK, THICK TO VERY THICK BEDDED, JOINT  
 DISCONTINUITIES, MODERATELY FRACTURED TO  
 FRACTURED, NARROW TO OPEN APERTURE WIDTH,  
 SLIGHTLY ROUGH SURFACE, BLOCKY STRUCTURE, FAIR  
 SURFACE; RQD 86%, REC 100%.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER



B-005-0-23



Run #	Depth (ft)		Recovery		RQD	
NQ2-1	49	54.3	63 in. / 63 in.	100%	53 in. / 63 in.	84%
NQ2-2	54.3	62.3	87 in. / 96 in.	91%	77 in. / 96 in.	80%

WAS-77-9.58 PID 115420





B-005-0-23







Run #	Depth (ft)		Recovery		RQD	
NQ2-2	54.3	62.3	87 in. / 96 in.	91%	77 in. / 96 in.	80%
NQ2-3	62.3	69.1	80 in. / 81 in.	99%	63 in. / 81 in.	78%

WAS-77-9.58 PID 115420





MATERIAL DESCRIPTION AND NOTES		ELEV. 809.8	DEPTHS		SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
										GR	CS	FS	SI	CL	LL	PL	PI			
HARD, RED-BROWN, <b>SILT AND CLAY</b> , LITTLE SAND, DAMP (RESIDUUM)		804.8	TR	31	6	33	100	SS-12	4.00	0	6	6	43	45	34	21	13	19	A-6a (9)	
				32	7															
				33	16															
				34																
				35																
<b>CLAYSTONE</b> , RED-BROWN, TRACE PURPLE, HIGHLY WEATHERED, VERY WEAK.		802.1	EOB	35	50/3"	-	33	SS-13	-	-	-	-	-	-	-	-	6	Rock (V)		
				36																
				37																
					50/2"	-	0	SS-14	-	-	-	-	-	-	-	-	6	Rock (V)		

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/7/23 10:15 - C:\PWORKING\EAST01\D3386644\WAS-77-9.58 BORING LOGS.GPJ

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

[illegible]

[illegible]

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT GDT - 9/7/23 10:15 - C:\P\WORKING\GEAST01\D338664\WAS-77-9.58 BORING LOGS.GPJ

PID: 115420	SFN:	PROJECT: WAS-77-09.58	STATION / OFFSET: 505+17, 280' LT.	START: 7/12/23	END: 7/13/23	PG 3 OF 3	B-007-0-23												
MATERIAL DESCRIPTION AND NOTES			ELEV. 787.6	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC SAMPLE (%) ID	HP (tsf)	GRADATION (%)					ATTERBERG				ODOT CLASS (GI)	HOLE SEALED
									GR	CS	FS	SI	CL	LL	PL	PI	WC		
<div>SILTSTONE, RED-BROWN AND GRAY, MODERATELY WEATHERED, WEAK, MEDIUM BEDDED, JOINT DISCONTINUITIES, FRACTURED, NARROW TO OPEN APERTURE WIDTH, SLIGHTLY ROUGH SURFACE, BLOCKY STRUCTURE, FAIR SURFACE; RQD 71%, REC 100%.</div> <div>CLAYSTONE, RED-BROWN, MODERATELY WEATHERED, VERY WEAK, THIN BEDDED, JOINT DISCONTINUITIES, FRACTURED, NARROW APERTURE WIDTH, SLIGHTLY ROUGH SURFACE, BLOCKY STRUCTURE, FAIR SURFACE; RQD 71%, REC 100%.</div>																			
NOTES: NONE																			
ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER																			



B-007-0-23



Run #	Depth (ft)		Recovery		RQD	
NQ2-1	36.5	39.0	30 in. / 30 in.	100%	23 in. / 30 in.	77%
NQ2-2	39	43.4	53 in. / 53 in.	100%	36 in. / 53 in.	68%
NQ2-3	43.4	49.0	61 in. / 67 in.	91%	34 in. / 67 in.	51%

WAS-77-9.58 PID 115420





B-007-0-23



Run #	Depth (ft)		Recovery		RQD	
NQ2-3	43.4	49.0	61 in. / 67 in.	91%	34 in. / 67 in.	51%
NQ2-4	49	56.5	90 in. / 90 in.	100%	59 in. / 90 in.	66%

WAS-77-9.58 PID 115420



## **Soil Strength Parameter Determination And Laboratory Testing**

Layer						Dry Unit Weight (pcf)		Moist Unit Wt. (pcf)		Adopted Short Term Parameters	Long-Term Strength Values						Adopted Long Term Strength Parameters	
	Undrained Shear Strength (Su) (psf)				N <sub>60</sub> Value						ODOT GB-7 Correlations		Tested					
	PPR	N-values		Tested		Cohesion (psf)	phi (deg)	Cohesion (psf)	phi (deg)									
		Sowers	T and P	Values														
Layer 1  SOFT TO MEDIUM STIFF COHESIVE	Max	1500	1225	931		95		120		S <sub>u</sub> = 750 psf	Max	7	88	22		c' = 65 psf		
	Min	250	700	532		90		105		Φ = 0 deg	Min	4	50	20		Φ' = 21 deg		
	Average	688	919	698		93		114			Average	5	66	21				
	Std Dev	554	263	200		3		8			Std Dev	2	19	1				
										Y <sub>dry</sub> = 95 pcf						Y <sub>dry</sub> = 95 pcf		
	Avg + Std	1242	1181	898		95		121		Y <sub>moist</sub> = 115 pcf	Avg + Std	7	85	21		Y <sub>moist</sub> = 115 pcf		
	Avg - Std	133	656	499		90		106			Avg - Std	4	47	20				
Layer 2  MEDIUM STIFF TO STIFF COHESIVE	Max	3000	3500	1862	1499	115	121	130	138	S <sub>u</sub> = 1500 psf	Max	14	143	24		c' = 115 psf		
	Min	500	1050	798	1499	95	121	110	138	Φ = 0 deg	Min	6	75	21		Φ' = 23 deg		
	Average	1429	2057	1397	1499	105	121	121	138		Average	11	116	23				
	Std Dev	879	662	372		7		7		Y <sub>dry</sub> = 120 pcf	Std Dev	3	23	1		Y <sub>dry</sub> = 120 pcf		
										Y <sub>moist</sub> = 140 pcf						Y <sub>moist</sub> = 140 pcf		
	Avg + Std	2308	2719	1768		111		128			Avg + Std	13	139	24				
Avg - Std	549	1395	1025		98		115			Avg - Std	8	93	22					
Layer 3  STIFF TO VERY STIFF COHESIVE	Max	4000	4000	4000		130		140		S <sub>u</sub> = 3000 psf	Max	33	200	27		c' = 175 psf		
	Min	500	3325	2527		110		125		Φ = 0 deg	Min	19	163	25		Φ' = 25 deg		
	Average	2091	3820	3085		119		133			Average	24	177	25				
	Std Dev	1038	254	521		5		4		Y <sub>dry</sub> = 120 pcf	Std Dev	5	13	1		Y <sub>dry</sub> = 120 pcf		
										Y <sub>moist</sub> = 135 pcf						Y <sub>moist</sub> = 135 pcf		
	Avg + Std	3129	4075	3606		124		137			Avg + Std	29	190	26				
Avg - Std	1052	3566	2564		114		129			Avg - Std	19	164	24					
Layer 4  HARD COHESIVE	Max	4500	4000	4000		135		145		S <sub>u</sub> = 4000 psf	Max	84	250	28		c' = 250 psf		
	Min	4500	4000	4000		130		140		Φ = 0 deg	Min	46	250	28		Φ' = 28 deg		
	Average	4500	4000	4000		133		143			Average	65	250	28				
	Std Dev	0	0	0		4		4		Y <sub>dry</sub> = 135 pcf	Std Dev	27	0	0		Y <sub>dry</sub> = 135 pcf		
										Y <sub>moist</sub> = 145 pcf						Y <sub>moist</sub> = 145 pcf		
	Avg + Std	4500	4000	4000		136		146			Avg + Std	92	250	28				
Avg - Std	4500	4000	4000		129		139			Avg - Std	38	250	28					

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													Short-Term Cohesion (psf)			LT Cohesion (pcf)	phi	Midpoint Sample	Midpoint Sample	Dry Unit Wt. (pcf)	Moist Unit Wt. (pcf)	Correlated	Assumed Specific Gravity (G <sub>s</sub> )	Computed Void Ratio (e)	
	N <sub>60</sub>	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC		N-values											
														PPR	Sowers	T & P	per GB-7	(deg)	Depth (ft.)	Elevation (ft.)	per GB-7	per GB-7	C <sub>c</sub>		
Max	7	83	1.5	4	8	11	40	37	38	21	17	23	Max	1500	1225	931	88	22	12.0	849.7	95	120	0.252	2.72	0.886
Min	4	72	0.3	4	8	11	40	37	38	21	17	17	Min	250	700	532	50	20	1.0	841.7	90	105	0.252	2.70	0.773
Average	5	76	0.7	4	8	11	40	37	38	21	17	21	Average	688	919	698	66	21	7.5	846.7	93	114	0.252	2.71	0.830
Std Dev	2	5	0.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	Std Dev	554	263	200	19	1	4.7	3.6	3	8	N/A	0.01	0.065
Avg + Std	7	82	1.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	23	Avg + Std	1242	1181	898	85	21	12.2	850.3	95	121	N/A	2.72	0.895
Avg - Std	4	71	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	18	Avg - Std	133	656	499	47	20	2.8	843.2	90	106	N/A	2.70	0.765

Alignment	Surface Elevation	Exploration ID	From		To	Sample ID	N <sub>60</sub>	% Rec	HP	% Gr	CS	FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf)			Correlated	phi (deg)	Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated	Correlated	Correlated C <sub>c</sub>	Assumed Specific Gravity (G <sub>s</sub> )	Computed
																						LT Cohesion (psf)	N-values		per GB-7				Dry Unit Wt. (pcf)	Moist Unit Wt. (pcf)			Void Ratio (e)
																							PPR	Sowers									
I-77	858.7	B-005-0-23	8.5	-	10	SS-4	7	72	0.5	4	8	11	40	37	38	21	17	21	A-6b	Cohesive	1	500	1225	931	88	22	9.0	849.7	95	120	0.252	2.70	0.773
I-77	858.7	B-005-0-23	11	-	12.5	SS-5	6	83	0.25	-	-	-	-	-	-	-	-	23	A-6b	Cohesive	1	250	1050	798	75	21	12.0	846.7	95	120		2.70	0.773
I-77	849.7	B-007-0-23	0	-	1.5	SS-1	4	78	1.5	-	-	-	-	-	-	-	-	17	A-6a	Cohesive	1	1500	700	532	50	20	1.0	848.7	90	105		2.72	0.886
I-77	849.7	B-007-0-23	7.5	-	9	SS-4	4	72	0.5	-	-	-	-	-	-	-	-	21	A-6a	Cohesive	1	500	700	532	50	20	8.0	841.7	90	110		2.72	0.886

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														Short-Term Cohesion (psf)			Correlated		Midpoint Sample Depth (ft.)	Midpoint Sample Elevation (ft.)	Correlated		Correlated		Assumed Specific Gravity (G <sub>s</sub> )	Computed Void Ratio (e)	Strength Testing		
		N <sub>60</sub>	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	N-values			LT Cohesion (psf) per GB-7	phi (deg)			Moist Unit Wt. (pcf) per GB-7	Moist Unit Wt. (pcf) per GB-7	Correlated C <sub>c</sub>	Dry Unit Wt (pcf)			Moist Unit Wt (pcf)	Qu/UU Su (psf)	
Max	14	100	3.0	12	13	15	53	46	50	23	28	24	Max	3000	3500	1862	143	24	26.0	856.7	115	130	0.360	2.72	0.787	121	138	1499	
Min	6	11	0.5	0	2	6	29	30	34	19	13	15	Min	500	1050	798	75	21	1.0	813.8	95	110	0.216	2.65	0.476	121	138	1499	
Average	11	79	1.4	6	8	11	39	36	39	21	18	19	Average	1429	2057	1397	116	23	11.0	837.2	105	121	0.259	2.69	0.610	121	138	1499	
Std Dev	3	28	0.9	4	3	3	7	5	5	1	4	2	Std Dev	879	662	372	23	1	7.9	13.0	7	7	0.044	0.03	0.104	N/A	N/A	N/A	
Avg + Std	13	108	2.3	10	11	14	46	41	44	22	22	21	Avg + Std	2308	2719	1768	139	24	18.9	850.1	111	128	0.303	2.72	0.715	N/A	N/A	N/A	
Avg - Std	8	51	0.5	2	5	9	31	31	34	20	13	16	Avg - Std	549	1395	1025	93	22	3.1	824.2	98	115	0.215	2.67	0.506	N/A	N/A	N/A	

Alignment	Surface Elevation	Exploration ID	From	To	Sample ID	N <sub>60</sub>	% Rec	HP	% Gr	% CS	FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf)			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 <sub>c</sub>	Assumed Specific Gravity (G <sub>s</sub> )	Computed Void Ratio (e)	Strength Testing			
																					PPR	N-values Sowers	T & P										Dry Unit Wt (pcf)	Moist Unit Wt (pcf)	Qu/UU Su (psf)	
I-77	858.7	B-005-0-23	1	-	2.5	SS-1	6	72	1.5	6	7	10	38	39	41	21	20	17	A-7-6	Cohesive	2	1500	1500	798	75	21	2.0	856.7	95	110	0.279	2.65	0.741	121.1	138.3	1499
I-77	858.7	B-005-0-23	3.5	-	5	SS-2	9	17	-	-	-	-	-	-	-	-	24	A-7-6	Cohesive	2	N/A	2250	1197	107	22	4.0	854.7	100	120	0.654						
I-77	858.7	B-005-0-23	6	-	7.5	SS-3	12	67	1	5	8	12	35	40	38	21	17	21	A-6b	Cohesive	2	1000	2100	1596	129	23	7.0	851.7	105	125	0.252	2.70	0.605			
I-77	858.7	B-005-0-23	13.5	-	15.5	ST-6	ST	58	1.25	3	2	9	53	33	36	19	17	15	A-6b	Cohesive	2	1250	N/A	N/A	143	24	15.0	843.7	110	125	0.234	2.70	0.532			
I-77	858.7	B-005-0-23	15.5	-	17	SS-7	14	89	0.75	12	7	6	29	46	50	22	28	21	A-7-6	Cohesive	2	750	3500	1862	129	23	16.0	842.7	110	125	0.36	2.65	0.503			
I-77	858.7	B-005-0-23	18.5	-	20	SS-8	12	94	1	-	-	-	-	-	-	-	17	A-7-6	Cohesive	2	1000	3000	1596	129	23	19.0	839.7	110	125	0.27	2.70	0.685				
I-77	839.8	B-006-0-23	0	-	1.5	SS-1	7	100	2	-	-	-	-	-	-	-	19	A-6b	Cohesive	2	2000	1225	931	88	22	1.0	838.8	95	110	0.252	2.70	0.532				
I-77	839.8	B-006-0-23	2.5	-	4	SS-2	9	89	2.5	3	10	12	38	37	40	21	19	18	A-6b	Cohesive	2	2500	1575	1197	107	22	3.0	836.8	100	120	0.27	2.70	0.685			
I-77	839.8	B-006-0-23	5	-	6.5	SS-3	10	89	1.5	-	-	-	-	-	-	-	20	A-6b	Cohesive	2	1500	1750	1330	114	23	6.0	833.8	105	125	0.252	2.70	0.532				
I-77	839.8	B-006-0-23	12.5	-	14	SS-6	10	89	3	-	-	-	-	-	-	-	16	A-6b	Cohesive	2	3000	1750	1330	114	23	13.0	826.8	110	125	0.252	2.70	0.532				
I-77	839.8	B-006-0-23	15	-	16.5	SS-7	13	100	0.5	5	9	13	39	34	38	21	17	19	A-6b	Cohesive	2	500	2275	1729	136	23	16.0	823.8	110	125	0.252	2.70	0.532			
I-77	839.8	B-006-0-23	17.5	-	19	SS-8	13	100	0.5	-	-	-	-	-	-	-	20	A-6b	Cohesive	2	500	2275	1729	136	23	18.0	821.8	110	125	0.252	2.70	0.532				
I-77	839.8	B-006-0-23	20	-	22	ST-9	ST	92	0.5	12	9	11	38	30	38	23	15	18	A-6a	Cohesive	2	500	N/A	N/A	143	24	21.0	818.8	115	130	0.216	2.72	0.476			
I-77	839.8	B-006-0-23	25.3	-	26.5	SS-11B	14	100	3	0	5	13	47	35	34	21	13	18	A-6a	Cohesive	2	3000	2450	1862	75	21	26.0	813.8	95	110	0.216	2.72	0.787			
I-77	849.7	B-007-0-23	2.5	-	4	SS-2	6	100	1	8	13	15	32	32	34	20	14	17	A-6a	Cohesive	2	1000	1050	798	75	21	3.0	846.7	95	110	0.216	2.72	0.787			
I-77	849.7	B-007-0-23	5	-	6.5	SS-3	12	11	-	-	-	-	-	-	-	-	18	A-6a	Cohesive	2	N/A	2100	1596	129	23	6.0	843.7	105	125	2.72	0.616					



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													Short-Term Cohesion (psf)			LT Cohesion	phi	Midpoint	Midpoint	Dry Unit Wt.	Moist Unit Wt.	Correlated	Assumed	Computed	
	N <sub>60</sub>	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	N-values												
													PPR	Sowers	T & P	per GB-7	(deg)	Depth (ft.)	Elevation (ft.)	per GB-7	per GB-7	C <sub>c</sub>	Specific Gravity (G <sub>s</sub> )	Void Ratio (e)	
Max	33	100	4.0	13	11	21	45	46	42	23	19	22	Max	4000	4000	4000	200	27	39.0	838.7	130	140	0.288	2.72	0.532
Min	19	6	0.5	0	2	6	36	23	34	21	13	14	Min	500	3325	2527	163	25	8.0	808.8	110	125	0.216	2.65	0.306
Average	24	84	2.1	4	7	13	41	36	37	21	16	18	Average	2091	3820	3085	177	25	21.2	828.3	119	133	0.244	2.71	0.420
Std Dev	5	28	1.0	4	2	5	4	8	3	1	2	3	Std Dev	1038	254	521	13	1	10.0	8.3	5	4	0.025	0.02	0.063
Avg + Std	29	113	3.1	8	9	17	45	44	40	22	18	20	Avg + Std	3129	4075	3606	190	26	31.2	836.7	124	137	0.269	2.73	0.483
Avg - Std	19	56	1.1	-1	4	8	37	28	34	21	13	15	Avg - Std	1052	3566	2564	164	24	11.2	820.0	114	129	0.220	2.69	0.356

Alignment	Surface Elevation	Exploration ID	From	To	Sample ID	N <sub>60</sub>	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf)			Correlated		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 <sub>c</sub>	Assumed Specific Gravity (G <sub>s</sub> )	Computed Void Ratio (e)	
																					LT Cohesion (psf) per GB-7	phi (deg)	N-values	T & P									
																									PPR								Sowers
I-77	858.7	B-005-0-23	23.5	-	25	SS-9	22	6	-	1	6	11	36	46	-	-	-	19	A-6a	Cohesive	3	N/A	3850	2926	173	25	24.0	834.7	120	135	2.72	0.414	
I-77	858.7	B-005-0-23	33.5	-	35	SS-11	20	94	1.75	3	7	9	45	36	38	21	17	17	A-6b	Cohesive	3	1750	3500	2660	167	25	34.0	824.7	120	135	0.252	2.70	0.404
I-77	858.7	B-005-0-23	38.5	-	40	SS-12	20	100	2.5	0	2	21	36	41	42	23	19	20	A-7-6	Cohesive	3	2500	4000	2660	167	25	39.0	819.7	120	135	0.288	2.65	0.378
I-77	839.8	B-006-0-23	7.5	-	9	SS-4	20	100	2	2	7	12	44	35	38	21	17	16	A-6b	Cohesive	3	2000	3500	2660	167	25	8.0	831.8	110	125	0.252	2.70	0.532
I-77	839.8	B-006-0-23	10	-	11.5	SS-5	26	89	3	-	-	-	-	-	-	-	-	14	A-6b	Cohesive	3	3000	4000	3458	187	25	11.0	828.8	115	130	2.70	0.465	
I-77	839.8	B-006-0-23	30	-	31.5	SS-12	33	100	4	0	6	6	43	45	34	21	13	19	A-6a	Cohesive	3	4000	4000	4000	200	27	31.0	808.8	130	140	0.216	2.72	0.306
I-77	849.7	B-007-0-23	10	-	11.5	SS-5	22	89	2	5	8	14	39	34	38	21	17	14	A-6b	Cohesive	3	2000	3850	2926	173	25	11.0	838.7	115	130	0.252	2.70	0.465
I-77	849.7	B-007-0-23	12.5	-	14	SS-6	33	100	3	-	-	-	-	-	-	-	-	20	A-6b	Cohesive	3	3000	4000	4000	200	27	13.0	836.7	125	135	2.70	0.348	
I-77	849.7	B-007-0-23	15	-	17	ST-7	ST	50	0.5	13	11	12	41	23	35	21	14	15	A-6a	Cohesive	3	500	N/A	N/A			16.0	833.7			0.225	2.72	
I-77	849.7	B-007-0-23	17	-	18.5	SS-8	23	89	0.5	-	-	-	-	-	-	-	-	19	A-6a	Cohesive	3	500	4000	3059	177	25	18.0	831.7	115	130	2.72	0.476	
I-77	849.7	B-007-0-23	22	-	23.5	SS-9	19	100	1.75	4	7	17	44	28	35	22	13	19	A-6a	Cohesive	3	1750	3325	2527	163	25	23.0	826.7	120	135	0.225	2.72	0.414
I-77	849.7	B-007-0-23	25	-	26.5	SS-10	23	94	2	-	-	-	-	-	-	-	22	A-6a	Cohesive	3	2000	4000	3059	177	25	26.0	823.7	120	135	2.72	0.414		

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													Short-Term Cohesion (psf)			LT Cohesion	phi	Midpoint	Midpoint	Dry Unit Wt.	Moist Unit Wt.	Correlated	Assumed	Computed	
	N <sub>60</sub>	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	N-values			(pcf)	(deg)	Sample	Sample	(pcf)	(pcf)	C <sub>c</sub>	Specific	Void	
													PPR	Sowers	T & P	per GB-7		Depth (ft.)	Elevation (ft.)	per GB-7	per GB-7		Gravity (G <sub>s</sub> )	Ratio (e)	
Max	84	100	4.5	15	6	8	41	47	43	23	20	23	Max	4500	4000	4000	250	28	44.0	818.7	135	145	0.297	2.70	0.296
Min	46	100	4.5	2	4	6	31	40	38	21	17	18	Min	4500	4000	4000	250	28	31.0	814.7	130	140	0.252	2.65	0.225
Average	65	100	4.5	9	5	7	36	44	41	22	19	21	Average	4500	4000	4000	250	28	37.5	816.7	133	143	0.275	2.68	0.260
Std Dev	27	0	0.0	9	1	1	7	5	4	1	2	4	Std Dev	0	0	0	0	0	9.2	2.8	4	4	0.032	0.04	0.050
Avg + Std	92	100	4.5	18	6	8	43	48	44	23	21	24	Avg + Std	4500	4000	4000	250	28	46.7	819.6	136	146	0.306	2.71	0.311
Avg - Std	38	100	4.5	-1	4	6	29	39	37	21	16	17	Avg - Std	4500	4000	4000	250	28	28.3	813.9	129	139	0.243	2.64	0.210

Alignment	Surface Elevation	Exploration ID	From	To	Sample ID	N <sub>60</sub>	% Rec	HP	% Gr	% CS	% FS	% Silt	% Clay	LL	PL	PI	% WC	ODOT Class.	Soil Type	Layer	Short-Term Cohesion (psf)			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 <sub>c</sub>	Assumed Specific Gravity (G <sub>s</sub> )	Computed Void Ratio (e)	
																					N-values												
																					PPR	Sowers	T & P										
I-77	858.7	B-005-0-23	43.5	-	45	SS-13	84	100	4.5	2	4	6	41	47	43	23	20	23	A-7-6	Cohesive	4	4500	4000	4000	250	28	44.0	814.7	135	145	0.297	2.65	0.225
I-77	849.7	B-007-0-23	30	-	31.5	SS-11	46	100	4.5	15	6	8	31	40	38	21	17	18	A-6b	Cohesive	4	4500	4000	4000	250	28	31.0	818.7	130	140	0.252	2.70	0.296

## **Unconfined Compressive Strength of Cohesive Soil (ASTM D2166)**

(Project: WAS-77-9.58, Boring Location: B-005-0-23, ST-6, Depth: 13.9 - 14.4ft)

Tested Date: 8/7/2023

### **Specimen Properties**

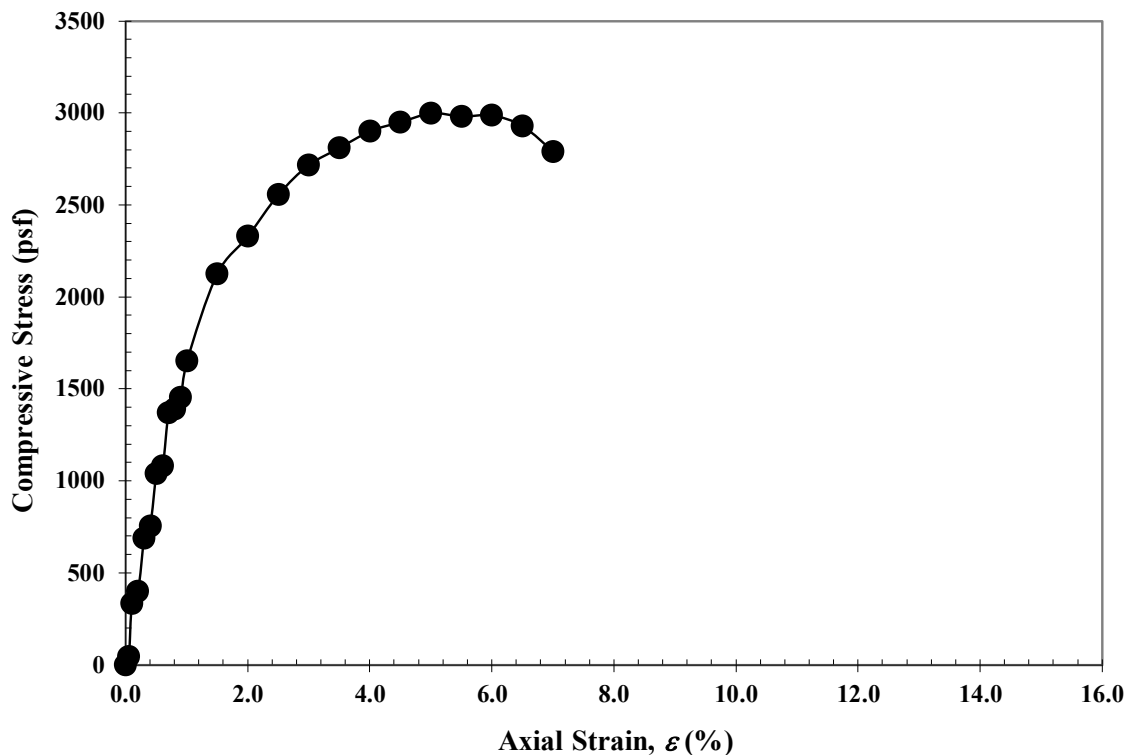
Average Dia., $D_{avg}$ (in):	2.87
Average Height, $H_{avg}$ (in):	5.74
Area, $A$ (in <sup>2</sup> ):	6.48
Volume, $V$ (in <sup>3</sup> ):	37.18
Wet Mass of Specimen (lb):	3.0
Moisture Content (%):	14.2
Dry Mass of Specimen (lb):	2.6
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	138.3
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	121.1

### **Final Specimen Figure**



### **Results**

Unconfined Compressive Strength (psf):	<b>2998</b>
Strain (%):	<b>5.0</b>



**Notes:** Stiff, red-brown, SILTY CLAY, little sand, trace gravel, damp.

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/7/23 10:15 - C:\P\WORKING\GEAST01\338664\WAS-77-9.58 BORING LOGS.GPJ

PROJECT: WAS-77-09.58		DRILLING FIRM / OPERATOR: CENTRAL STAR / T.S.		DRILL RIG: DIETRICH D-50		STATION / OFFSET: 50+48, 243' LT.		EXPLORATION ID B-005-0-23											
TYPE: RETAINING WALL		SAMPLING FIRM / LOGGER: HDR / A.K.B.		HAMMER: I-77		EOB: 69.1 ft.		PAGE 1 OF 3											
PID: 115420 SFN:		DRILLING METHOD: 3.25" HSA / NQ2		CALIBRATION:		2305.781.445576													
START: 7/17/23 END: 7/17/23		SAMPLING METHOD: SPT / ST / NQ2		ENERGY:															
MATERIAL DESCRIPTION AND NOTES		ELEV.	DEPTHS	SPT/RQD	N <sub>60</sub>	High moisture contents with decreased N-values and HP readings. Groundwater considered at 7.5' (based on B-007-0-23).										ERBERG	WC	ODOT CLASS (GI)	HOLE SEALED
						PL	RI												
TOPSOIL (2")		858.7																	
MEDIUM STIFF TO STIFF, BROWN, <b>CLAY</b> , "AND" SILT, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP (FILL)  Layer 2		858.5	1	3															
			2	2	6	72	SS-1	1.50	6	7	10	38	39	41	21	20	17	A-7-6 (12)	
			3																
			4	4	3	9	17	SS-2	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
STIFF, RED-BROWN, <b>SILTY CLAY</b> , LITTLE SAND, TRACE STONE FRAGMENTS, DAMP (FILL)		852.7	5																
SOFT TO MEDIUM STIFF, RED-BROWN, <b>SILTY CLAY</b> , LITTLE SAND, TRACE STONE FRAGMENTS, DAMP (FILL)  Layer 1		850.2	6	4	12	67	SS-3	1.00	5	8	12	35	40	38	21	17	21	A-6b (11)	
			7	4															
			8																
			9	2	7	72	SS-4	0.50	4	8	11	40	37	38	21	17	21	A-6b (11)	
@13.9' - 14.4': Qu = 2998 psf, γ = 138 pcf		843.2	10	3															
			11	2															
			12	1	6	83	SS-5	0.25	-	-	-	-	-	-	-	-	23	A-6b (V)	
			13	3															
MEDIUM STIFF TO STIFF, RED-BROWN, <b>CLAY</b> , SOME SILT, LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP (FILL)		843.2	14			58	ST-6	1.25	3	2	9	53	33	36	19	17	15	A-6b (11)	
Layer 2			15	2															
			16	4	14	89	SS-7	0.75	12	7	6	29	46	50	22	28	21	A-7-6 (17)	
			17	6															
		18																	
VERY STIFF, BROWN, <b>SILT AND CLAY</b> , LITTLE SAND, TRACE STONE FRAGMENTS, DAMP (FILL)  Layer 3		835.2	19	3	12	94	SS-8	1.00	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
			20	5															
			21																
			22																
MEDIUM DENSE, RED-BROWN TO BROWN, <b>STONE FRAGMENTS WITH SAND, SILT, AND CLAY</b> , DAMP (FILL)		830.2	23																
			24	5	22	6	SS-9	-	1	6	11	36	46	-	-	-	19	A-6a (V)	
			25	6															
			26	9															
Omit granular layer as outlier.		830.2	27																
			28																
			29	8	30	94	SS-10	1.50	48	13	8	18	13	33	20	13	9	A-2-6 (0)	
			30	10															
			31	11															

High moisture contents with decreased N-values and HP readings. Groundwater considered at 7.5' (based on B-007-0-23).

Omit granular layer as outlier.

[illegible]

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/7/23 10:15 - C:\P\WORKING\EAST01\D3386644\WAS-77-9.58 BORING LOGS.GPJ



SLIGHTLY STRONG, VERY THIN TO THIN BEDDED;  
**CLAYSTONE**, RED-BROWN TO GRAY, SEVERELY TO  
 HIGHLY WEATHERED, VERY WEAK, LAMINATED TO VERY  
 THIN BEDDED.

**CLAYSTONE**, PURPLE, GREEN, AND BROWN, SEVERELY  
 TO HIGHLY WEATHERED, VERY WEAK, VERY THIN BEDDED,  
 JOINT AND BEDDING DISCONTINUITIES, FRACTURED TO  
 HIGHLY FRACTURED, OPEN APERTURE WIDTH,  
 SLICKENSIDED TO SLIGHTLY ROUGH SURFACE,  
 BLOCKY/DISTURBED/SEAMY STRUCTURE, VERY POOR  
 SURFACE; RQD 17%, REC 66%. *(continued)*





**CLAYSTONE**, RED-BROWN, MODERATELY WEATHERED,  
 VERY WEAK, THICK TO VERY THICK BEDDED, JOINT  
 DISCONTINUITIES, MODERATELY FRACTURED TO  
 FRACTURED, NARROW TO OPEN APERTURE WIDTH,  
 SLIGHTLY ROUGH SURFACE, BLOCKY STRUCTURE, FAIR  
 SURFACE; RQD 86%, REC 100%.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/7/23 10:15 - C:\P\WORKING\GEAST01\D338664\WAS-77-9.58 BORING LOGS.GPJ

PROJECT: WAS-77-09.58		DRILLING FIRM / OPERATOR: CENTRAL STAR / T.S.		DRILL RIG: DIEDRICH D-50		STATION / OFFSET: 504+40, 322' LT.		EXPLORATION ID B-006-0-23												
TYPE: RETAINING WALL		SAMPLING FIRM / LOGGER: HDR / D.C.M.		HAMMER: DIEDRICH AUTOMATIC		ALIGNMENT: I-77		PAGE 1 OF 2												
PID: 115420 SFN:		DRILLING METHOD: 3.25" HSA		CALIBRATION DATE: 3/7/22		ELEVATION: 839.8 (MSL) EOB: 37.7 ft.														
START: 7/12/23 END: 7/12/23		SAMPLING METHOD: SPT / ST		ENERGY RATIO (%): 86.8		LAT / LONG: 39.532204, -81.445824														
MATERIAL DESCRIPTION AND NOTES		ELEV. 839.8	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED	
MEDIUM STIFF TO STIFF, RED-BROWN, SILTY CLAY, SOME SAND, TRACE STONE FRAGMENTS, DAMP (FILL)  Layer 2		831.8	1	1	7	100	SS-1	2.00	-	-	-	-	-	-	-	-	19	A-6b (V)		
			2	2	3															
			3	3	3	9	89	SS-2	2.50	3	10	12	38	37	40	21	19	18		A-6b (12)
			4																	
			5	3																
			6	3	4	10	89	SS-3	1.50	-	-	-	-	-	-	-	-	20		A-6b (V)
			7																	
STIFF TO VERY STIFF, RED-BROWN, TRACE GRAY AND LIGHT BROWN, SILTY CLAY, LITTLE SAND, TRACE STONE FRAGMENTS, DAMP (FILL)  Layer 3		824.3	8	10	7	20	100	SS-4	2.00	2	7	12	44	35	38	21	17	16	A-6b (11)	
			9		7															
			10	11																
			11	10	8	26	89	SS-5	3.00	-	-	-	-	-	-	-	-	14	A-6b (V)	
			12																	
			13	5	3	10	89	SS-6	3.00	-	-	-	-	-	-	-	-	16	A-6b (V)	
			14		4															
MEDIUM STIFF TO STIFF, RED-BROWN, TRACE LIGHT BROWN, SILTY CLAY, SOME SAND, TRACE STONE FRAGMENTS, DAMP (FILL)  Layer 2		819.8	15	4																
			16	4	5	13	100	SS-7	0.50	5	9	13	39	34	38	21	17	19		A-6b (10)
			17																	
			18	4	5	13	100	SS-8	0.50	-	-	-	-	-	-	-	-	20		A-6b (V)
MEDIUM STIFF TO STIFF, RED-BROWN, TRACE LIGHT BROWN, SILT AND CLAY, LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP (FILL)		814.8	19																	
			20																	
			21				92	ST-9	0.50	12	9	11	38	30	38	23	15	18		A-6a (9)
			22	50/3"	-	100	SS-10	-	-	-	-	-	-	-	-	-	-	23		A-6a (V)
STIFF TO VERY STIFF, RED-BROWN, SILT AND CLAY, LITTLE SAND, DAMP @25': 2" of black plastic/tar/rubber, 1" of rounded 1/4" gravel		809.8	23																	
			24																	
			25	19				SS-11A	-	-	-	-	-	-	-	-	-	-		
			26	5	5	14	100	SS-11B	3.00	0	5	13	47	35	34	21	13	18		A-6a (9)
			27																	
			28																	
			29																	

Sample SS-10 omitted as outlier.

MATERIAL DESCRIPTION AND NOTES		ELEV. 809.8	DEPTHS		SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED	
										GR	CS	FS	SI	CL	LL	PL	PI				
HARD, RED-BROWN, <b>SILT AND CLAY</b> , LITTLE SAND, DAMP (RESIDUUM)		804.8	TR	31	6	33	100	SS-12	4.00	0	6	6	43	45	34	21	13	19	A-6a (9)		
				32	7																
				33	16																
				34																	
				35																	
<b>CLAYSTONE</b> , RED-BROWN, TRACE PURPLE, HIGHLY WEATHERED, VERY WEAK.		802.1	EOB	35	50/3"	-	33	SS-13	-	-	-	-	-	-	-	-	6	Rock (V)			
				36																	
				37																	
					50/2"	-	0	SS-14	-	-	-	-	-	-	-	-	6	Rock (V)			

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/7/23 10:15 - C:\PWORKING\EAST01\D3386644\WAS-77-9.58 BORING LOGS.GPJ

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/7/23 10:15 - C:\P\WORKING\EA\ST01\D338664\WAS-77-9.58 BORING LOGS.GPJ

PROJECT: WAS-77-09.58		DRILLING FIRM / OPERATOR: CENTRAL STAR / T.S.		DRILL RIG: D		decreased N-value and HP reading. Groundwater considered at 7.5'.										LT.	EXPLORATION ID B-007-0-23			
TYPE: RETAINING WALL		SAMPLING FIRM / LOGGER: HDR / D.C.M./A.K.B.		HAMMER: DIEDER												PAGE 1 OF 3				
PID: 115420 SFN:		DRILLING METHOD: 3.25" HSA / NQ2		CALIBRATION DATE: 3/7/22		ELEVATION: 849.7 (MSL) EOB: 56.5 ft.														
START: 7/12/23 END: 7/13/23		SAMPLING METHOD: SPT / ST / NQ2		ENERGY RATIO (%): 86.8		LAT / LONG: 39.532416, -81.445785														
MATERIAL DESCRIPTION AND NOTES			ELEV. 849.7	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG				ODOT CLASS (GI)	HOLE SEALED
MEDIUM STIFF TO STIFF, RED-BROWN, SILT AND CLAY, SOME SAND, TRACE STONE FRAGMENTS, DAMP (FILL)				1	2	4	78	SS-1	1.50	-	-	-	-	-	-	-	17	A-6a (V)		
					2	1														
Layer 2				2	2	6	100	SS-2	1.00	8	13	15	32	32	34	20	14	17		A-6a (7)
					3	2														
					4	2														
					5	4														
Layer 1				6	3	12	11	SS-3	-	-	-	-	-	-	-	-	18	A-6a (V)		
					5															
Layer 1				7	2	4	72	SS-4	0.50	-	-	-	-	-	-	-	21	A-6a (V)		
					8	1														
					9	2														
VERY STIFF TO HARD, RED-BROWN, SILTY CLAY, SOME SAND, TRACE GRAVEL, DAMP				10	4	22	89	SS-5	2.00	5	8	14	39	34	38	21	17	14		A-6b (10)
					5	10														
					11															
					12															
Layer 3				13	8	33	100	SS-6	3.00	-	-	-	-	-	-	-	20	A-6b (V)		
					11	12														
					12															
STIFF TO VERY STIFF, RED-BROWN, SILT AND CLAY, SOME SAND, LITTLE GRAVEL AND STONE FRAGMENTS, DAMP				14																
					15															
					16		50	ST-7	0.50	13	11	12	41	23	35	21	14	15		A-6a (7)
					17	6	23	89	SS-8	0.50	-	-	-	-	-	-	-	19		A-6a (V)
STIFF TO VERY STIFF, RED-BROWN, SILT AND CLAY, SOME SAND, TRACE GRAVEL AND STONE FRAGMENTS, DAMP				18	7															
					9															
					19															
					20															
					21															
					22	5														
					23	6	19	100	SS-9	1.75	4	7	17	44	28	35	22	13		19
				24																
					25	7														
					26	7	23	94	SS-10	2.00	-	-	-	-	-	-	-	22	A-6a (V)	
					9															
					27															
					28															
				29																

High moisture content with  
decreased N-value and HP reading.  
Groundwater considered at 7.5'.

[illegible]

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/7/23 10:15 - C:\P\WORKING\EAST01\D3386644\WAS-77-9.58 BORING LOGS.GPJ



STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 9/7/23 10:15 - C:\P\WORKING\GEAST01\D338664\WAS-77-9.58 BORING LOGS.GPJ

PID: 115420	SFN:	PROJECT: WAS-77-09.58	STATION / OFFSET: 505+17, 280' LT.	START: 7/12/23	END: 7/13/23	PG 3 OF 3	B-007-0-23												
MATERIAL DESCRIPTION AND NOTES			ELEV. 787.6	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC SAMPLE (%) ID	HP (tsf)	GRADATION (%)					ATTERBERG				ODOT CLASS (GI)	HOLE SEALED
									GR	CS	FS	SI	CL	LL	PL	PI	WC		
<p><b>SILTSTONE</b>, RED-BROWN AND GRAY, MODERATELY WEATHERED, WEAK, MEDIUM BEDDED, JOINT DISCONTINUITIES, FRACTURED, NARROW TO OPEN APERTURE WIDTH, SLIGHTLY ROUGH SURFACE, BLOCKY STRUCTURE, FAIR SURFACE; RQD 71%, REC 100%.</p> <p><b>CLAYSTONE</b>, RED-BROWN, MODERATELY WEATHERED, VERY WEAK, THIN BEDDED, JOINT DISCONTINUITIES, FRACTURED, NARROW APERTURE WIDTH, SLIGHTLY ROUGH SURFACE, BLOCKY STRUCTURE, FAIR SURFACE; RQD 71%, REC 100%.</p>																			
NOTES: NONE																			
ABANDONMENT METHODS, MATERIALS, QUANTITIES: TREMIED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 50 GAL. WATER																			



## **Rock Strength Parameter Determination and Laboratory Testing**

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 USE	Em (Hoek & Brown) Modulus (GPa) (psi)	Lesser of Er vs Em (psi)	Em (Yang) Modulus (MPa) (psi)
WAS-77-9.58	B-005-0-23	53.2	NQ2-1	Claystone	Red-brown	158.2	1129 7.8	332,059 2289	35-45 40	1.6 227556	227556	144.6 20974
WAS-821-3.68	B-010-2-12	84.3	NQ-13	Claystone	Red-brown	165.1	1202 8.3	240,400 1657	25-35 30	0.9 132036	132036	66.0 9578
				Claystone	Maximum	165.1	1202			Claystone	Maximum	227556
					Minimum	158.2	1129				Minimum	132036
					Average	162	1166				Average	179796
					Std Dev	5	52				Std Dev	67542
					Adopted Value	160	1150				Adopted Value	179800

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 USE	Em (Hoek & Brown) Modulus (GPa) (psi)	Lesser of Er vs Em (psi)	Em (Yang) Modulus (MPa) (psi)
WAS-821-3.68 (3.79)	B-009-1-12	33	NQ-4	Claystone	Red-brown	154	648.9 4.5	85,395 589	15-25 20	0.4 54554	54554	14.8 2146
WAS-821-3.68 (3.79)	B-012-1-12	18.5	NQ-2	Claystone	Red-brown	145.6	189.1 1.3	12,286 85	15-25 20	0.2 29450	12286	2.1 309
WAS-821-3.68 (3.79)	B-012-2-12	30.8	NQ-6	Claystone	Red-brown	145.5	375.4 2.6	53,629 370	30-40 35	0.7 98398	53629	18.5 2690
WAS-821-3.60	B-001-0-10	31.2	NX-2	Claystone	Red	206	1.4	0	15-25 20	0.2 30738	30738	0.0 0
WAS-821-3.60	B-001-0-10	32.6	NX-2	Claystone	Red	357	2.5	0	15-25 20	0.3 40465	40465	0.0 0
WAS-821-3.60	B-002-0-10	32.1	NX-2	Claystone	Red/Gray	539	3.7	0	20-30 25	0.5 66303	66303	0.0 0
WAS-821-3.60	B-003-0-10	22.7	NX-1	Claystone	Red/Brown	6.6	0.0	0	10-20 15	0.0 4126	4126	0.0 0
				Claystone	Maximum	154	648.9			Claystone	Maximum	66303
					Minimum	145.5	6.6				Minimum	4126
					Average	148	332				Average	37443
					Std Dev	5	219				Std Dev	23039
					Adopted Value	150	330				Adopted Value	37400

krm 0.0005

Table 10.4.6.5-1—Estimation of  $E_m$  Based on GSI

Expression	Notes/Remarks	Reference
$E_m (GPa) = \sqrt{\frac{q_u}{100}} 10^{\frac{GSI-10}{40}} \text{ for } q_u \leq 100 \text{ MPa}$	Accounts for rocks with $q_u < 100$ MPa; notes $q_u$ in MPa	Hoek and Brown (1997); Hoek et al. (2002)
$E_m (GPa) = 10^{\frac{GSI-10}{40}} \text{ for } q_u \leq 100 \text{ MPa}$		
$E_m = \frac{E_R}{100} e^{\frac{GSI}{21.7}}$	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.		

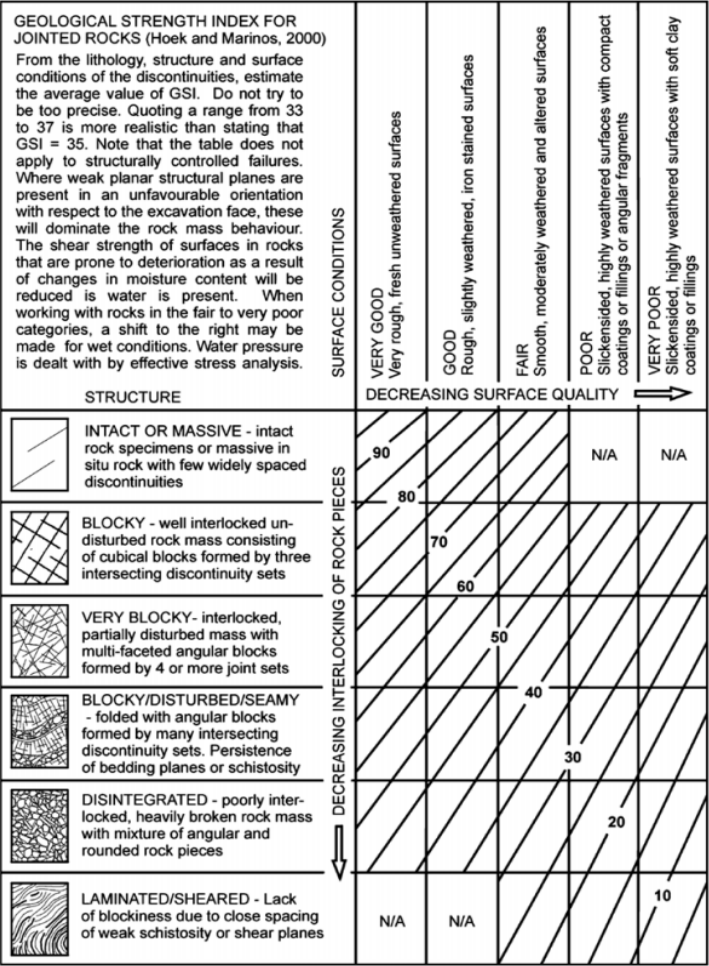


Figure 10.4.6.4-1—Determination of  $GSI$  for Jointed Rock Mass (Hoek and Marinos, 2000)

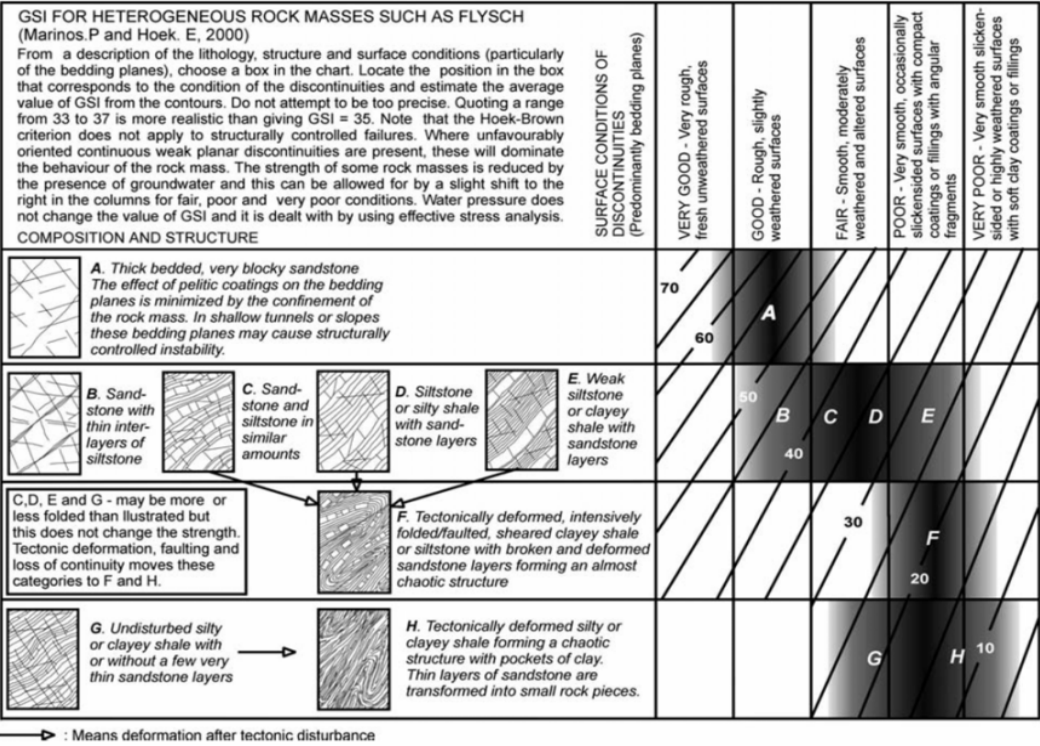


Figure 10.4.6.4-2—Determination of  $GSI$  for Tectonically Deformed Heterogeneous Rock Masses (Marinos and Hoek 2000)

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

(Project: WAS-77-9.58, Boring Location: B-005-0-23, NQ2-1, Depth: 53.2 - 53.6ft)

Tested Date: 8/10/2023

### Specimen Properties

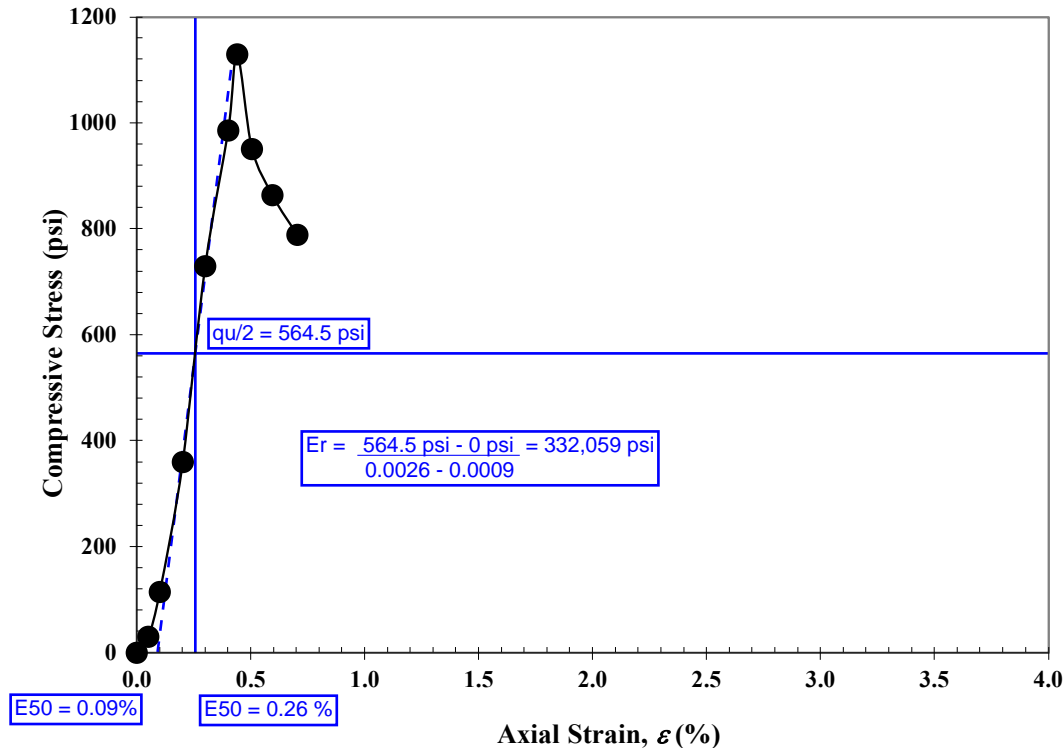
Average Dia., $D_{avg}$ (in):	1.99
Average Height, $H_{avg}$ (in):	4.55
Length to Diameter Ratio:	2.28
Area, $A$ (in <sup>2</sup> ):	3.11
Volume, $V$ (in <sup>3</sup> ):	14.15
Wet Mass of Specimen (lb):	1.3
Moisture Content (%):	5.0
Dry Mass of Specimen (lb):	1.2
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	158.2
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	150.8

### Final Specimen Figure



### Results

Unconfined Compressive Strength (psi):	<b>1129</b>	
Strain (%):	<b>0.4</b>	<b>8</b> (MPa)



**Notes:** Claystone, red-brown, moderately weathered, weak.

## Unconfined Compressive Strength Test

(Project: WAS-821-3.79, Boring Location: B-010-2-12, R-13, Depth: 84.3 - 84.7 ft)

Tested Date: 5/29/2012

### Specimen Properties

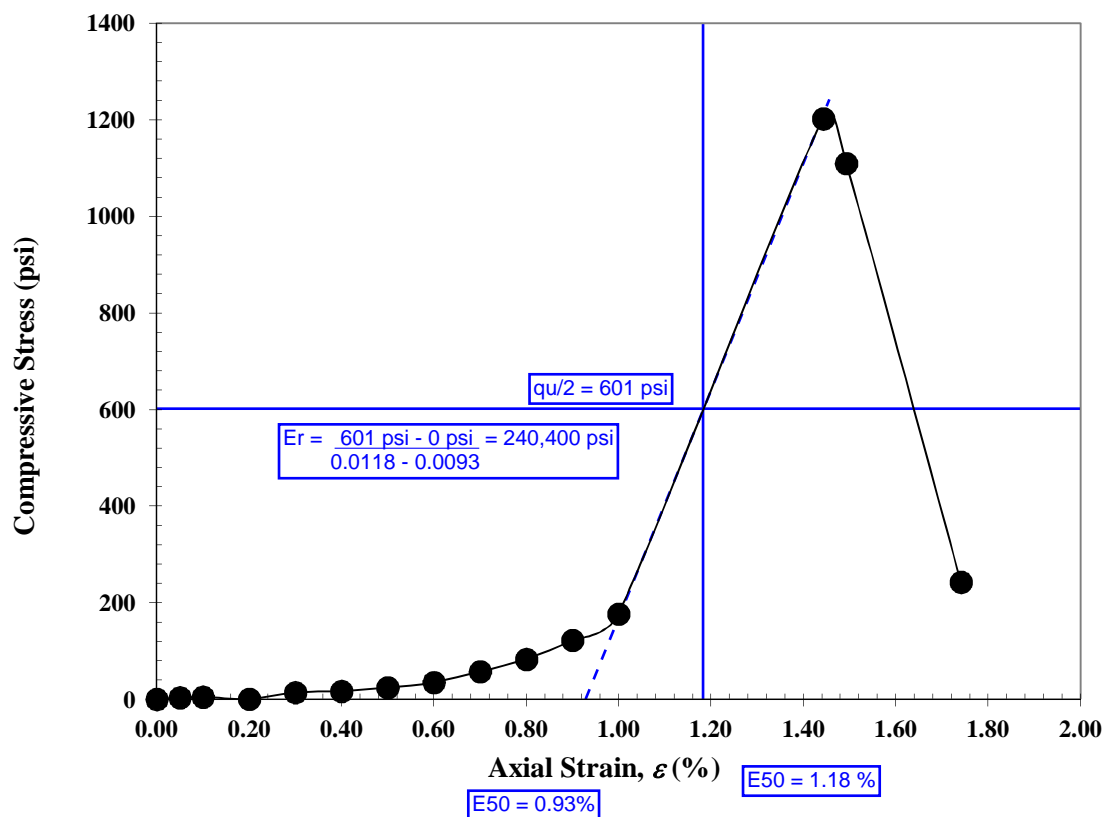
Average Dia., $D_{avg}$ (in):	1.98
Average Height, $H_{avg}$ (in):	4.02
Area, $A$ (in <sup>2</sup> ):	3.08
Volume, $V$ (in <sup>3</sup> ):	12.40
Wet Mass of Specimen (lb):	1.2
Moisture Content (%):	4.2
Dry Mass of Specimen (lb):	1.1
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	165.1
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	158.4

### Final Specimen Figure



### Results

Unconfined Compressive Strength (psi): **1202.0**  
Strain (%): **1.44**



**NOTES:** Weak, red -brown, CLAYSTONE. Failed along slickensides.



## Unconfined Compressive Strength Test

(Project: WAS-821-3.79, Boring Location: B-009-1-12, R-4, Depth: 33.0 - 33.4 ft)

Tested Date: 5/29/2012

### Specimen Properties

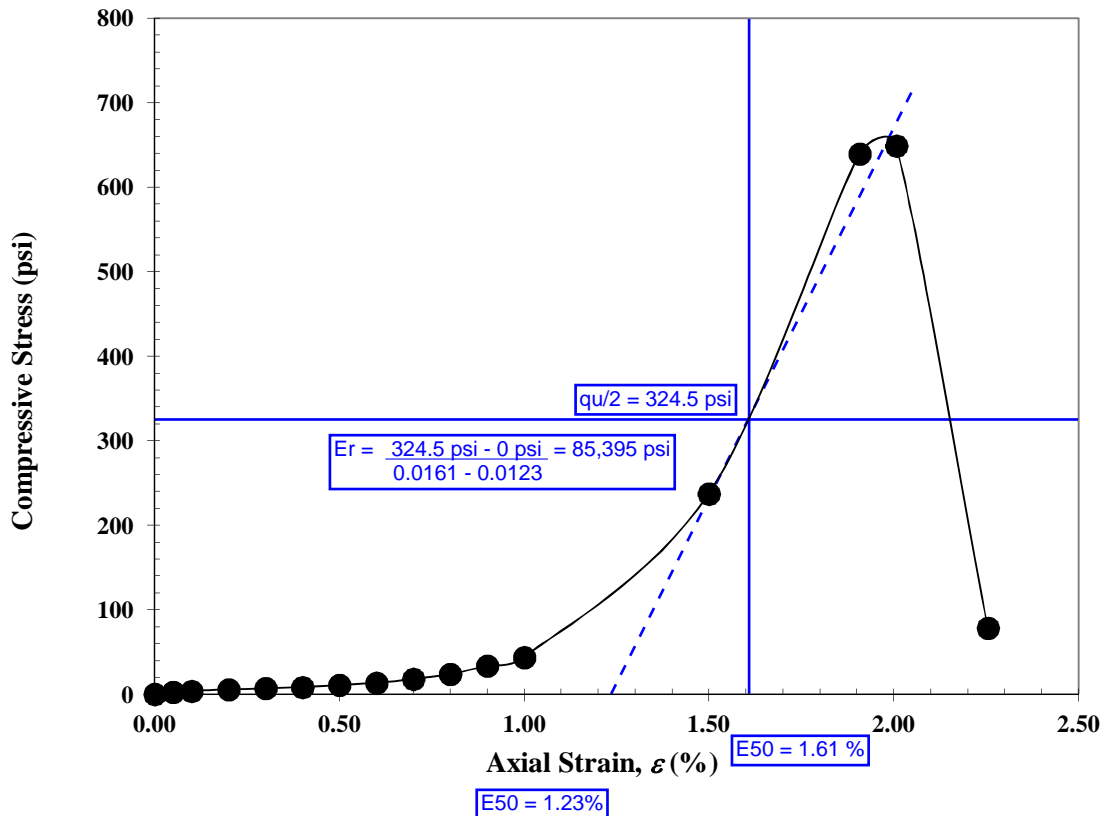
Average Dia., $D_{avg}$ (in):	1.97
Average Height, $H_{avg}$ (in):	4.03
Area, $A$ (in <sup>2</sup> ):	3.04
Volume, $V$ (in <sup>3</sup> ):	12.27
Wet Mass of Specimen (lb):	1.1
Moisture Content (%):	6.0
Dry Mass of Specimen (lb):	1.0
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	154.0
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	145.3

### Final Specimen Figure



### Results

Unconfined Compressive Strength (psi):	<b>648.9</b>
Strain (%):	<b>2.0</b>



**NOTES:** Very weak, red-brown with gray, CLAYSTONE.

## Unconfined Compressive Strength Test

(Project: WAS-821-3.79, Boring Location: B-012-1-12, R-2, Depth: 18.5 - 18.9 ft)

Tested Date: 5/29/2012

### Specimen Properties

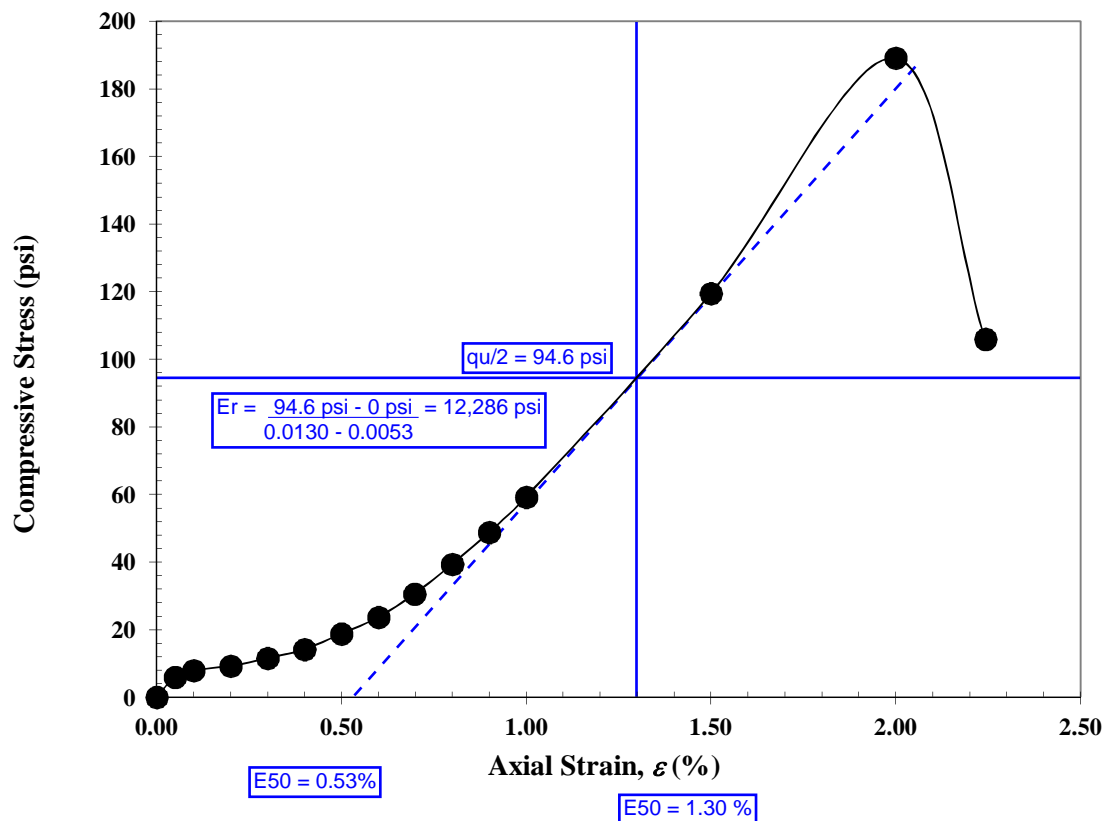
Average Dia., $D_{avg}$ (in):	1.96
Average Height, $H_{avg}$ (in):	4.01
Area, $A$ (in <sup>2</sup> ):	3.03
Volume, $V$ (in <sup>3</sup> ):	12.14
Wet Mass of Specimen (lb):	1.0
Moisture Content (%):	7.8
Dry Mass of Specimen (lb):	0.9
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	145.6
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	135.1

### Final Specimen Figure



### Results

Unconfined Compressive Strength (psi):	<b>189.1</b>
Strain (%):	<b>2.0</b>



**NOTES:** Very weak, red-brown with brown, CLAYSTONE. Failed along slickensides.

## Unconfined Compressive Strength Test

(Project: WAS-821-3.79, Boring Location: B-012-2-12, R-6, Depth: 30.8 - 31.2 ft)

Tested Date: 5/29/2012

### Specimen Properties

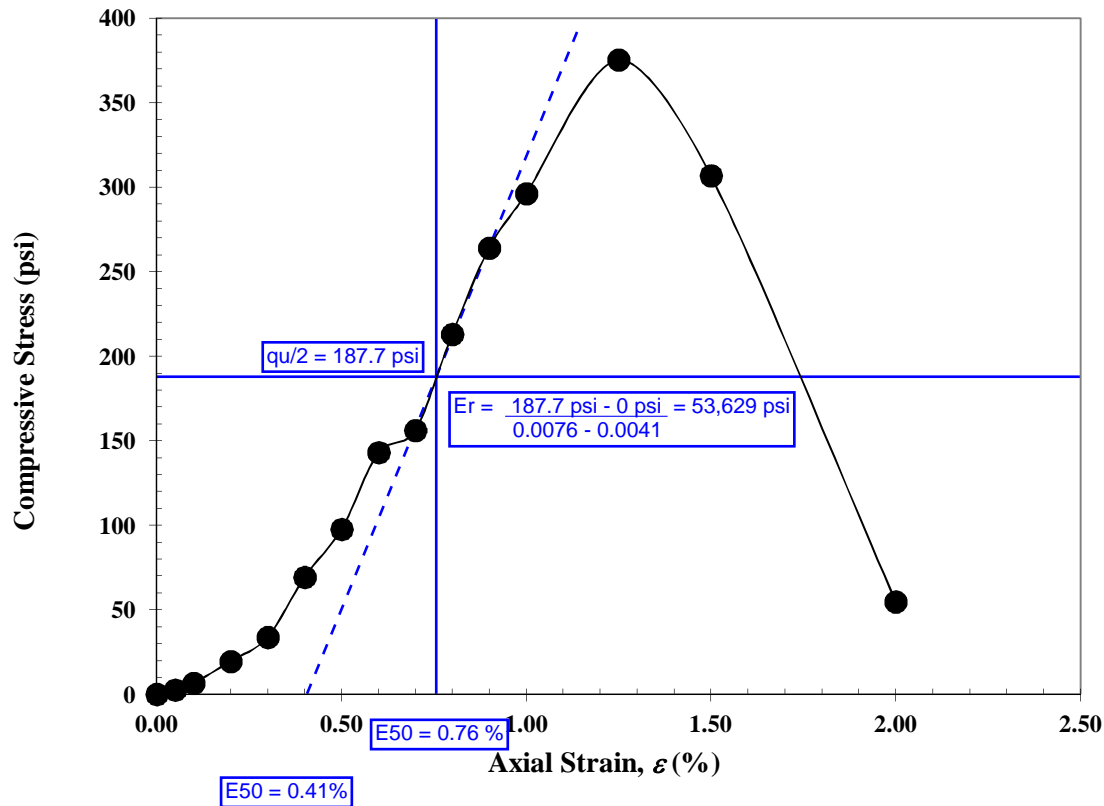
Average Dia., $D_{avg}$ (in):	1.98
Average Height, $H_{avg}$ (in):	4.00
Area, $A$ (in <sup>2</sup> ):	3.08
Volume, $V$ (in <sup>3</sup> ):	12.31
Wet Mass of Specimen (lb):	1.0
Moisture Content (%):	9.9
Dry Mass of Specimen (lb):	0.9
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	145.5
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	132.4

### Final Specimen Figure



### Results

Unconfined Compressive Strength (psi):	<b>375.4</b>
Strain (%):	<b>1.3</b>



### NOTES:

Very weak, red-brown with brown and gray, CLAYSTONE.

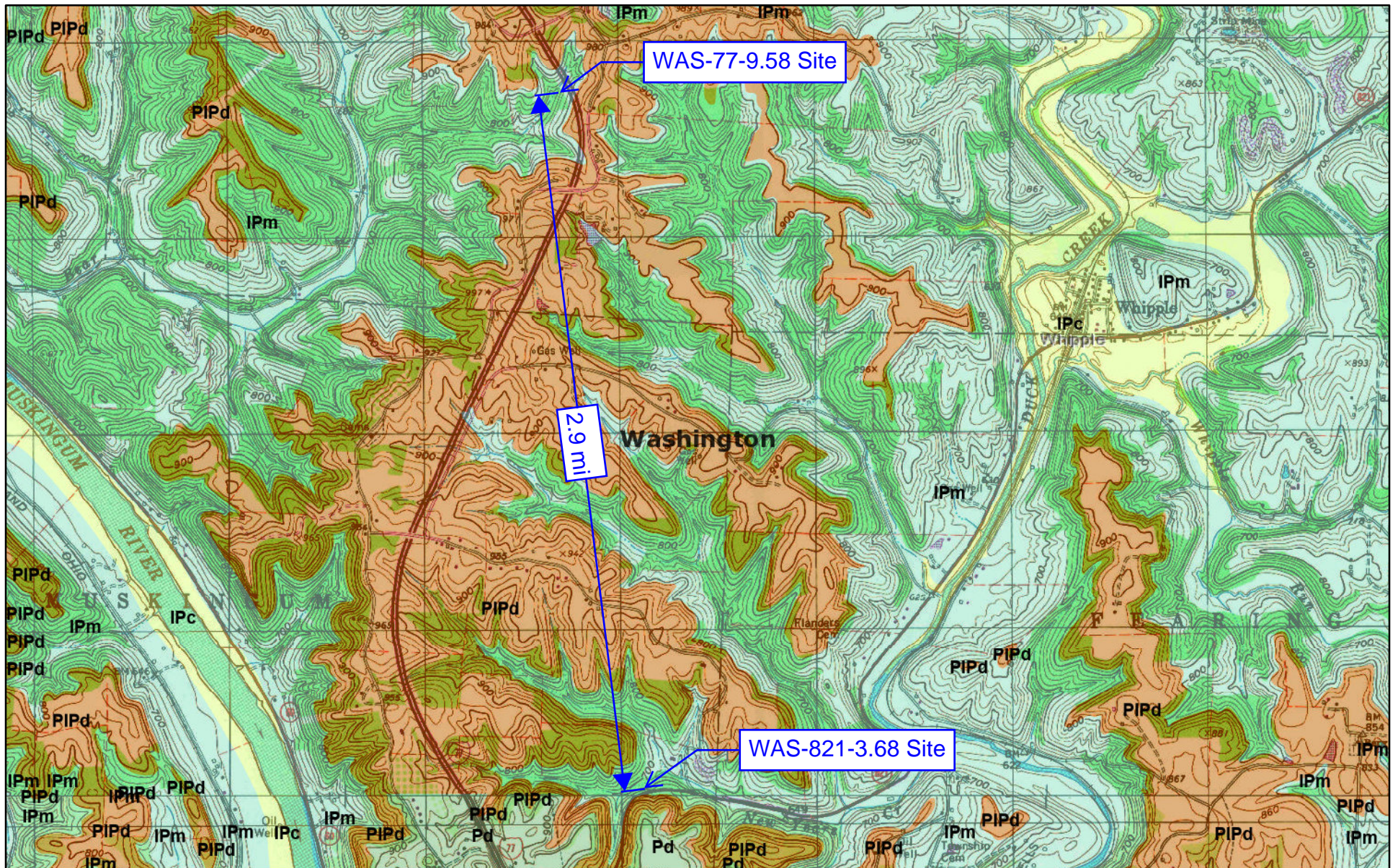


## Historical Records


WAS-821-3.68 (2012)



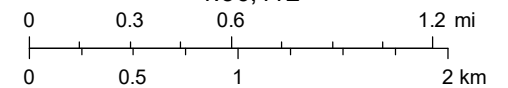
# WAS-77-9.58 Bedrock Geology



August 17, 2023

 Counties

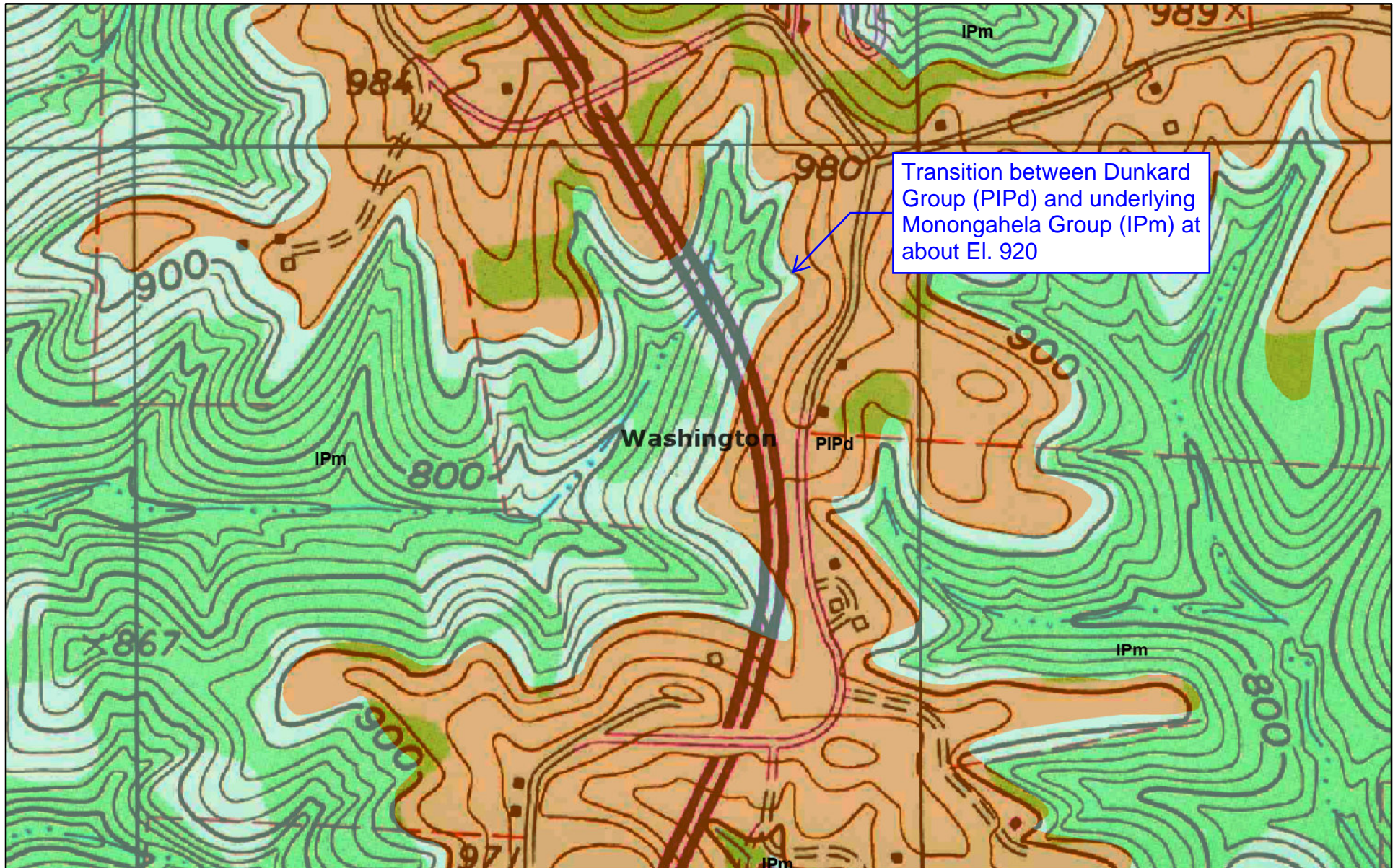
1:36,112




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# WAS-77-9.58 Bedrock Geology



August 17, 2023

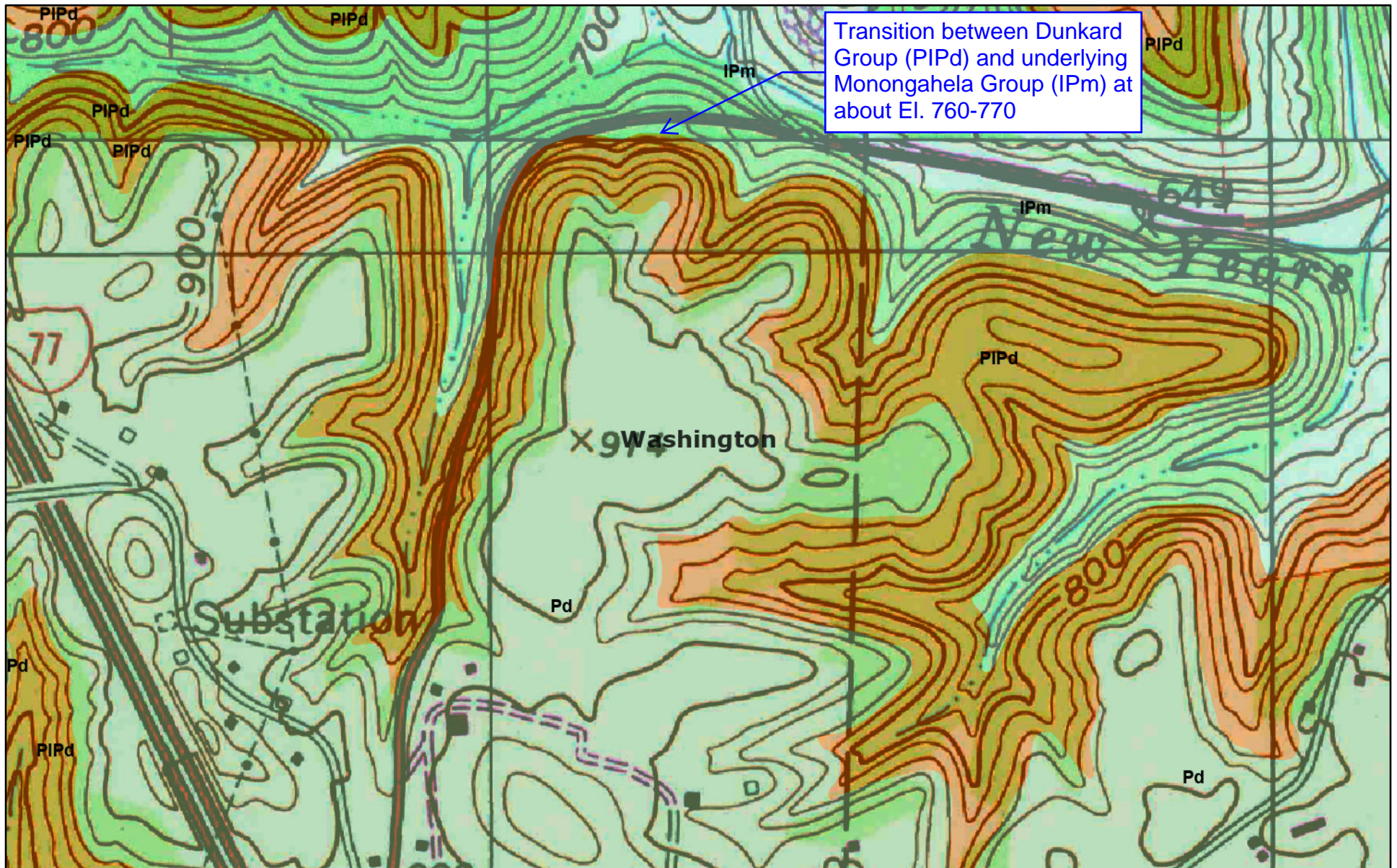
 Counties

1:9,028  
0 0.075 0.15 0.3 mi  
0 0.1 0.2 0.4 km


Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

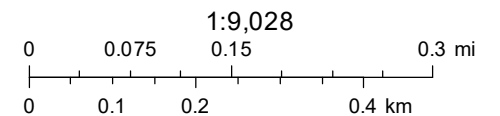


# WAS-821-3.68 Bedrock Geology



August 17, 2023

 Counties



Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

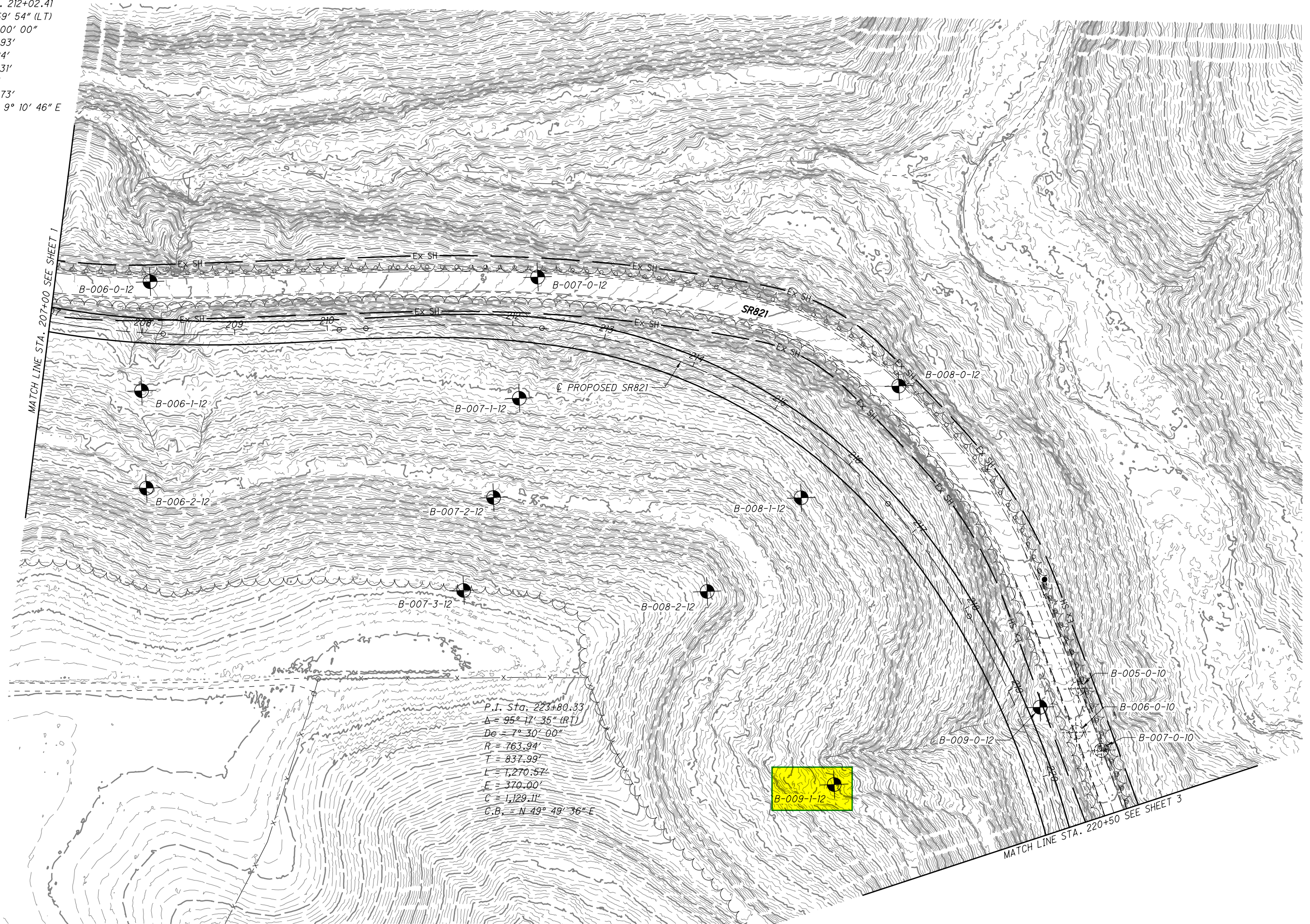






c:\pwworking\pitt\d0645149\91295\F011.dgn 1/23/2014 2:47:31 PM CWahibri

P.I. Sta. 212+02.41  
 $\Delta = 13^\circ 59' 54''$  (LT)  
 $Dc = 6^\circ 00' 00''$   
 $R = 954.93'$   
 $T = 117.24'$   
 $L = 233.31'$   
 $E = 7.17'$   
 $C = 232.73'$   
 $C.B. = N 9^\circ 10' 46'' E$



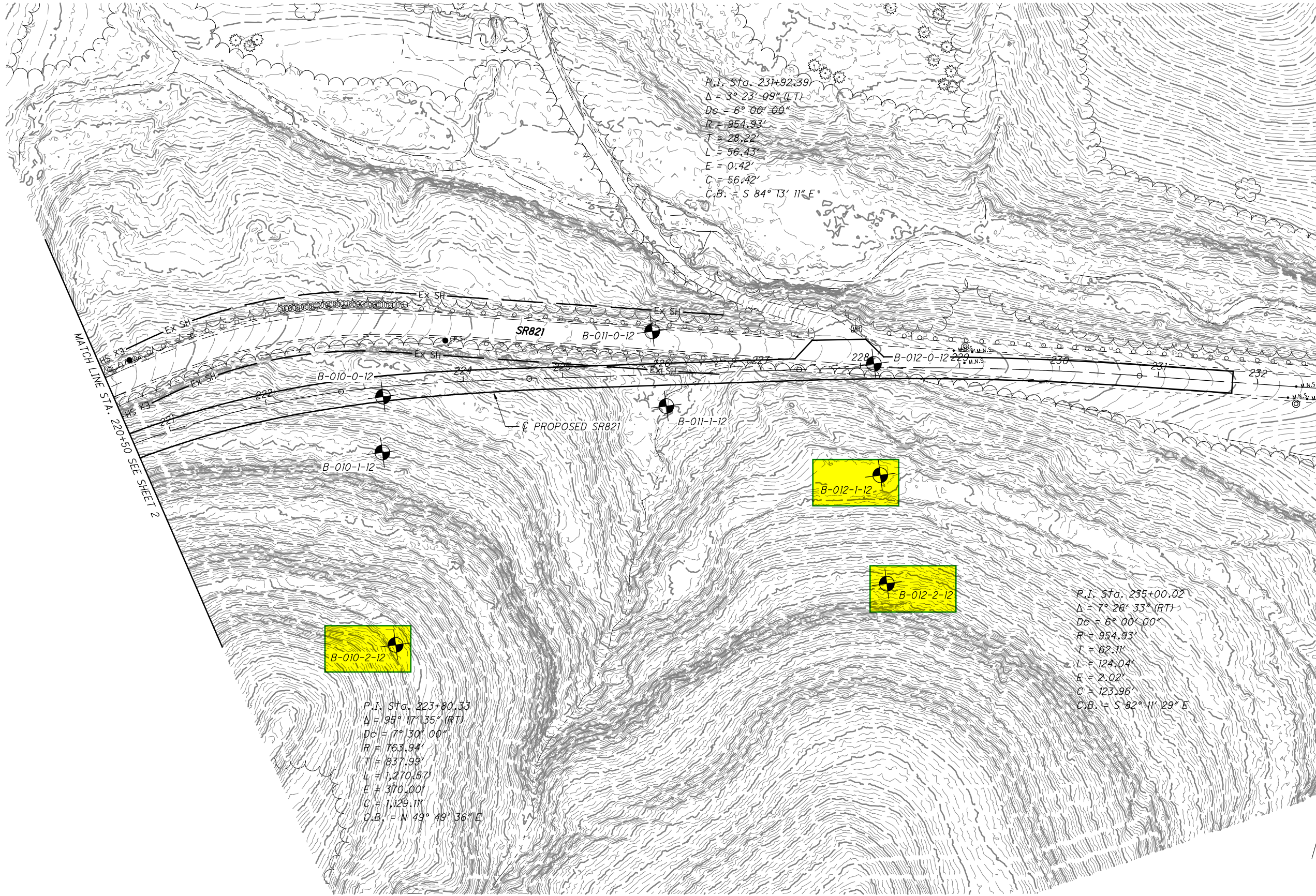
0 50 100  
HORIZONTAL  
SCALE IN FEET

CALCULATED  
CLW  
CHECKED  
DMV

**BORING LOCATION PLAN  
EXHIBIT NO. 7B**

**WAS-821-3.68**







[illegible]

[illegible]



## Unconfined Compressive Strength Test

(Project: WAS-821-3.79, Boring Location: B-009-1-12, R-4, Depth: 33.0 - 33.4 ft)

Tested Date: 5/29/2012

### Specimen Properties

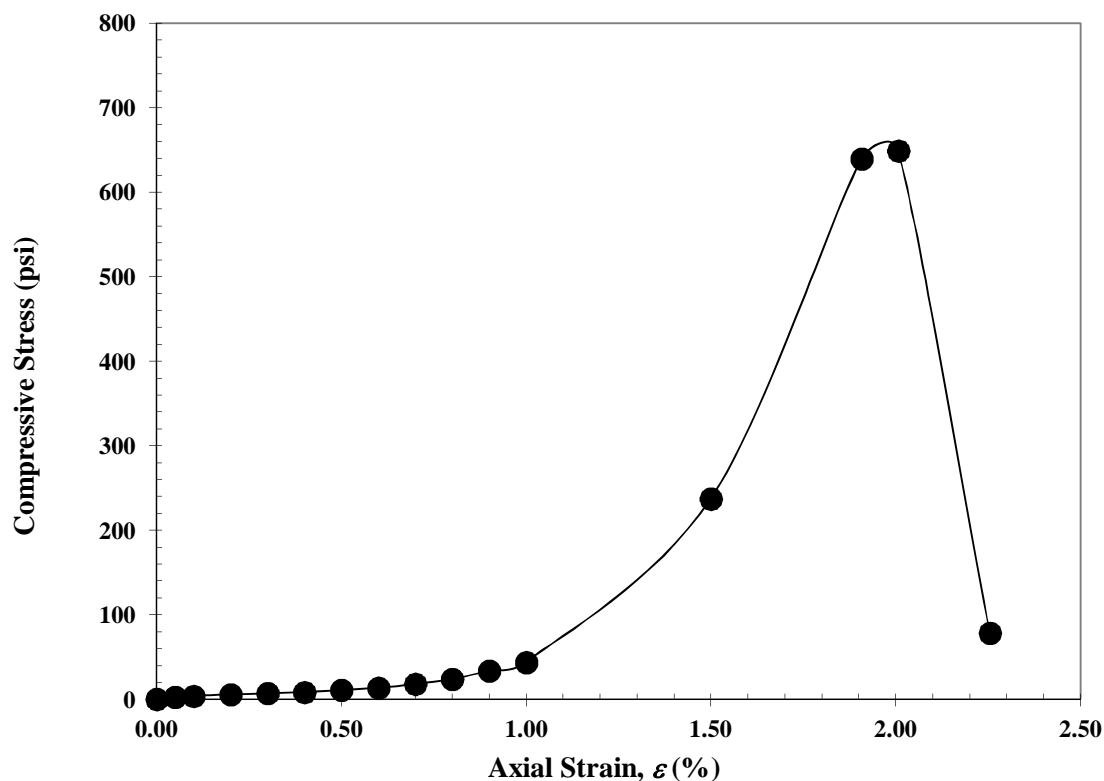
Average Dia., $D_{avg}$ (in):	1.97
Average Height, $H_{avg}$ (in):	4.03
Area, $A$ (in <sup>2</sup> ):	3.04
Volume, $V$ (in <sup>3</sup> ):	12.27
Wet Mass of Specimen (lb):	1.1
Moisture Content (%):	6.0
Dry Mass of Specimen (lb):	1.0
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	154.0
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	145.3

### Final Specimen Figure



### Results

Unconfined Compressive Strength (psi):	<b>648.9</b>
Strain (%):	<b>2.0</b>



**NOTES:** Very weak, red-brown with gray, CLAYSTONE.



PROJECT: WAS-821-3.79		DRILLING FIRM / OPERATOR: C. S. / T. S.		DRILL RIG: CME 55 TRACK		STATION / OFFSET: 223+04, 260.0 RT				EXPLORATION ID B-010-2-12												
TYPE: ROADWAY		SAMPLING FIRM / LOGGER: HDR / D. MATCHISON		HAMMER: AUTOMATIC HAMMER		ALIGNMENT: SR 821, CL																
PID: 91295 BR ID:		DRILLING METHOD: 3.25" HSA		CALIBRATION DATE: 4/24/12		ELEVATION: 832.4 (MSL) EOB: 85.75 ft.				PAGE 1 OF 4												
START: 4/5/12 END: 4/6/12		SAMPLING METHOD: SPT / NQ		ENERGY RATIO (%): 74.9		COORD: 547924.026 N, 2267950.086 E																
MATERIAL DESCRIPTION AND NOTES		ELEV.	DEPTHS	SPT/RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED			
									GR	CS	FS	SI	CL	LL	PL	PI						
STIFF, REDDISH BROWN, TRACE BROWN, <b>CLAY</b> , SOME SILT, TRACE SAND, DAMP		832.4		1	3	12	44	SS-1	2.00	0	4	5	32	59	41	19	22	16	A-7-6 (13)			
				2																	4	6
				3																		
HARD, REDDISH BROWN, <b>SILTY CLAY</b> , TRACE SAND, DAMP		827.9		4	10	37	44	SS-2	-	0	1	3	42	54	36	18	18	10	A-6b (11)			
		5	14	16																		
HARD, REDDISH BROWN AND BROWN, <b>SILT AND CLAY</b> , SOME SAND, TRACE CLAYSTONE FRAGMENTS, (RESIDIUM)		826.4		6	15	49	100	SS-3	-	1	14	15	32	38	30	16	14	5	A-6a (9)			
				7	23	16																
Weathered Sandstone Fragments Encountered		818.9		8																		
				9	30	84	67	SS-4	-	-	-	-	-	-	-	-	9	A-6a (V)				
				10	32	35																
				11	38																	
				12	50/4"	-	120	SS-5	-	-	-	-	-	-	-	-	8	A-6a (V)				
<b>SILTSTONE</b> , REDDISH BROWN, COMPLETELY WEATHERED, VERY WEAK.		816.4		13																		
				14	21	69	100	SS-6	-	-	-	-	-	-	-	-	13	Rock (V)				
<b>CLAYSTONE</b> , REDDISH BROWN WITH BROWN, HIGHLY WEATHERED, VERY WEAK.		808.4	TR	15	25																	
				16	30																	
				17	50/3"	-	33	SS-7	-	-	-	-	-	-	-	-	-	-	Rock (V)			
				18																		
				19	50/3"	-	33	SS-8	-	-	-	-	-	-	-	-	-	-	Rock (V)			
				20																		
				21	50/2"	-	100	SS-9	-	-	-	-	-	-	-	-	-	-	Rock (V)			
				22																		
				23																		
				24	50/3"	-	-	SS-10	-	-	-	-	-	-	-	-	-	-	-	Rock (V)		

[illegible]

[illegible]

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/16/14 10:52 - C:\USERS\AENTINGE\DESKTOP\DOUG\ DARREN\WAS\1-16-14\WAS-821-3-79.GPJ





## Unconfined Compressive Strength Test

(Project: WAS-821-3.79, Boring Location: B-010-2-12, R-13, Depth: 84.3 - 84.7 ft)

Tested Date: 5/29/2012

### Specimen Properties

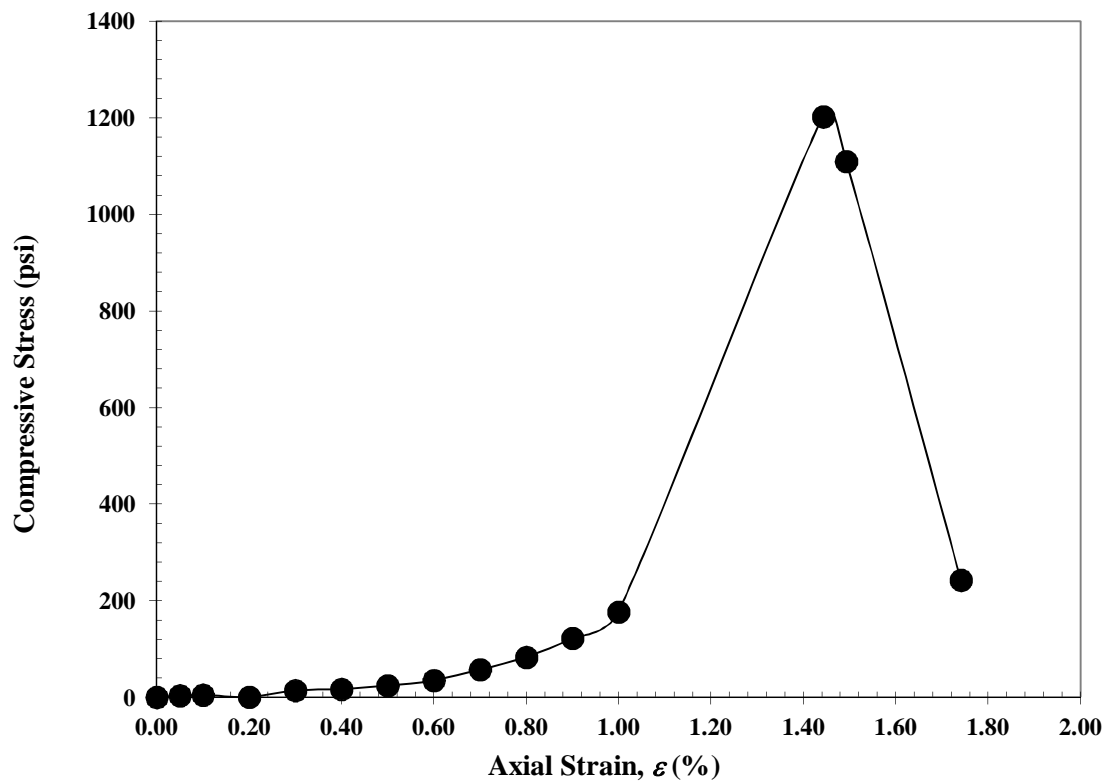
Average Dia., $D_{avg}$ (in):	1.98
Average Height, $H_{avg}$ (in):	4.02
Area, $A$ (in <sup>2</sup> ):	3.08
Volume, $V$ (in <sup>3</sup> ):	12.40
Wet Mass of Specimen (lb):	1.2
Moisture Content (%):	4.2
Dry Mass of Specimen (lb):	1.1
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	165.1
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	158.4

### Final Specimen Figure



### Results

Unconfined Compressive Strength (psi): 1202.0  
Strain (%): 1.44



**NOTES:** Weak, red -brown, CLAYSTONE. Failed along slickensides.





### Unconfined Compressive Strength Test

(Project: WAS-821-3.79, Boring Location: B-012-1-12, R-2, Depth: 18.5 - 18.9 ft)

Tested Date: 5/29/2012

#### **Specimen Properties**

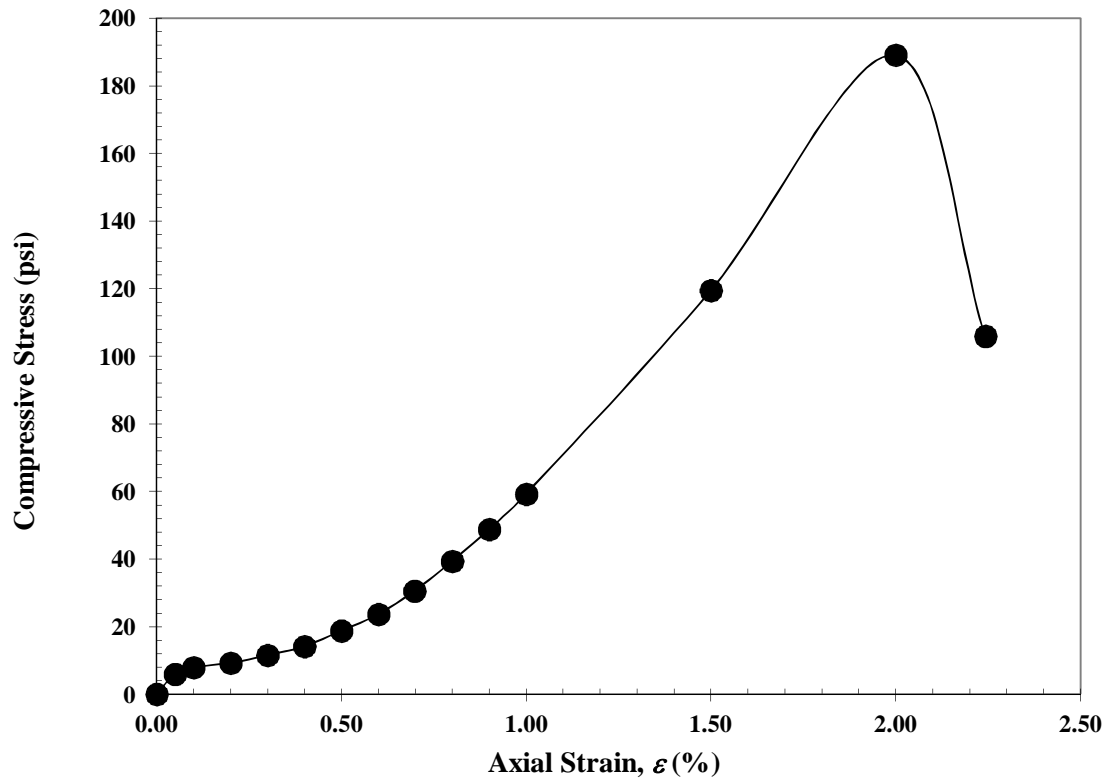
Average Dia., $D_{avg}$ (in):	1.96
Average Height, $H_{avg}$ (in):	4.01
Area, $A$ (in <sup>2</sup> ):	3.03
Volume, $V$ (in <sup>3</sup> ):	12.14
Wet Mass of Specimen (lb):	1.0
Moisture Content (%):	7.8
Dry Mass of Specimen (lb):	0.9
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	145.6
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	135.1

#### **Final Specimen Figure**



#### **Results**

Unconfined Compressive Strength (psi):	<b>189.1</b>
Strain (%):	<b>2.0</b>



**NOTES:** Very weak, red-brown with brown, CLAYSTONE. Failed along slickensides.





[illegible]

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/16/14 10:53 - C:\USERS\AENTINGE\DESKTOP\DOUG.DARREN\WAS11-16-14\WAS-821-3.79.GPJ

PID: 91295	BR ID:	PROJECT: WAS-821-3.79	STATION / OFFSET: 228+25, 217.0 RT	START: 4/4/12	END: 4/5/12	PG 3 OF 3	B-012-2-12												
MATERIAL DESCRIPTION AND NOTES		ELEV.	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
		716.2							GR	CS	FS	SI	CL	LL	PL	PI			
CLAYSTONE, REDDISH BROWN WITH GRAY AND BROWN, MODERATELY WEATHERED, SLIGHTLY TO MODERATELY STRONG, INDISTINCT, FRACTURED TO MODERATELY FRACTURED; RQD 84%.		716.0	52	75		100	NQ-14										CORE		
		53																	
		54																	
		55	95	100	NQ-15								CORE						
		56																	
711.0	57	EOB																	
NOTES: NONE																			
ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH 12 LB. BENTONITE POWDER (QUICK GEL); 94 LB. CEMENT; 55 GAL. WATER																			

## Unconfined Compressive Strength Test

(Project: WAS-821-3.79, Boring Location: B-012-2-12, R-6, Depth: 30.8 - 31.2 ft)

Tested Date: 5/29/2012

### Specimen Properties

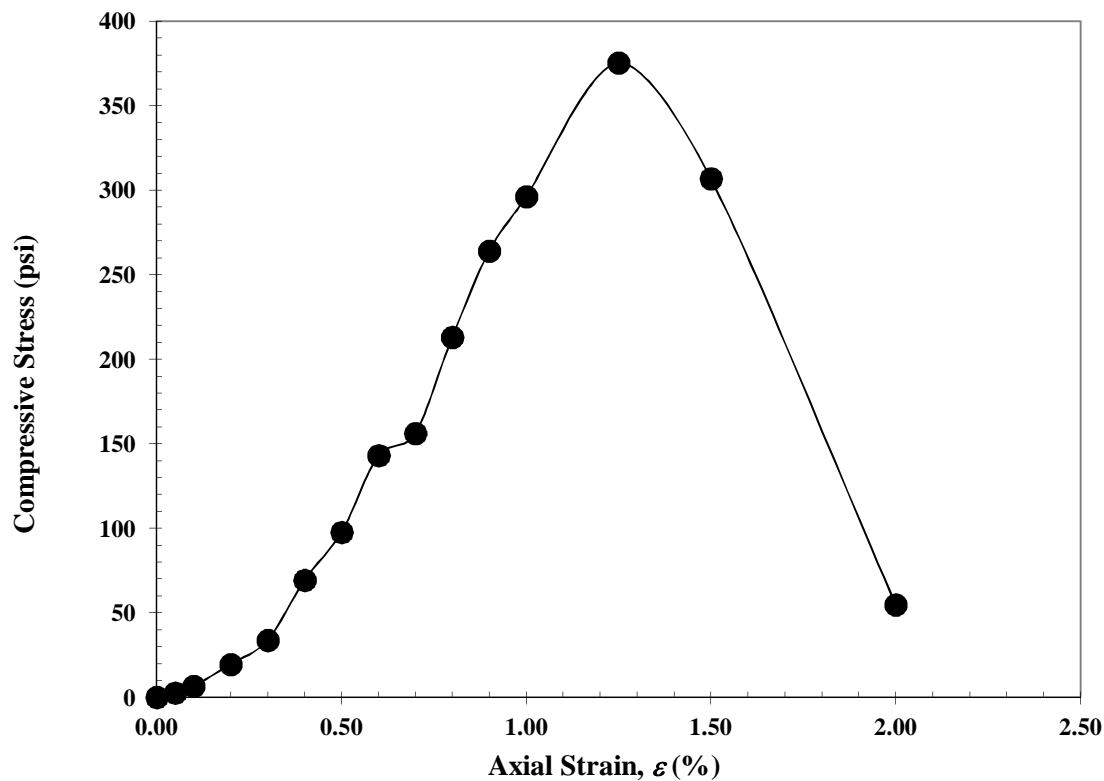
Average Dia., $D_{avg}$ (in):	1.98
Average Height, $H_{avg}$ (in):	4.00
Area, $A$ (in <sup>2</sup> ):	3.08
Volume, $V$ (in <sup>3</sup> ):	12.31
Wet Mass of Specimen (lb):	1.0
Moisture Content (%):	9.9
Dry Mass of Specimen (lb):	0.9
Wet Unit Weight, $\gamma$ (lb/ft <sup>3</sup> ):	145.5
Dry Unit Weight, $\gamma_d$ (lb/ft <sup>3</sup> ):	132.4

### Final Specimen Figure



### Results

Unconfined Compressive Strength (psi):	<b>375.4</b>
Strain (%):	<b>1.3</b>



**NOTES:** Very weak, red-brown with brown and gray, CLAYSTONE.



[illegible]



PROJECT: WAS-821-03.60	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG/MOBILE B-53 R TRAILER	STATION / OFFSET: 201+68, 10.0 LT	EXPLORATION ID B-002-0-10
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / WILLIS	HAMMER: SAFETY HAMMER	ALIGNMENT: CL SR 821	
PID: 85205 BR ID: N/A	DRILLING METHOD: 3.25" HSA / NX	CALIBRATION DATE: N/A	ELEVATION: 793.0 (MSL) EOB: 37.5 ft.	PAGE 1 OF 2
START: 6/23/10 END: 6/24/10	SAMPLING METHOD: SPT/NX	ENERGY RATIO (%): 60	LAT / LONG: Not Recorded	

MATERIAL DESCRIPTION AND NOTES	ELEV. 793.0	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	HOLE SEALED
								GR	CS	FS	SI	CL	LL	PL	PI			
ASPHALT (22")																		
	791.2	1																
MEDIUM DENSE, BLACK, GRAVEL WITH SAND, "AND" ASPHALT FRAGMENTS, DAMP	790.2	2	29	11	14	100	SS-1	-	-	-	-	-	-	-	-	4	A-1-b (V)	
VERY STIFF, REDDISH BROWN, SILT AND CLAY, SOME STONE FRAGMENTS, LITTLE SAND, DAMP TO MOIST		3	2	3	6	89	SS-2	2.00	-	-	-	-	-	-	-	19	A-6a (V)	
		4	3	3	6	78	SS-3	2.75	25	5	8	34	28	31	17	14	17	A-6a (7)
		5	3	3	6	78	SS-3	3.00	-	-	-	-	-	-	-	-	18	A-6a (V)
@6.0'; $\gamma$ = 138.37 PCF; QU = 28.41 PSI		6																
@ 6.0' - 8.0'; LITTLE STONE FRAGMENTS		7			100		ST-4	-	14	5	14	33	34	34	21	13	21	A-6a (8)
@8.0'; REDDISH BROWN		8	2	3	6	100	SS-5	2.50	23	5	6	29	37	32	22	10	21	A-4a (6)
		9	2	3	9	100	SS-6	3.00	-	-	-	-	-	-	-	-	21	A-6a (V)
	782.0	10	2	4	5													
CLAYSTONE, VARIEGATED DARK REDDISH BROWN AND OLIVE BROWN, HIGHLY WEATHERED, VERY WEAK, THICK BEDDED, ARENACEOUS.		11	5	16	36	100	SS-7	4.5+	-	-	-	-	-	-	-	-	13	Rock (V)
		12	17	20	53	100	SS-8	-	-	-	-	-	-	-	-	-	12	Rock (V)
@14.0'; DARK REDDISH BROWN		13	17	25	53	100	SS-8	-	-	-	-	-	-	-	-	-	12	Rock (V)
		14	30	31	59	100	SS-9	-	-	-	-	-	-	-	-	-	13	Rock (V)
		15	14	17	43	100	SS-10	-	-	-	-	-	-	-	-	-	12	Rock (V)
		16	19	29	69	100	SS-11	-	-	-	-	-	-	-	-	-	10	Rock (V)
		17	18	34	84	94	SS-12	-	-	-	-	-	-	-	-	-	14	Rock (V)
		18	14	12	30	94	SS-13	-	-	-	-	-	-	-	-	-	10	Rock (V)
@21.0' - 22.0'; WET		19	6	7	19	100	SS-14	-	-	-	-	-	-	-	-	-	13	Rock (V)
@22.0'; DARK REDDISH BROWN AND LIGHT OLIVE GRAY	770.0	20	15	25	61	100	SS-15	-	-	-	-	-	-	-	-	-	10	Rock (V)
SHALE, LIGHT OLIVE GRAY, HIGHLY WEATHERED, VERY WEAK, LAMINATED TO VERY THIN BEDDED.		21	24	30	60	94	SS-16	-	-	-	-	-	-	-	-	-	10	Rock (V)
	766.5	22	17	45	-	92	SS-17	-	-	-	-	-	-	-	-	-	11	Rock (V)
CLAYSTONE, DARK REDDISH BROWN TO DARK GRAY, HIGHLY WEATHERED, VERY WEAK.	765.5	23																
SANDSTONE, DARK GRAY, SLIGHTLY WEATHERED, MODERATELY STRONG, VERY FINE TO FINE GRAINED, THIN BEDDED, SILICEOUS, JOINT, SLIGHTLY FRACTURED, NARROW, SLIGHTLY ROUGH; ROD 88%.	763.4	24																
		25	74		95		NX-1											CORE
		26																
		27																
		28																
		29																

[illegible]

—EOB

NOTES: WATER ENCOUNTERED @ 21.0 FEET; ELEVATIONS ESTIMATED FROM TOPO MAPS.



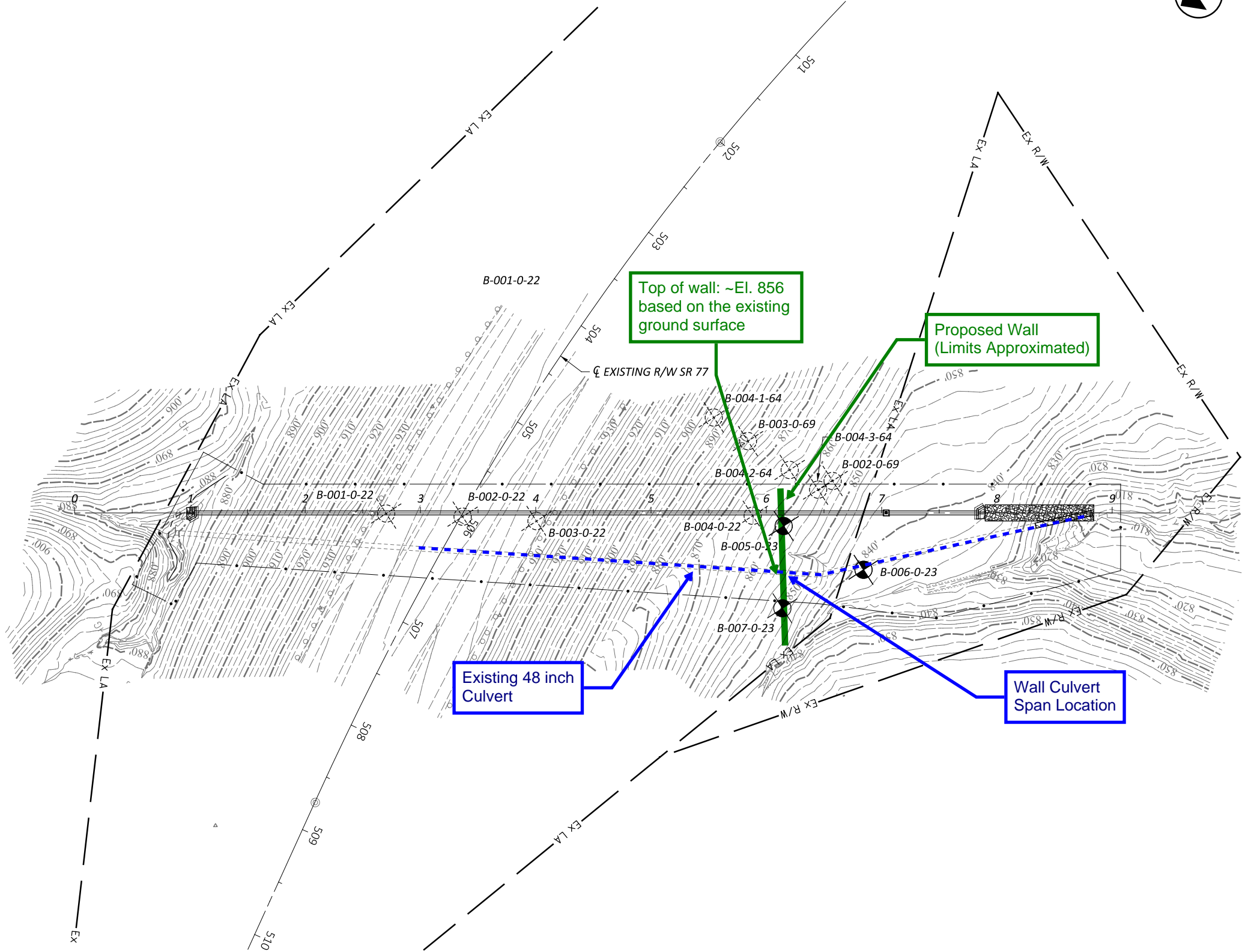
[illegible]

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT GDT - 12/8/10 17:58 - X:\GINT\PROJECTS\100350.GPJ

PID: 85205	BR ID: N/A	PROJECT: WAS-821-03.60	STATION / OFFSET: 202+30, 10.0 LT		START: 6/28/10	END: 6/29/10	PG 2 OF 2		B-003-0-10													
MATERIAL DESCRIPTION AND NOTES			ELEV.	DEPTHS		SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG				ODOT CLASS (GI)	INCL.	
			761.0										GR	CS	FS	SI	CL	LL	PL	PI	WC	
RQD 71%, REC 90%. @28.0' - 28.3'; Qu = 8,309 psi @28.4' - 28.7'; Qu = 9,376 psi <b>SANDSTONE</b> , GREENISH GRAY WITH DARK SEAMS, SLIGHTLY WEATHERED, STRONG, VERY FINE TO FINE GRAINED, MEDIUM BEDDED, MICACEOUS; RQD 98%, REC 98%. (continued) @31.0'; GREENISH GRAY																						
			759.0	EOB		92		92	NX-3													CORE
NOTES: HOLE DRY BEFORE CORING; ELEVATIONS ESTIMATED FROM TOPO MAPS.																						
ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 25 LB. BENTONITE POWDER; 94 LB. CEMENT; 30 GAL. WATER																						



## Wall Calculations



BORING LOCATION PLAN

DESIGN AGENCY



DESIGNER

AKB

REVIEWER

DMV 08/23/23

PROJECT ID

115420

SHEET

1

TOTAL

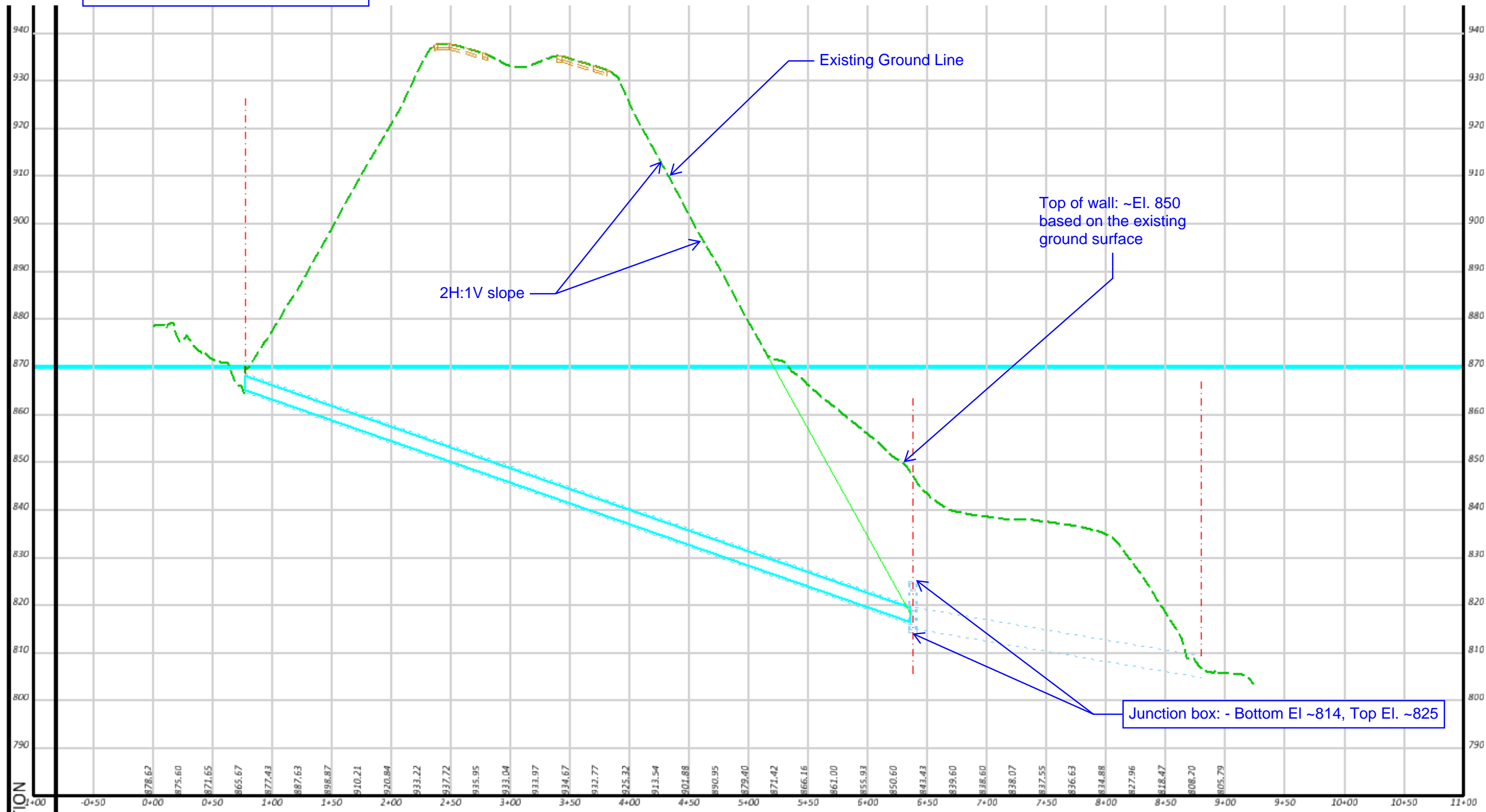
0

HORIZONTAL  
SCALE IN FEET





From drainage drawing:  
115420\_DP001





## **LPILE Analyses (Tangent Drilled Shaft Wall)**

## Geometry

	Elevation (ft)		Horiz. Distance from C/L (ft)		
Top of Backfill =	865.0	at Bottom of Embankment	Start of Wall Backfill =	50.0	at Bottom of Embankment
Top of Wall =	856.0	at C/L of Wall	Wall =	0.0	at C/L of Wall
Existing Ground Surface =	857.0	at C/L of Wall			
Bottom of Wall =	814.0	at C/L of Wall	Backfill Slope Angle =	5.6	H:1V
Groundwater =	848.5	at C/L of Wall		10.2	degrees

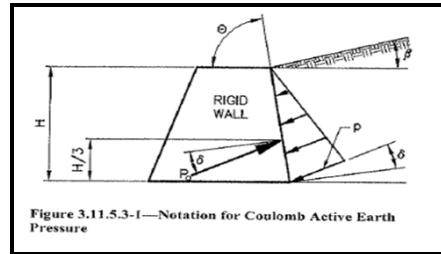
## Wall Loading Profile B-005-0-23)

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	856.0	5.8	115	23	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	1.7	65	21	115
Layer 1 Soft to Medium Stiff Cohesive	848.5	3.3	65	21	52.6
Layer 2 Medium Stiff to Stiff Cohesive	845.2	10.0	115	23	77.6
Layer 3 Stiff to Very Stiff Cohesive	835.2	20.0	175	25	72.6
Layer 4 Hard Cohesive	815.2	1.2	250	28	82.6
Bottom of Wall/Maintenance Bench	814.0				
Weighted Value		42.0	140	24	85

Effective unit weights used below the water table. Hydrostatic earth pressures are added separately.

## Earth Pressure Coefficients

	Deg	
Shear Resistance, $\Phi$ =	26	
Wall Friction, $\delta^A$ =	0.0	
Wall Slope, $\theta$ =	90	
Backfill Slope, $\beta$ =	10.20	
Revised Backfill Slope, $\beta$ =	10.20	
Backfill Condition	INFINITE	
Horz. Backslope Dist.	50.0	feet (C/L of Wall - Edge of Shoulder)
Wall Height (H)	42.0	feet (Top of Wall - Maintenance Bench)
Slope Height (h)	9.0	feet (Top of Backfill - Top of Wall)
$l$ =	6.12	degrees



## Active Earth Coefficient

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

$K_a = 0.447$

## At-Rest Earth Coefficient

$$K_o = (1 - \sin(\Phi)) \cdot (1 + \sin(\beta))$$

$K_o = 0.664$

## Notes:

- Wall friction neglected
- Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).
- The wall backfill will consist of existing fill and cohesive overburden. Using the soil layer thicknesses and respective soil parameters, a weighted average was determined and assumed for the entire backfill ( $c' = 140$  psf and  $\phi' = 24^\circ$ ). The parameters were converted to equivalent soil strength parameters  $c' = 0$  psf and  $\phi' = 26^\circ$  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).

## LPile Soil Lateral Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)	$\epsilon_{50}$	k
Hard Cohesive	814.0	42.0	4000	0	82.6	0.005	N/A
Bedrock	810.2	45.8	N/A	N/A	N/A	N/A	N/A

## LPile Bedrock Lateral Design Profile

	Top Elev	Depth (ft)	$q_u$ (psi)	$E_m$ (psi)	Unit Wt (pcf)	RQD (%)	k <sub>rm</sub>
Claystone	810.2	45.8	330	37400	150	64	0.0005
Claystone	807.3	48.7	1150	179800	160	100	0.0005
Sandstone/Claystone	800.8	55.2	1150	179800	160	91	0.0005
Claystone	798.1	57.9	330	37400	150	17	0.0005
Claystone	795.7	60.3	330	37400	150	86	0.0005

Depths referenced below the top of wall, starting at the bottom of the wall.  $\epsilon_{50}$  and k values per LPile Technical Manual.

## Wall Loading Computations

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

1) Soil Unit Weight = **85** pcf Weighted Average Along Cantilevered Wall Height

2) Determine Coefficient of Earth Pressure (K)

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

Ka = **0.447**

3) Determine Equivalent Fluid Weight (G<sub>H</sub>)

G<sub>H</sub> = (γ<sub>m</sub>) \* (K<sub>a</sub>)

G<sub>H</sub> = **38** For application to CONVENTIONAL Earth Pressure Model

4) Artificially Lowered Ground Surface (ODOT GDM Section 903.3.2, pg. 9-14) for FS<sub>dh</sub> < 1.30

Consider Lowered G. S.? **NO**

Lowered Ground Surface (ft) = **0.0** = dt (tan(β<sub>dh</sub>))

β<sub>dh</sub> = = steepness of the slope downhill of the drilled shaft

FS<sub>dh</sub> = = Factor of Safety down slope of the proposed wall

d<sub>t</sub> = **N/A** = 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<sub>m</sub> = 0.64\*(S/D)<sup>0.34</sup> (Ref: Reese, Isenhower, & Wang - 2006 for 1 ≤ S/D < 3.75, where 0.5 ≤ P<sub>m</sub> < 1.0)

D = **4.5** feet (shaft diameter or pile flange width)

Assumed Shaft Spacing = **3.25** feet (center-to-center pile spacing)

P<sub>m</sub> = **0.50** (Ref: PYWall user's manual indicates "For a continuous diaphragm wall or drilled shaft wall, the p-multiplier of 0.5 has been widely used by engineers.")

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<sub>UAS</sub> = = Factor of Safety from UASlope including shafts

p-multiplier = **0.50** = (P<sub>m</sub> - P<sub>m</sub>/FS<sub>UAS</sub>) From top of wall to bottom of shear plane

6) Determine Lateral Thrust

Conventional Earth Pressure Theory

Exposed Wall Height (H) = **42** feet

Wall Height (H) + GS<sub>AL</sub> = **42.0**

P = 1/2 \* G<sub>H</sub> \* H<sup>2</sup>

P = **33521** lbs/foot

P<sub>SH</sub> = P \* (Shaft Spacing) (earth loading)

P<sub>SH</sub> = **108942** lbs/shaft

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

w = 2 \* P<sub>SH</sub>/H

w = **5188** lbs/foot per shaft (Earth - Service Limit)

w = **432** lbs/inch per shaft (Earth - Service Limit)

γ<sub>E</sub> = **1.5** Earth Load Factor

w = (2 \* P<sub>SH</sub>/H) \* γ<sub>E</sub>

w = **648** lbs/inch per shaft (Earth - Strength Limit)

8) Determine live-load traffic surcharge force (P<sub>s</sub>)

Surcharge Pressure (q<sub>s</sub>) = **NA** psf

Include traffic surcharge? **NO**

P<sub>s</sub> = K<sub>a</sub> \* q<sub>s</sub> \* H

P<sub>s</sub> = **NA** lbs/foot

(surcharge resolved to distributed load)

P<sub>s</sub> = **NA** lbs/shaft

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

w = P<sub>s</sub>/H

w = **0** lbs/foot per shaft (surcharge - unfactored)

w = **0** lbs/inch per shaft (surcharge - unfactored)

γ<sub>S</sub> = **1.75** Surcharge Load Factor - Strength I

w = (P<sub>s</sub>/H) \* γ<sub>S</sub>

w = **0** lbs/inch per shaft (Surcharge - Strength I)

10) Determine hydrostatic loading as distributed triangular load (for LPILE)

Groundwater Height (H<sub>w</sub>) = **34.5** feet

Include hydrostatic loading? **YES**

Above bottom of wall

P<sub>w</sub> = 1/2 \* γ<sub>w</sub> \* H<sub>w</sub><sup>2</sup>

P<sub>w</sub> = **37136** lbs/foot

P<sub>wSH</sub> = P<sub>w</sub> \* (Shaft Spacing)

P<sub>wSH</sub> = **120691** lbs/shaft

w = 2 \* P<sub>wSH</sub>/H

w = **6997** lbs/foot per shaft (Earth - Service Limit)

w = **583** lbs/inch per shaft (Earth - Service Limit)

γ<sub>E</sub> = **1.5** Earth Load Factor

w = (2 \* P<sub>wSH</sub>/H) \* γ<sub>E</sub>

w = **875** lbs/inch per shaft (Earth - Strength Limit)

Distributed Lateral Loads for LPILE

**CONVENTIONAL**

Depth (ft.)	Service (lb/in)	Strength-I (lb/in)
0	0	0
42.0	1015	1523

As the S/D value is less than 1, the equation is not valid and a P-multiplier of 0.5 was used based on review of wall design software reference manuals.



## Steel Beam and Cross-Section Properties

Assumed Pile Shape **W 44x408**

### Pile Availability

AISC Member Producers	<b>1</b>
Non-Member Producers	<b>0</b>

### Shaft Geometry

Shaft Diameter	<b>54</b>	in
Longest Beam Dimension	<b>47.619368</b>	in
Clear Distance	<b>3.1903162</b>	in

### Steel Beam Geometry

Beam Depth (D)	<b>44.8</b>	in
Web Thickness (t <sub>w</sub> )	<b>1.22</b>	in
Flange Width (B <sub>f</sub> )	<b>16.1</b>	in
Flange Thickness (t <sub>f</sub> )	<b>2.165</b>	in
Area of Steel (A <sub>s</sub> )	<b>120.5</b>	in <sup>2</sup>

### Steel Properties

Yield Strength of Steel	<b>50</b>	ksi
Moment of Inertia (I <sub>xx</sub> ) of Steel	<b>38500</b>	in <sup>4</sup>
Modulus of Elasticity of Steel (E)	<b>29000</b>	ksi
Modulus of Elasticity of Steel (E)	<b>29000000</b>	psi
EI (Steel Only)	<b>1.117E+12</b>	lb*in <sup>2</sup>
Section Modulus (S <sub>x</sub> )	<b>1720</b>	in <sup>3</sup>
Section Modulus (Z <sub>x</sub> )	<b>1990</b>	in <sup>3</sup>
Shear-Buckling Coefficient (k)	<b>5</b>	
Ratio of Shear-Buckling Resistance (C)	<b>1</b>	
D/t <sub>w</sub>	<b>36.721311</b>	
1.12VEk/F <sub>yw</sub>	<b>60.313846</b>	
1.40VEk/F <sub>yw</sub>	<b>75.392307</b>	

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

$$V_u \leq \phi V_{cr}$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$
$$V_{cr} = \text{shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)}$$
$$V_n = V_{cr} = C V_p$$
$$V_p = 0.58 F_{yw} D t_w$$
$$V_p = \text{plastic shear force (kips)}$$
$$C = \text{ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6}$$
$$V_p = 0.58 * 50 * 44.8 * 1.22$$
$$V_p = \boxed{1585.0} \text{ kips}$$
$$\phi V_{cr} = \phi * C * V_p$$
$$\phi V_{cr} = 1 * 1 * 1585.0$$
$$\phi V_{cr} = \boxed{1585.0} \text{ kips}$$
$$V_u = \boxed{1402.1} \text{ kips (from LPILE)}$$
$$\boxed{\phantom{000}} \text{ kips (from PYWALL)}$$
$$V_u < \phi V_{cr} \quad \text{OK}$$

### Flexure Capacity Calculation

$$M_u \leq \phi M_n$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$M_u = \text{Moment due to the factored loads}$$
$$M_n = \text{Nominal flexural resistance of a section}$$
$$S_x = \text{Elastic section modulus about the x-axis}$$
$$\phi M_n = \phi * F_y * S_x$$
$$\phi M_n = 1 * 50 * 1720$$
$$\phi M_n = \boxed{86000} \text{ in*kips}$$
$$M_u = \boxed{85504} \text{ in*kips (from LPILE)}$$
$$M_u = \boxed{\phantom{000}} \text{ in*kips (from PYWALL)}$$
$$M_u < \phi M_n \quad \text{OK}$$

### Deflection Criteria

Pile Length Above Rock = <b>45.8</b>	ft	Exposed Wall Height = <b>42</b>	ft
Pile Length Above Rock = <b>549.6</b>	in	Exposed Wall Height = <b>504</b>	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

**5.496**

in

$\delta = \boxed{5.246}$  in (from LPILE)

1.5% Wall Height - PYWALL

**5.496**

in

$\delta = \boxed{5.246}$  in (from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement

**NO**



## Service Limit Analysis (Tangent Drilled Shaft Wall)

=====

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\d3420675\

Name of input data file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Main Wall Service Case.lp11

Name of output report file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Main Wall Service Case.lp11

Name of plot output file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Main Wall Service Case.lp11

Name of runtime message file:

WAS-77-9.58 42' Wall with Hydrostatic Loading Main Wall Service Case.lp11

---

Date and Time of Analysis

---

Date: August 24, 2023

Time: 13:36:54

---

Problem Title

---

Project Name: WAS-77-9.58

Job Number:

Client: ODOT D10

Engineer: HDR

Description: 42' Wall 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 = 63.000 ft
- Depth of ground surface below top of pile = 42.0000 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	54.0000
2	63.000	54.0000

Input Structural Properties for Pile Sections:  
-----

Pile Section No. 1:

Section 1 is an elastic pile	
Cross-sectional Shape	= Circular Pile
Length of section	= 63.000000 ft
Width of top of section	= 54.000000 in
Width of bottom of section	= 54.000000 in
Top Area	= 120.500000 sq. in
Bottom Area	= 120.500000 sq. in
Moment of Inertia at Top	= 38500. in^4
Moment of Inertia at Bottom	= 38500. 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	=	42.000000 ft
Distance from top of pile to bottom of layer	=	45.800000 ft
Effective unit weight at top of layer	=	82.600000 pcf
Effective unit weight at bottom of layer	=	82.600000 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 2 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	45.800000 ft
Distance from top of pile to bottom of layer	=	48.700000 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	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	64.000000 %
RQD of rock at bottom of layer	=	64.000000 %
k <sub>rm</sub> of rock at top of layer	=	0.0005000
k <sub>rm</sub> of rock at bottom of layer	=	0.0005000

Layer 3 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	48.700000 ft
Distance from top of pile to bottom of layer	=	55.200000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	1150. psi
Uniaxial compressive strength at bottom of layer	=	1150. psi
Initial modulus of rock at top of layer	=	179800. psi
Initial modulus of rock at bottom of layer	=	179800. psi

RQD of rock at top of layer	=	100.000000 %
RQD of rock at bottom of layer	=	100.000000 %
k rm of rock at top of layer	=	0.0005000
k rm of rock at bottom of layer	=	0.0005000

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	55.200000 ft
Distance from top of pile to bottom of layer	=	57.900000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	1150. psi
Uniaxial compressive strength at bottom of layer	=	1150. psi
Initial modulus of rock at top of layer	=	179800. psi
Initial modulus of rock at bottom of layer	=	179800. psi
RQD of rock at top of layer	=	91.000000 %
RQD of rock at bottom of layer	=	91.000000 %
k rm of rock at top of layer	=	0.0005000
k rm of rock at bottom of layer	=	0.0005000

Layer 5 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	57.900000 ft
Distance from top of pile to bottom of layer	=	60.300000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	17.000000 %
RQD of rock at bottom of layer	=	17.000000 %
k rm of rock at top of layer	=	0.0005000
k rm of rock at bottom of layer	=	0.0005000

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

Distance from top of pile to top of layer	=	60.300000 ft
Distance from top of pile to bottom of layer	=	100.000000 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	=	330.000000	psi
Uniaxial compressive strength at bottom of layer	=	330.000000	psi
Initial modulus of rock at top of layer	=	37400.	psi
Initial modulus of rock at bottom of layer	=	37400.	psi
RQD of rock at top of layer	=	86.000000	%
RQD of rock at bottom of layer	=	86.000000	%
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 37.000 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 6, for effective unit weight = 160.00 pcf

This data may be erroneous. Please check your data.

-----  
Summary of Input Soil Properties  
-----

Layer	Soil Type	Layer	Effective	Undrained	Uniaxial		E50	Rock Mass
Layer	Name	Depth	Unit Wt.	Cohesion	qu	RQD %	or	Modulus
Num.	(p-y Curve Type)	ft	pcf	psf	psi		krm	psi
-----	-----	-----	-----	-----	-----	-----	-----	-----
1	Stiff Clay	42.0000	82.6000	4000.	--	--	0.00500	--
	w/o Free Water	45.8000	82.6000	4000.	--	--	0.00500	--

2	Weak	45.8000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
	Rock	48.7000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
3	Weak	48.7000	160.0000	--	1150.	100.0000	5.00E-04	179800.
	Rock	55.2000	160.0000	--	1150.	100.0000	5.00E-04	179800.
4	Weak	55.2000	160.0000	--	1150.	91.0000	5.00E-04	179800.
	Rock	57.9000	160.0000	--	1150.	91.0000	5.00E-04	179800.
5	Weak	57.9000	160.0000	--	330.0000	17.0000	5.00E-04	37400.
	Rock	60.3000	160.0000	--	330.0000	17.0000	5.00E-04	37400.
6	Weak	60.3000	150.0000	--	330.0000	86.0000	5.00E-04	37400.
	Rock	100.0000	150.0000	--	330.0000	86.0000	5.00E-04	37400.

-----

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	42.000	0.5000	1.0000
2	45.800	0.5000	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	0.000
2	504.000	1015.000

-----  
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  
-----

-----  
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	42.0000	0.00	N.A.	No	0.00	226958.
2	45.8000	3.8000	No	Yes	N.A.	N.A.
3	48.7000	6.7000	No	Yes	N.A.	N.A.
4	55.2000	13.2000	No	Yes	N.A.	N.A.
5	57.9000	15.9000	No	Yes	N.A.	N.A.
6	60.3000	18.3000	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	5.2459	-2.95E-04	0.00	-0.01064	2.07E-07	1.12E+12	0.00	0.00	3.8062
0.6300	5.1655	108.7702	71.9381	-0.01064	0.07628	1.12E+12	0.00	0.00	15.2250
1.2600	5.0850	1088.	244.5896	-0.01064	0.7628	1.12E+12	0.00	0.00	30.4500
1.8900	5.0046	3807.	532.3421	-0.01064	2.6698	1.12E+12	0.00	0.00	45.6750
2.5200	4.9242	9137.	935.1956	-0.01064	6.4076	1.12E+12	0.00	0.00	60.9000
3.1500	4.8437	17947.	1453.	-0.01064	12.5863	1.12E+12	0.00	0.00	76.1250
3.7800	4.7633	31108.	2086.	-0.01064	21.8162	1.12E+12	0.00	0.00	91.3500
4.4100	4.6829	49491.	2834.	-0.01064	34.7077	1.12E+12	0.00	0.00	106.5750
5.0400	4.6024	73964.	3698.	-0.01064	51.8708	1.12E+12	0.00	0.00	121.8000
5.6700	4.5220	105399.	4676.	-0.01064	73.9159	1.12E+12	0.00	0.00	137.0250
6.3000	4.4416	144665.	5769.	-0.01064	101.4532	1.12E+12	0.00	0.00	152.2500
6.9300	4.3612	192632.	6978.	-0.01064	135.0929	1.12E+12	0.00	0.00	167.4750
7.5600	4.2808	250172.	8302.	-0.01063	175.4453	1.12E+12	0.00	0.00	182.7000
8.1900	4.2004	318154.	9740.	-0.01063	223.1207	1.12E+12	0.00	0.00	197.9250
8.8200	4.1200	397447.	11294.	-0.01063	278.7292	1.12E+12	0.00	0.00	213.1500
9.4500	4.0397	488923.	12963.	-0.01063	342.8812	1.12E+12	0.00	0.00	228.3750
10.0800	3.9593	593452.	14747.	-0.01062	416.1868	1.12E+12	0.00	0.00	243.6000
10.7100	3.8791	711903.	16646.	-0.01062	499.2563	1.12E+12	0.00	0.00	258.8250
11.3400	3.7988	845146.	18661.	-0.01061	592.7000	1.12E+12	0.00	0.00	274.0500
11.9700	3.7186	994053.	20790.	-0.01061	697.1281	1.12E+12	0.00	0.00	289.2750
12.6000	3.6384	1159493.	23035.	-0.01060	813.1509	1.12E+12	0.00	0.00	304.5000
13.2300	3.5583	1342336.	25394.	-0.01059	941.3785	1.12E+12	0.00	0.00	319.7250
13.8600	3.4783	1543453.	27869.	-0.01058	1082.	1.12E+12	0.00	0.00	334.9500
14.4900	3.3983	1763713.	30459.	-0.01057	1237.	1.12E+12	0.00	0.00	350.1750
15.1200	3.3184	2003987.	33163.	-0.01056	1405.	1.12E+12	0.00	0.00	365.4000
15.7500	3.2387	2265145.	35983.	-0.01054	1589.	1.12E+12	0.00	0.00	380.6250
16.3800	3.1590	2548056.	38919.	-0.01053	1787.	1.12E+12	0.00	0.00	395.8500
17.0100	3.0795	2853593.	41969.	-0.01051	2001.	1.12E+12	0.00	0.00	411.0750
17.6400	3.0001	3182623.	45134.	-0.01049	2232.	1.12E+12	0.00	0.00	426.3000
18.2700	2.9209	3536018.	48414.	-0.01047	2480.	1.12E+12	0.00	0.00	441.5250
18.9000	2.8419	3914648.	51810.	-0.01044	2745.	1.12E+12	0.00	0.00	456.7500



19.5300	2.7631	4319383.	55320.	-0.01041	3029.	1.12E+12	0.00	0.00	471.9750
20.1600	2.6845	4751093.	58946.	-0.01038	3332.	1.12E+12	0.00	0.00	487.2000
20.7900	2.6061	5210648.	62687.	-0.01035	3654.	1.12E+12	0.00	0.00	502.4250
21.4200	2.5280	5698919.	66543.	-0.01031	3997.	1.12E+12	0.00	0.00	517.6500
22.0500	2.4502	6216775.	70514.	-0.01027	4360.	1.12E+12	0.00	0.00	532.8750
22.6800	2.3727	6765087.	74600.	-0.01023	4744.	1.12E+12	0.00	0.00	548.1000
23.3100	2.2956	7344724.	78801.	-0.01018	5151.	1.12E+12	0.00	0.00	563.3250
23.9400	2.2188	7956558.	83117.	-0.01013	5580.	1.12E+12	0.00	0.00	578.5500
24.5700	2.1424	8601458.	87549.	-0.01007	6032.	1.12E+12	0.00	0.00	593.7750
25.2000	2.0665	9280294.	92095.	-0.01001	6508.	1.12E+12	0.00	0.00	609.0000
25.8300	1.9911	9993937.	96757.	-0.00995	7009.	1.12E+12	0.00	0.00	624.2250
26.4600	1.9161	1.07E+07	101533.	-0.00988	7534.	1.12E+12	0.00	0.00	639.4500
27.0900	1.8418	1.15E+07	106425.	-0.00980	8085.	1.12E+12	0.00	0.00	654.6750
27.7200	1.7680	1.24E+07	111432.	-0.00972	8663.	1.12E+12	0.00	0.00	669.9000
28.3500	1.6948	1.32E+07	116554.	-0.00963	9267.	1.12E+12	0.00	0.00	685.1250
28.9800	1.6223	1.41E+07	121791.	-0.00954	9899.	1.12E+12	0.00	0.00	700.3500
29.6100	1.5506	1.51E+07	127143.	-0.00944	10558.	1.12E+12	0.00	0.00	715.5750
30.2400	1.4796	1.60E+07	132611.	-0.00934	11247.	1.12E+12	0.00	0.00	730.8000
30.8700	1.4094	1.71E+07	138193.	-0.00922	11965.	1.12E+12	0.00	0.00	746.0250
31.5000	1.3401	1.81E+07	143891.	-0.00910	12712.	1.12E+12	0.00	0.00	761.2500
32.1300	1.2717	1.92E+07	149703.	-0.00898	13490.	1.12E+12	0.00	0.00	776.4750
32.7600	1.2044	2.04E+07	155631.	-0.00884	14300.	1.12E+12	0.00	0.00	791.7000
33.3900	1.1380	2.16E+07	161674.	-0.00870	15141.	1.12E+12	0.00	0.00	806.9250
34.0200	1.0728	2.28E+07	167832.	-0.00855	16014.	1.12E+12	0.00	0.00	822.1500
34.6500	1.0087	2.41E+07	174105.	-0.00839	16920.	1.12E+12	0.00	0.00	837.3750
35.2800	0.9459	2.55E+07	180493.	-0.00822	17860.	1.12E+12	0.00	0.00	852.6000
35.9100	0.8844	2.69E+07	186996.	-0.00805	18834.	1.12E+12	0.00	0.00	867.8250
36.5400	0.8242	2.83E+07	193614.	-0.00786	19843.	1.12E+12	0.00	0.00	883.0500
37.1700	0.7655	2.98E+07	200348.	-0.00766	20887.	1.12E+12	0.00	0.00	898.2750
37.8000	0.7083	3.13E+07	207196.	-0.00746	21967.	1.12E+12	0.00	0.00	913.5000
38.4300	0.6528	3.29E+07	214160.	-0.00724	23084.	1.12E+12	0.00	0.00	928.7250
39.0600	0.5989	3.46E+07	221239.	-0.00701	24238.	1.12E+12	0.00	0.00	943.9500
39.6900	0.5468	3.63E+07	228432.	-0.00677	25430.	1.12E+12	0.00	0.00	959.1750
40.3200	0.4965	3.80E+07	235741.	-0.00652	26660.	1.12E+12	0.00	0.00	974.4000
40.9500	0.4482	3.98E+07	243165.	-0.00626	27930.	1.12E+12	0.00	0.00	989.6250
41.5800	0.4019	4.17E+07	250704.	-0.00598	29239.	1.12E+12	0.00	0.00	1005.
42.2100	0.3577	4.36E+07	251479.	-0.00569	30588.	1.12E+12	-968.7440	20472.	168.9552
42.8400	0.3158	4.55E+07	244809.	-0.00539	31905.	1.12E+12	-964.7764	23094.	0.00
43.4700	0.2762	4.73E+07	237542.	-0.00508	33184.	1.12E+12	-957.9108	26215.	0.00
44.1000	0.2391	4.91E+07	230338.	-0.00475	34424.	1.12E+12	-947.9449	29974.	0.00
44.7300	0.2044	5.08E+07	223221.	-0.00441	35626.	1.12E+12	-934.6519	34563.	0.00
45.3600	0.1724	5.25E+07	216219.	-0.00406	36791.	1.12E+12	-917.7776	40248.	0.00

45.9900	0.1430	5.41E+07	181723.	-0.00370	37919.	1.12E+12	-8208.	433859.	0.00
46.6200	0.1164	5.52E+07	115771.	-0.00333	38718.	1.12E+12	-9239.	599928.	0.00
47.2500	0.09266	5.58E+07	42707.	-0.00296	39147.	1.12E+12	-10090.	823176.	0.00
47.8800	0.07175	5.59E+07	-36040.	-0.00258	39171.	1.12E+12	-10743.	1131937.	0.00
48.5100	0.05370	5.53E+07	-118915.	-0.00220	38765.	1.12E+12	-11181.	1574162.	0.00
49.1400	0.03848	5.41E+07	-248345.	-0.00183	37910.	1.12E+12	-23059.	4530807.	0.00
49.7700	0.02602	5.15E+07	-422152.	-0.00147	36131.	1.12E+12	-22921.	6659494.	0.00
50.4000	0.01620	4.77E+07	-592511.	-0.00114	33434.	1.12E+12	-22147.	1.03E+07	0.00
51.0300	0.00882	4.26E+07	-753947.	-8.32E-04	29848.	1.12E+12	-20561.	1.76E+07	0.00
51.6600	0.00363	3.63E+07	-898536.	-5.65E-04	25439.	1.12E+12	-17691.	3.69E+07	0.00
52.2900	2.84E-04	2.90E+07	-1003285.	-3.44E-04	20321.	1.12E+12	-10021.	2.67E+08	0.00
52.9200	-0.00158	2.11E+07	-979359.	-1.74E-04	14801.	1.12E+12	16350.	7.85E+07	0.00
53.5500	-0.00235	1.42E+07	-845052.	-5.50E-05	9936.	1.12E+12	19181.	6.16E+07	0.00
54.1800	-0.00241	8327409.	-695444.	2.11E-05	5840.	1.12E+12	20398.	6.41E+07	0.00
54.8100	-0.00203	3652752.	-540398.	6.17E-05	2562.	1.12E+12	20620.	7.66E+07	0.00
55.4400	-0.00147	156584.	-373225.	7.46E-05	109.8119	1.12E+12	23606.	1.21E+08	0.00
56.0700	-9.06E-04	-1990410.	-201114.	6.84E-05	1396.	1.12E+12	21926.	1.83E+08	0.00
56.7000	-4.40E-04	-2884264.	-45822.	5.19E-05	2023.	1.12E+12	19157.	3.29E+08	0.00
57.3300	-1.21E-04	-2683241.	63002.	3.30E-05	1882.	1.12E+12	9633.	6.00E+08	0.00
57.9600	5.98E-05	-1931667.	95523.	1.74E-05	1355.	1.12E+12	-1030.	1.30E+08	0.00
58.5900	1.42E-04	-1238934.	82014.	6.68E-06	868.8627	1.12E+12	-2544.	1.35E+08	0.00
59.2200	1.61E-04	-691617.	61081.	1.47E-07	485.0301	1.12E+12	-2994.	1.41E+08	0.00
59.8500	1.44E-04	-315395.	39568.	-3.26E-06	221.1861	1.12E+12	-2698.	1.41E+08	0.00
60.4800	1.12E-04	-93350.	21488.	-4.65E-06	65.4659	1.12E+12	-2085.	1.41E+08	0.00
61.1100	7.40E-05	9507.	8374.	-4.93E-06	6.6674	1.12E+12	-1384.	1.41E+08	0.00
61.7400	3.70E-05	33271.	529.7389	-4.79E-06	23.3329	1.12E+12	-691.4320	1.41E+08	0.00
62.3700	1.65E-06	17517.	-2200.	-4.61E-06	12.2846	1.12E+12	-30.8436	1.41E+08	0.00
63.0000	-3.28E-05	0.00	0.00	-4.55E-06	0.00	1.12E+12	612.9767	7.07E+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	=	5.24589595 inches
Computed slope at pile head	=	-0.01063933 radians
Maximum bending moment	=	55854861. inch-lbs
Maximum shear force	=	-1003285. lbs
Depth of maximum bending moment	=	47.88000000 feet below pile head
Depth of maximum shear force	=	52.29000000 feet below pile head
Number of iterations	=	25
Number of zero deflection points	=	3

-----  
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 feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
63.00000	5.24589595	55854861.	-1003285.
59.85000	5.27986267	56297970.	-1005481.
56.70000	5.22436518	56131307.	-989415.
53.55000	12.64227967	54788343.	-1352085.

-----  
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	5.2459	-0.01064	-1003285.	5.59E+07

Maximum pile-head deflection = 5.2458959528 inches

Maximum pile-head rotation = -0.0106393326 radians = -0.609589 deg.

---

Summary of Warning Messages

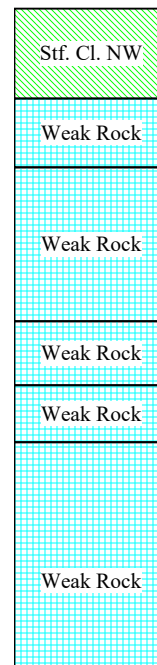
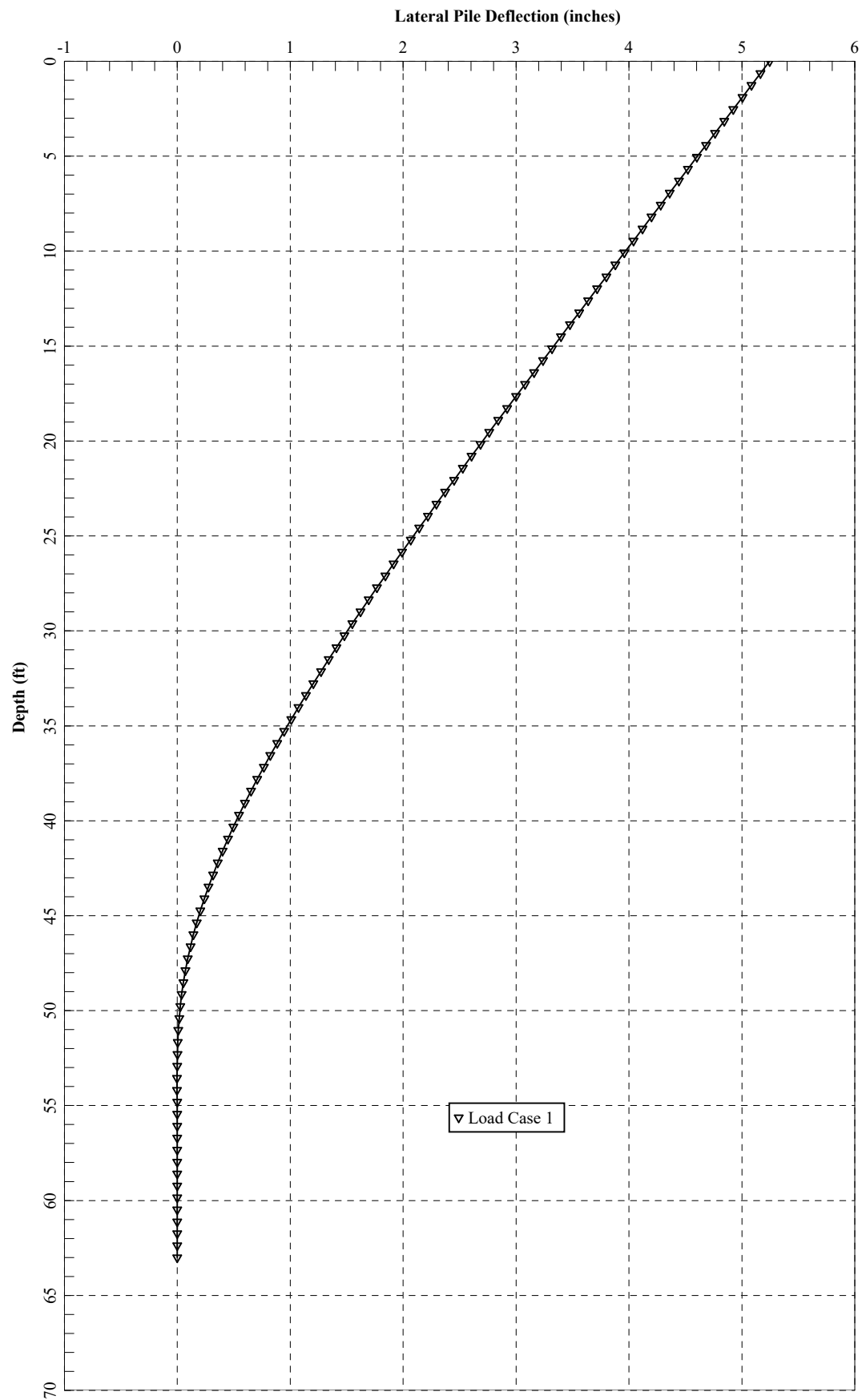
---

The following warning was reported 2214 times

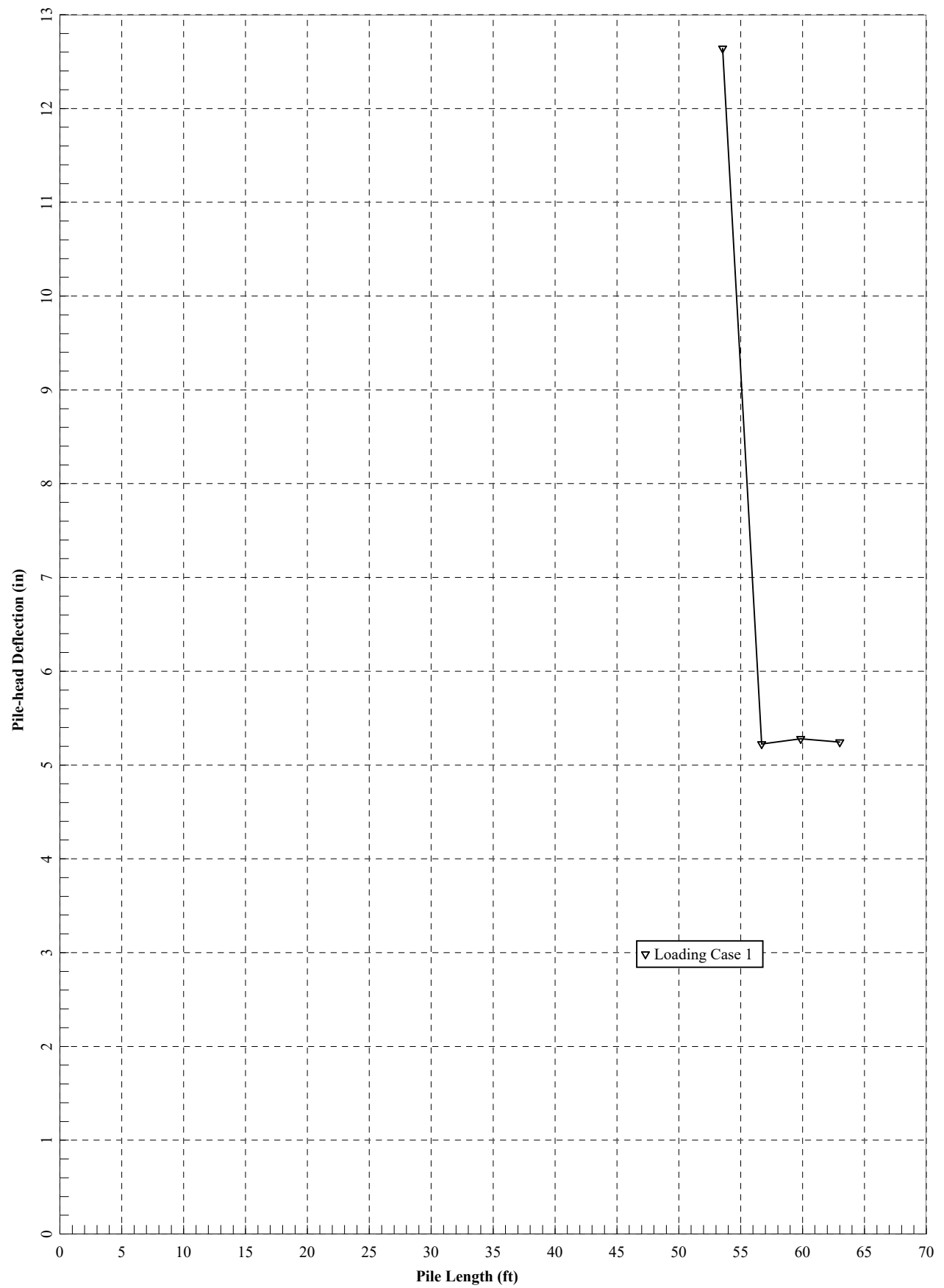
\*\*\*\* Warning \*\*\*\*

An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.









## Strength Limit Analysis (Tangent Drilled Shaft Wall)

=====

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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-----

Files Used for Analysis

-----

Path to file locations:  
\pwworking\east01\d3420675\

Name of input data file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Main Wall Strength Case.lp11

Name of output report file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Main Wall Strength Case.lp11

Name of plot output file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Main Wall Strength Case.lp11

Name of runtime message file:

WAS-77-9.58 42' Wall with Hydrostatic Loading Main Wall Strength Case.lp11

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

Date: August 24, 2023                      Time: 13:40:08

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

Project Name: WAS-77-9.58

Job Number:

Client: ODOT D10

Engineer: HDR

Description: 42' Wall 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 = 63.000 ft
- Depth of ground surface below top of pile = 42.0000 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	54.0000
2	63.000	54.0000

Input Structural Properties for Pile Sections:  
-----

Pile Section No. 1:

Section 1 is an elastic pile	
Cross-sectional Shape	= Circular Pile
Length of section	= 63.000000 ft
Width of top of section	= 54.000000 in
Width of bottom of section	= 54.000000 in
Top Area	= 120.500000 sq. in
Bottom Area	= 120.500000 sq. in
Moment of Inertia at Top	= 38500. in^4
Moment of Inertia at Bottom	= 38500. 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	=	42.000000 ft
Distance from top of pile to bottom of layer	=	45.800000 ft
Effective unit weight at top of layer	=	82.600000 pcf
Effective unit weight at bottom of layer	=	82.600000 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 2 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	45.800000 ft
Distance from top of pile to bottom of layer	=	48.700000 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	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	64.000000 %
RQD of rock at bottom of layer	=	64.000000 %
k <sub>rm</sub> of rock at top of layer	=	0.0005000
k <sub>rm</sub> of rock at bottom of layer	=	0.0005000

Layer 3 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	48.700000 ft
Distance from top of pile to bottom of layer	=	55.200000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	1150. psi
Uniaxial compressive strength at bottom of layer	=	1150. psi
Initial modulus of rock at top of layer	=	179800. psi
Initial modulus of rock at bottom of layer	=	179800. psi

RQD of rock at top of layer	=	100.000000 %
RQD of rock at bottom of layer	=	100.000000 %
k rm of rock at top of layer	=	0.0005000
k rm of rock at bottom of layer	=	0.0005000

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	55.200000 ft
Distance from top of pile to bottom of layer	=	57.900000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	1150. psi
Uniaxial compressive strength at bottom of layer	=	1150. psi
Initial modulus of rock at top of layer	=	179800. psi
Initial modulus of rock at bottom of layer	=	179800. psi
RQD of rock at top of layer	=	91.000000 %
RQD of rock at bottom of layer	=	91.000000 %
k rm of rock at top of layer	=	0.0005000
k rm of rock at bottom of layer	=	0.0005000

Layer 5 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	57.900000 ft
Distance from top of pile to bottom of layer	=	60.300000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	17.000000 %
RQD of rock at bottom of layer	=	17.000000 %
k rm of rock at top of layer	=	0.0005000
k rm of rock at bottom of layer	=	0.0005000

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

Distance from top of pile to top of layer	=	60.300000 ft
Distance from top of pile to bottom of layer	=	100.000000 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	=	330.000000	psi
Uniaxial compressive strength at bottom of layer	=	330.000000	psi
Initial modulus of rock at top of layer	=	37400.	psi
Initial modulus of rock at bottom of layer	=	37400.	psi
RQD of rock at top of layer	=	86.000000	%
RQD of rock at bottom of layer	=	86.000000	%
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 37.000 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 6, for effective unit weight = 160.00 pcf

This data may be erroneous. Please check your data.

-----  
Summary of Input Soil Properties  
-----

Layer	Soil Type	Layer	Effective	Undrained	Uniaxial		E50	Rock Mass
Layer	Name	Depth	Unit Wt.	Cohesion	qu	RQD %	or	Modulus
Num.	(p-y Curve Type)	ft	pcf	psf	psi		krm	psi
-----	-----	-----	-----	-----	-----	-----	-----	-----
1	Stiff Clay	42.0000	82.6000	4000.	--	--	0.00500	--
	w/o Free Water	45.8000	82.6000	4000.	--	--	0.00500	--

2	Weak	45.8000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
	Rock	48.7000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
3	Weak	48.7000	160.0000	--	1150.	100.0000	5.00E-04	179800.
	Rock	55.2000	160.0000	--	1150.	100.0000	5.00E-04	179800.
4	Weak	55.2000	160.0000	--	1150.	91.0000	5.00E-04	179800.
	Rock	57.9000	160.0000	--	1150.	91.0000	5.00E-04	179800.
5	Weak	57.9000	160.0000	--	330.0000	17.0000	5.00E-04	37400.
	Rock	60.3000	160.0000	--	330.0000	17.0000	5.00E-04	37400.
6	Weak	60.3000	150.0000	--	330.0000	86.0000	5.00E-04	37400.
	Rock	100.0000	150.0000	--	330.0000	86.0000	5.00E-04	37400.

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p-y Modification Factors for Group Action

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

Point No.	Depth X ft	p-mult	y-mult
1	42.000	0.5000	1.0000
2	45.800	0.5000	1.0000

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Static Loading Type

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



-----  
Distributed Lateral Loading Used For All Load Cases  
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Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lb/in
-----	-----	-----
1	0.000	0.000
2	504.000	1523.000

-----  
Pile-head Loading and Pile-head Fixity Conditions  
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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:

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Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers

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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	42.0000	0.00	N.A.	No	0.00	226958.
2	45.8000	3.8000	No	Yes	N.A.	N.A.
3	48.7000	6.7000	No	Yes	N.A.	N.A.
4	55.2000	13.2000	No	Yes	N.A.	N.A.
5	57.9000	15.9000	No	Yes	N.A.	N.A.
6	60.3000	18.3000	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.

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

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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	8.3616	4.16E-04	0.00	-0.01674	2.92E-07	1.12E+12	0.00	0.00	5.7112
0.6300	8.2350	163.2095	107.9426	-0.01674	0.1145	1.12E+12	0.00	0.00	22.8450
1.2600	8.1084	1632.	367.0049	-0.01674	1.1446	1.12E+12	0.00	0.00	45.6900
1.8900	7.9819	5712.	798.7754	-0.01674	4.0060	1.12E+12	0.00	0.00	68.5350
2.5200	7.8553	13710.	1403.	-0.01674	9.6145	1.12E+12	0.00	0.00	91.3800
3.1500	7.7287	26930.	2180.	-0.01674	18.8856	1.12E+12	0.00	0.00	114.2250
3.7800	7.6021	46678.	3130.	-0.01674	32.7351	1.12E+12	0.00	0.00	137.0700
4.4100	7.4755	74260.	4253.	-0.01674	52.0786	1.12E+12	0.00	0.00	159.9150
5.0400	7.3489	110982.	5548.	-0.01674	77.8317	1.12E+12	0.00	0.00	182.7600
5.6700	7.2223	158150.	7016.	-0.01674	110.9102	1.12E+12	0.00	0.00	205.6050
6.3000	7.0958	217068.	8657.	-0.01674	152.2297	1.12E+12	0.00	0.00	228.4500
6.9300	6.9692	289044.	10470.	-0.01674	202.7059	1.12E+12	0.00	0.00	251.2950
7.5600	6.8427	375381.	12457.	-0.01674	263.2544	1.12E+12	0.00	0.00	274.1400
8.1900	6.7161	477387.	14615.	-0.01673	334.7909	1.12E+12	0.00	0.00	296.9850
8.8200	6.5896	596367.	16947.	-0.01673	418.2311	1.12E+12	0.00	0.00	319.8300
9.4500	6.4632	733626.	19451.	-0.01673	514.4907	1.12E+12	0.00	0.00	342.6750
10.0800	6.3367	890470.	22128.	-0.01672	624.4852	1.12E+12	0.00	0.00	365.5200
10.7100	6.2104	1068205.	24978.	-0.01671	749.1305	1.12E+12	0.00	0.00	388.3650
11.3400	6.0840	1268136.	28000.	-0.01671	889.3420	1.12E+12	0.00	0.00	411.2100
11.9700	5.9578	1491569.	31195.	-0.01670	1046.	1.12E+12	0.00	0.00	434.0550
12.6000	5.8316	1739811.	34563.	-0.01669	1220.	1.12E+12	0.00	0.00	456.9000
13.2300	5.7055	2014165.	38104.	-0.01667	1413.	1.12E+12	0.00	0.00	479.7450
13.8600	5.5795	2315939.	41817.	-0.01666	1624.	1.12E+12	0.00	0.00	502.5900
14.4900	5.4536	2646438.	45703.	-0.01664	1856.	1.12E+12	0.00	0.00	525.4350
15.1200	5.3279	3006967.	49762.	-0.01662	2109.	1.12E+12	0.00	0.00	548.2800
15.7500	5.2023	3398833.	53993.	-0.01660	2384.	1.12E+12	0.00	0.00	571.1250
16.3800	5.0768	3823340.	58397.	-0.01658	2681.	1.12E+12	0.00	0.00	593.9700
17.0100	4.9516	4281795.	62974.	-0.01655	3003.	1.12E+12	0.00	0.00	616.8150
17.6400	4.8266	4775503.	67723.	-0.01652	3349.	1.12E+12	0.00	0.00	639.6600
18.2700	4.7019	5305769.	72645.	-0.01648	3721.	1.12E+12	0.00	0.00	662.5050
18.9000	4.5774	5873901.	77740.	-0.01645	4119.	1.12E+12	0.00	0.00	685.3500

19.5300	4.4532	6481202.	83008.	-0.01640	4545.	1.12E+12	0.00	0.00	708.1950
20.1600	4.3293	7128980.	88448.	-0.01636	5000.	1.12E+12	0.00	0.00	731.0400
20.7900	4.2059	7818539.	94061.	-0.01631	5483.	1.12E+12	0.00	0.00	753.8850
21.4200	4.0828	8551185.	99847.	-0.01625	5997.	1.12E+12	0.00	0.00	776.7300
22.0500	3.9601	9328225.	105805.	-0.01619	6542.	1.12E+12	0.00	0.00	799.5750
22.6800	3.8380	1.02E+07	111937.	-0.01613	7119.	1.12E+12	0.00	0.00	822.4200
23.3100	3.7163	1.10E+07	118240.	-0.01605	7729.	1.12E+12	0.00	0.00	845.2650
23.9400	3.5952	1.19E+07	124717.	-0.01598	8373.	1.12E+12	0.00	0.00	868.1100
24.5700	3.4747	1.29E+07	131366.	-0.01589	9051.	1.12E+12	0.00	0.00	890.9550
25.2000	3.3549	1.39E+07	138188.	-0.01580	9766.	1.12E+12	0.00	0.00	913.8000
25.8300	3.2358	1.50E+07	145183.	-0.01570	10517.	1.12E+12	0.00	0.00	936.6450
26.4600	3.1175	1.61E+07	152350.	-0.01560	11305.	1.12E+12	0.00	0.00	959.4900
27.0900	3.0000	1.73E+07	159690.	-0.01549	12132.	1.12E+12	0.00	0.00	982.3350
27.7200	2.8833	1.85E+07	167203.	-0.01536	12998.	1.12E+12	0.00	0.00	1005.
28.3500	2.7677	1.98E+07	174889.	-0.01523	13905.	1.12E+12	0.00	0.00	1028.
28.9800	2.6530	2.12E+07	182747.	-0.01510	14853.	1.12E+12	0.00	0.00	1051.
29.6100	2.5394	2.26E+07	190778.	-0.01495	15843.	1.12E+12	0.00	0.00	1074.
30.2400	2.4270	2.41E+07	198981.	-0.01479	16876.	1.12E+12	0.00	0.00	1097.
30.8700	2.3158	2.56E+07	207358.	-0.01462	17953.	1.12E+12	0.00	0.00	1119.
31.5000	2.2059	2.72E+07	215907.	-0.01444	19074.	1.12E+12	0.00	0.00	1142.
32.1300	2.0975	2.89E+07	224629.	-0.01425	20242.	1.12E+12	0.00	0.00	1165.
32.7600	1.9904	3.06E+07	233523.	-0.01405	21456.	1.12E+12	0.00	0.00	1188.
33.3900	1.8850	3.24E+07	242590.	-0.01384	22718.	1.12E+12	0.00	0.00	1211.
34.0200	1.7812	3.43E+07	251830.	-0.01361	24029.	1.12E+12	0.00	0.00	1234.
34.6500	1.6792	3.62E+07	261243.	-0.01337	25389.	1.12E+12	0.00	0.00	1256.
35.2800	1.5790	3.82E+07	270828.	-0.01312	26799.	1.12E+12	0.00	0.00	1279.
35.9100	1.4808	4.03E+07	280586.	-0.01286	28260.	1.12E+12	0.00	0.00	1302.
36.5400	1.3846	4.25E+07	290517.	-0.01258	29774.	1.12E+12	0.00	0.00	1325.
37.1700	1.2907	4.47E+07	300620.	-0.01228	31341.	1.12E+12	0.00	0.00	1348.
37.8000	1.1990	4.70E+07	310896.	-0.01197	32962.	1.12E+12	0.00	0.00	1371.
38.4300	1.1097	4.94E+07	321345.	-0.01164	34638.	1.12E+12	0.00	0.00	1394.
39.0600	1.0229	5.19E+07	331967.	-0.01130	36369.	1.12E+12	0.00	0.00	1416.
39.6900	0.9388	5.44E+07	342761.	-0.01094	38158.	1.12E+12	0.00	0.00	1439.
40.3200	0.8575	5.70E+07	353728.	-0.01056	40004.	1.12E+12	0.00	0.00	1462.
40.9500	0.7791	5.98E+07	364868.	-0.01017	41908.	1.12E+12	0.00	0.00	1485.
41.5800	0.7037	6.26E+07	376180.	-0.00975	43873.	1.12E+12	0.00	0.00	1508.
42.2100	0.6316	6.54E+07	378617.	-0.00932	45897.	1.12E+12	-1117.	13366.	253.5160
42.8400	0.5628	6.83E+07	371141.	-0.00887	47887.	1.12E+12	-1115.	14974.	0.00
43.4700	0.4975	7.11E+07	362732.	-0.00840	49833.	1.12E+12	-1110.	16863.	0.00
44.1000	0.4358	7.38E+07	354374.	-0.00791	51734.	1.12E+12	-1101.	19106.	0.00
44.7300	0.3780	7.64E+07	346091.	-0.00740	53590.	1.12E+12	-1090.	21800.	0.00
45.3600	0.3240	7.90E+07	337910.	-0.00687	55403.	1.12E+12	-1075.	25075.	0.00

45.9900	0.2741	8.15E+07	297344.	-0.00633	57173.	1.12E+12	-9657.	266397.	0.00
46.6200	0.2283	8.35E+07	219511.	-0.00577	58556.	1.12E+12	-10933.	362047.	0.00
47.2500	0.1868	8.48E+07	132737.	-0.00520	59501.	1.12E+12	-12023.	486511.	0.00
47.8800	0.1497	8.55E+07	38486.	-0.00462	59964.	1.12E+12	-12911.	652077.	0.00
48.5100	0.1169	8.54E+07	-61661.	-0.00404	59909.	1.12E+12	-13583.	878164.	0.00
49.1400	0.08854	8.46E+07	-220359.	-0.00347	59310.	1.12E+12	-28401.	2424909.	0.00
49.7700	0.06449	8.21E+07	-436424.	-0.00290	57573.	1.12E+12	-28759.	3371456.	0.00
50.4000	0.04463	7.80E+07	-652983.	-0.00236	54682.	1.12E+12	-28532.	4832666.	0.00
51.0300	0.02877	7.22E+07	-865262.	-0.00185	50649.	1.12E+12	-27627.	7259315.	0.00
51.6600	0.01661	6.49E+07	-1067504.	-0.00139	45507.	1.12E+12	-25877.	1.18E+07	0.00
52.2900	0.00776	5.61E+07	-1251811.	-9.80E-04	39329.	1.12E+12	-22882.	2.23E+07	0.00
52.9200	0.00179	4.60E+07	-1402130.	-6.35E-04	32234.	1.12E+12	-16885.	7.14E+07	0.00
53.5500	-0.00183	3.49E+07	-1397854.	-3.61E-04	24461.	1.12E+12	18016.	7.43E+07	0.00
54.1800	-0.00367	2.48E+07	-1244087.	-1.59E-04	17411.	1.12E+12	22663.	4.67E+07	0.00
54.8100	-0.00423	1.61E+07	-1064810.	-2.02E-05	11270.	1.12E+12	24765.	4.42E+07	0.00
55.4400	-0.00397	8727335.	-856859.	6.37E-05	6120.	1.12E+12	30249.	5.76E+07	0.00
56.0700	-0.00327	3113886.	-628295.	1.04E-04	2184.	1.12E+12	30218.	6.99E+07	0.00
56.7000	-0.00240	-772480.	-403350.	1.12E-04	541.7394	1.12E+12	29291.	9.21E+07	0.00
57.3300	-0.00158	-2984763.	-188512.	9.90E-05	2093.	1.12E+12	27544.	1.32E+08	0.00
57.9600	-9.06E-04	-3622782.	-25451.	7.67E-05	2541.	1.12E+12	15593.	1.30E+08	0.00
58.5900	-4.19E-04	-3369576.	61857.	5.30E-05	2363.	1.12E+12	7504.	1.35E+08	0.00
59.2200	-1.04E-04	-2687499.	97573.	3.25E-05	1885.	1.12E+12	1945.	1.41E+08	0.00
59.8500	7.24E-05	-1894279.	99809.	1.70E-05	1328.	1.12E+12	-1353.	1.41E+08	0.00
60.4800	1.52E-04	-1178393.	83933.	6.58E-06	826.4052	1.12E+12	-2847.	1.41E+08	0.00
61.1100	1.72E-04	-625205.	61030.	4.70E-07	438.4556	1.12E+12	-3212.	1.41E+08	0.00
61.7400	1.59E-04	-255614.	37625.	-2.51E-06	179.2617	1.12E+12	-2979.	1.41E+08	0.00
62.3700	1.34E-04	-56310.	16906.	-3.57E-06	39.4901	1.12E+12	-2502.	1.41E+08	0.00
63.0000	1.05E-04	0.00	0.00	-3.76E-06	0.00	1.12E+12	-1970.	7.07E+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	=	8.36162776 inches
Computed slope at pile head	=	-0.01674488 radians
Maximum bending moment	=	85503998. inch-lbs
Maximum shear force	=	-1402130. lbs
Depth of maximum bending moment	=	47.88000000 feet below pile head
Depth of maximum shear force	=	52.92000000 feet below pile head
Number of iterations	=	32
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 feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
63.00000	8.36162776	85503998.	-1402130.
59.85000	8.41019285	86060062.	-1408437.
56.70000	8.49293018	85684800.	-1469558.

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Summary of Pile-head Responses for Conventional Analyses  
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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	8.3616	-0.01674	-1402130.	8.55E+07

Maximum pile-head deflection = 8.3616277620 inches

Maximum pile-head rotation = -0.0167448827 radians = -0.959411 deg.

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Summary of Warning Messages

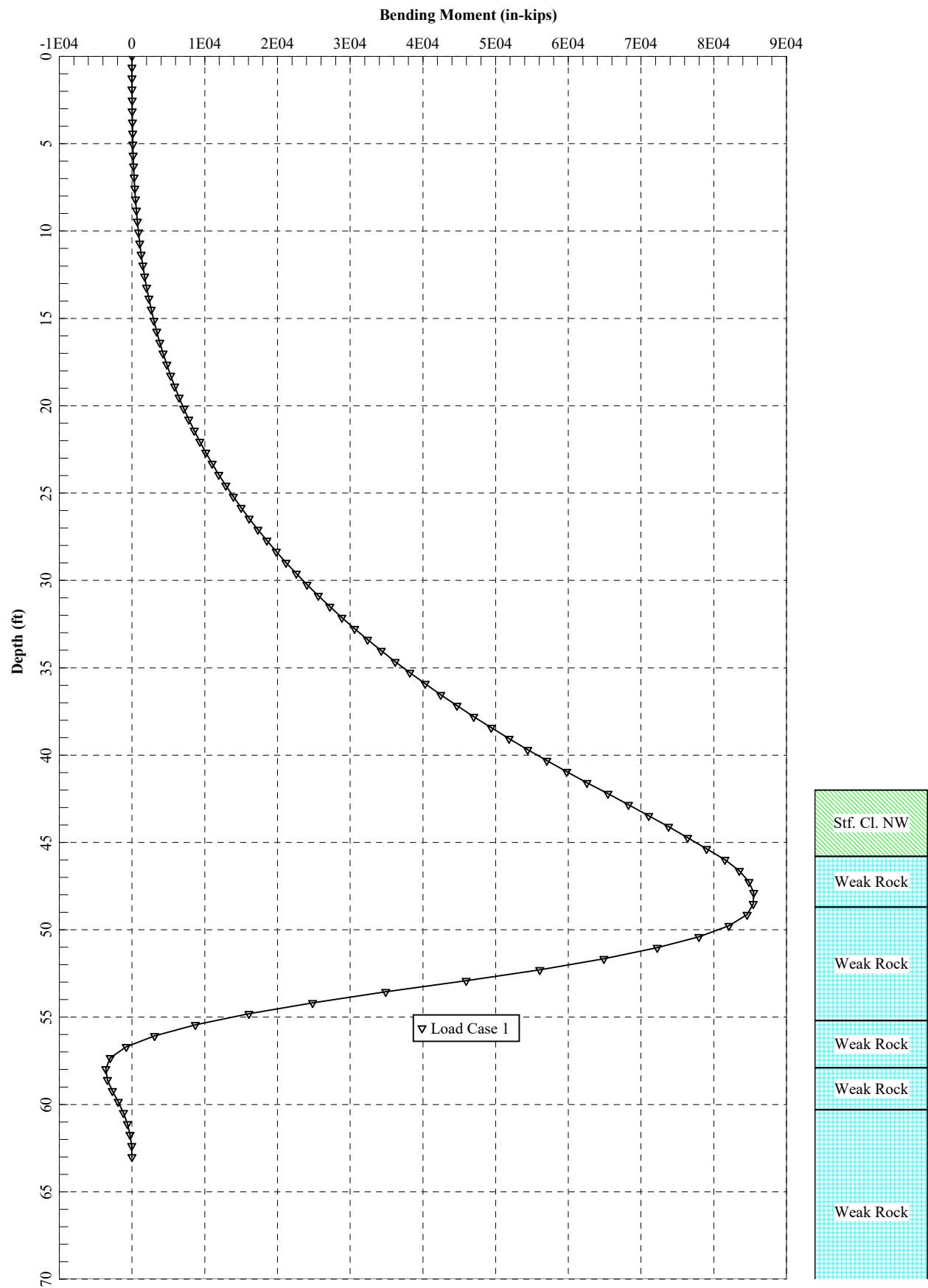
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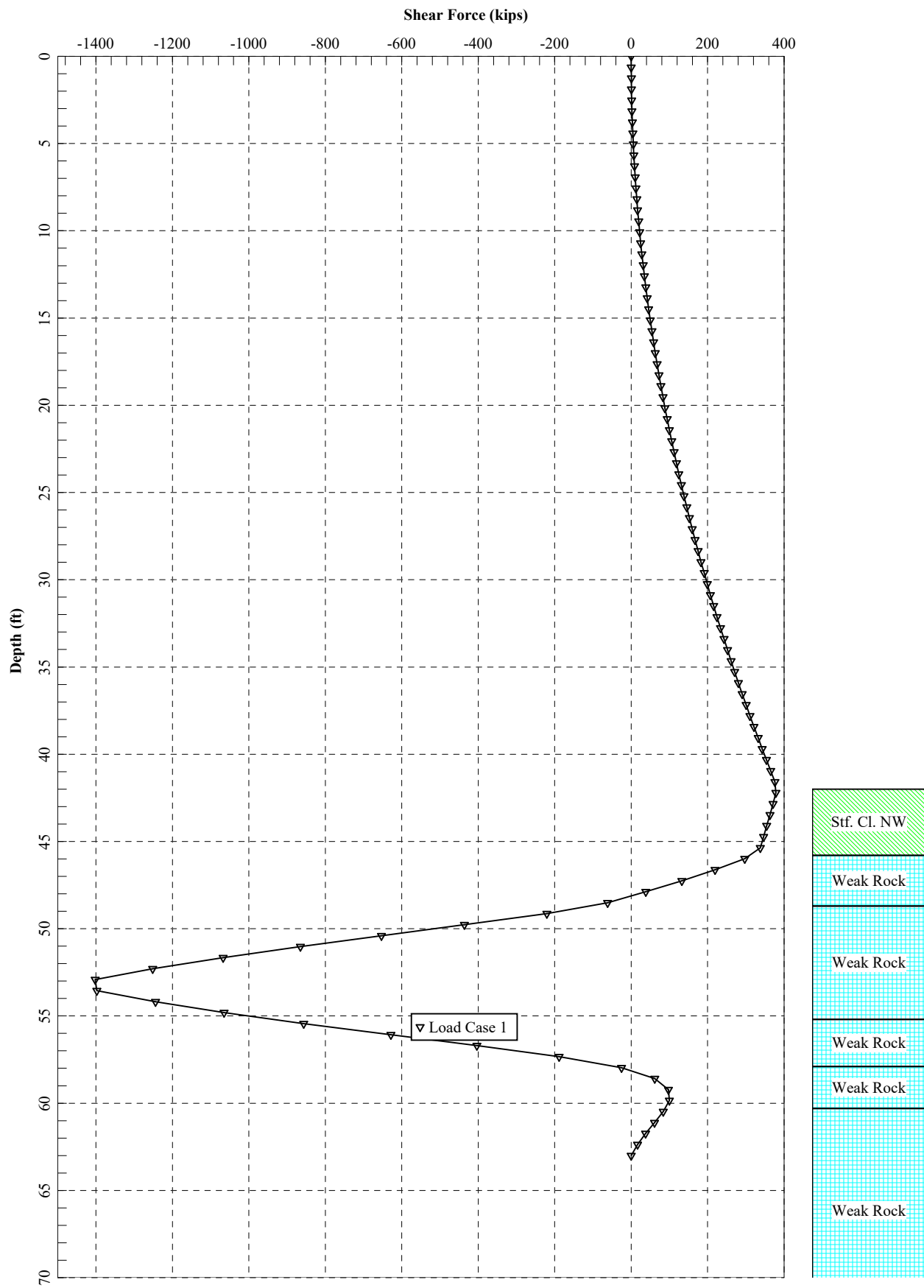
The following warning was reported 2036 times

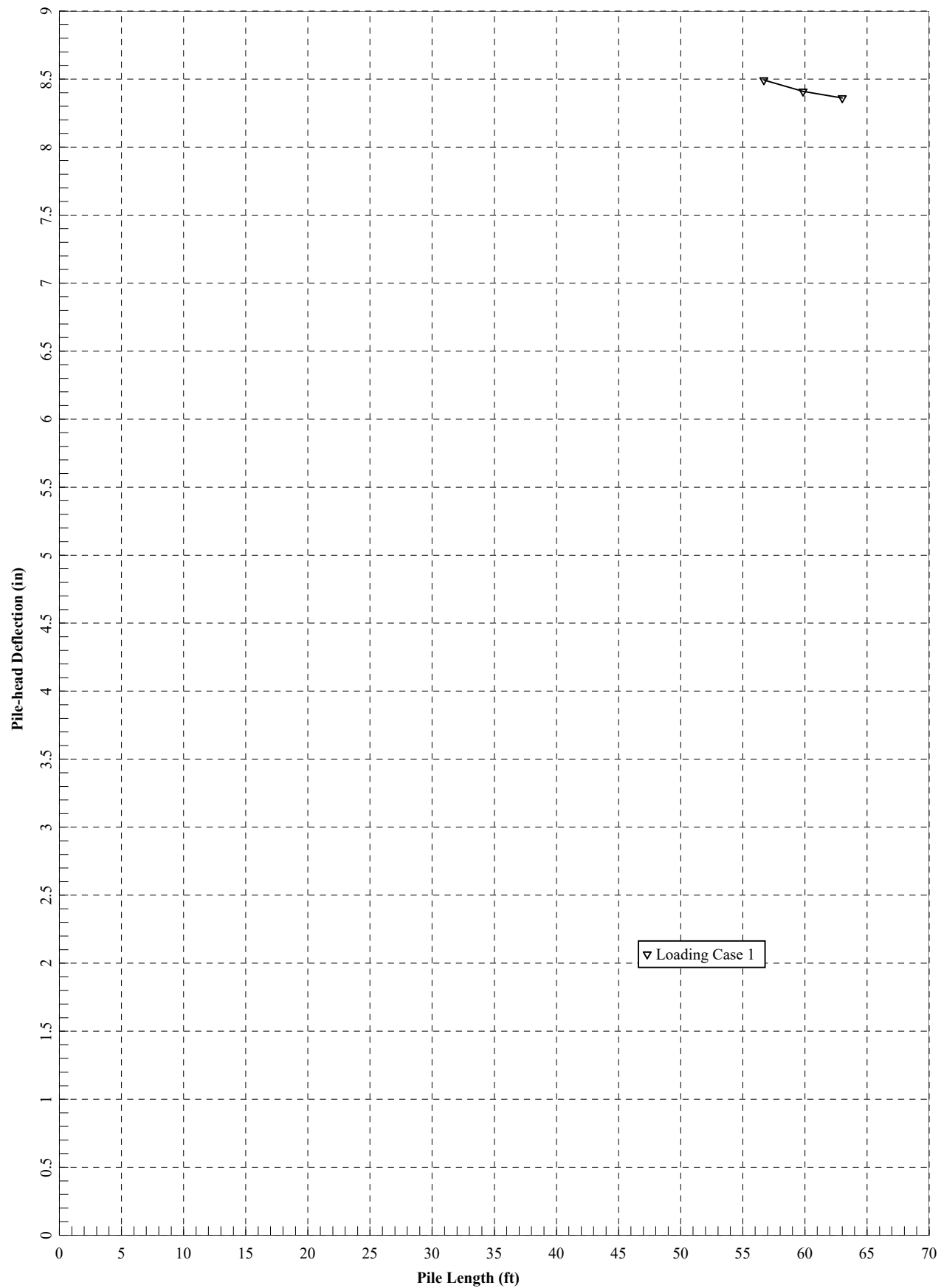
\*\*\*\* Warning \*\*\*\*

An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.











**LPILE Analyses**  
**(Cantilever Wall, Span Existing 48" Culvert)**

## Geometry

Elevation (ft)			Horiz. Distance from C/L (ft)		
Top of Backfill =	865.0	at Bottom of Embankment	Start of Wall Backfill =	50.0	at Bottom of Embankment
Top of Wall =	856.0	at C/L of Wall	Wall =	0.0	at C/L of Wall
Existing Ground Surface =	857.0	at C/L of Wall			
Bottom of Wall =	814.0	at C/L of Wall	Backfill Slope Angle =	5.6	H:1V
Groundwater =	814.0	at C/L of Wall		10.2	degrees

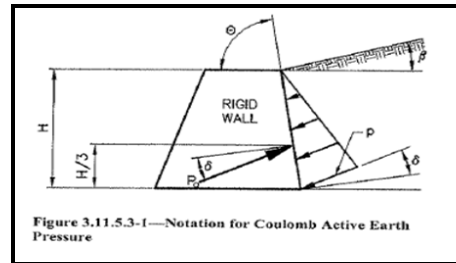
## Wall Loading Profile (B-005-0-23)

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	856.0	5.8	115	23	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	5.0	65	21	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	10.0	115	23	140
Layer 3 Stiff to Very Stiff Cohesive	835.2	20.0	175	25	135
Layer 4 Hard Cohesive	815.2	1.2	250	28	145
Bottom of Wall/Maintenance Bench	814.0				
Weighted Value		42.0	140	24	135

As a drainage system can be installed behind the lagging in this area of the wall, the total unit weight of the soil is utilized.

## Earth Pressure Coefficients

	Deg	
Shear Resistance, $\Phi$ =	26	
Wall Friction, $\delta^A$ =	0.0	
Wall Slope, $\theta$ =	90	
Backfill Slope, $\beta$ =	10.20	
Revised Backfill Slope, $\beta$ =	10.20	
Backfill Condition	INFINITE	
Horz. Backslope Dist.	50.0	feet (C/L of Wall - Edge of Shoulder)
Wall Height (H)	42.0	feet (Top of Wall - Maintenance Bench)
Slope Height (h)	9.0	feet (Top of Backfill - Top of Wall)
$l$ =	6.12	degrees



## Active Earth Coefficient

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

$K_a = 0.447$

## At-Rest Earth Coefficient

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

$K_o = 0.664$

## 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 existing fill and cohesive overburden. Using the soil layer thicknesses and respective soil parameters, a weighted average was determined and assumed for the entire backfill ( $c' = 140$  psf and  $\phi' = 24^\circ$ ). The parameters were converted to equivalent soil strength parameters  $c' = 0$  psf and  $\phi' = 26^\circ$  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).

## L-Pile Soil Lateral Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)	$\epsilon_{50}$	k
Hard Cohesive	814.0	42.0	4000	0	82.6	0.005	N/A
Bedrock	810.2	45.8	N/A	N/A	N/A	N/A	N/A

## L-Pile Bedrock Lateral Design Profile

	Top Elev	Depth (ft)	$q_u$ (psi)	$E_m$ (psi)	Unit Wt (pcf)	RQD (%)	$k_{rm}$
Claystone	810.2	45.8	330	37400	150	64	0.0005
Claystone	807.3	48.7	1150	179800	160	100	0.0005
Sandstone/Claystone	800.8	55.2	1150	179800	160	91	0.0005
Claystone	798.1	57.9	330	37400	150	17	0.0005
Claystone	795.7	60.3	330	37400	150	86	0.0005

Depths referenced below the top of wall, starting at the bottom of the wall.  $\epsilon_{50}$  and k values per L-Pile Technical Manual.

## Wall Loading Computations

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

1) Soil Unit Weight = **135** pcf Weighted Average Along Cantilevered Wall Height

2) Determine Coefficient of Earth Pressure (K)

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

Ka = **0.447**

3) Determine Equivalent Fluid Weight ( $G_H$ )

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

$G_H =$  **60** 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.? **NO**

Lowered Ground Surface (ft) = **0.0** =  $dt (\tan(\beta_{dh}))$

$\beta_{dh} =$  steepness of the slope downhill of the drilled shaft

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

$d_i =$  **N/A** = 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 for  $1 \leq S/D < 3.75$ , where  $0.5 \leq P_m < 1.0$ )

D = **4.5** feet (shaft diameter or pile flange width)

Assumed Shaft Spacing = **6.71** feet (center-to-center pile spacing)

$P_m =$  **0.73**  $(1/2)(3.25 \text{ ft pile spacing}) + (2.25 \text{ ft radius}) + (1/2)(4 \text{ ft culvert span}) + 10 \text{ inches of clearance}$

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 shaft:

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

$FS_{UAS} =$  Factor of Safety from UASlope including shafts

p-multiplier = **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

Exposed Wall Height (H) = **42** feet

Wall Height (H) +  $GS_{AL} =$  **42.0**

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

$P =$  **53239** lbs/foot

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

$P_{SH} =$  **357142** lbs/shaft

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

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

$w =$  **17007** lbs/foot per shaft (Earth - Service Limit)

$w =$  **1417** lbs/inch per shaft (Earth - Service Limit)

$\gamma_E =$  **1.5** Earth Load Factor

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

$w =$  **2126** lbs/inch per shaft (Earth - Strength Limit)

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

Include traffic surcharge? **NO**

Surcharge Pressure ( $q_s$ ) = **NA** psf

$P_s = K_a * q_s * H$

$P_s =$  **NA** lbs/foot (surcharge resolved to distributed load)

$P_s =$  **NA** lbs/shaft

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

$w = P_s / H$

$w =$  **0** lbs/foot per shaft (surcharge - unfactored)

$w =$  **0** lbs/inch per shaft (surcharge - unfactored)

$\gamma_s =$  **1.75** Surcharge Load Factor - Strength I

$w = (P_s / L) * \gamma_s$

$w =$  **0** lbs/inch per shaft (Surcharge - Strength I)

Distributed Lateral Loads for LPILE

CONVENTIONAL		
Depth (ft.)	Service (lb/in)	Strength-I (lb/in)
0	0	0
42.0	1417	2126

## Steel Beam and Cross-Section Properties

Assumed Pile Shape **W 36x652**

### Pile Availability

AISC Member Producers	<b>0</b>
Non-Member Producers	<b>1</b>

### Shaft Geometry

Shaft Diameter	<b>54</b> in
Longest Beam Dimension	<b>44.709842</b> in
Clear Distance	<b>4.6450788</b> in

### Steel Beam Geometry

Beam Depth (D)	<b>41.1</b> in
Web Thickness (t <sub>w</sub> )	<b>1.97</b> in
Flange Width (B <sub>f</sub> )	<b>17.6</b> in
Flange Thickness (t <sub>f</sub> )	<b>3.54</b> in
Area of Steel (A <sub>s</sub> )	<b>192</b> in <sup>2</sup>

### Steel Properties

Yield Strength of Steel	<b>50</b> ksi
Moment of Inertia (I <sub>xx</sub> ) of Steel	<b>50600</b> in <sup>4</sup>
Modulus of Elasticity of Steel (E)	<b>29000</b> ksi
Modulus of Elasticity of Steel (E)	<b>29000000</b> psi
EI (Steel Only)	<b>1.467E+12</b> lb*in <sup>2</sup>
Section Modulus (S <sub>x</sub> )	<b>2460</b> in <sup>3</sup>
Section Modulus (Z <sub>x</sub> )	<b>2910</b> in <sup>3</sup>
Shear-Buckling Coefficient (k)	<b>5</b>
Ratio of Shear-Buckling Resistance (C)	<b>1</b>
D/t <sub>w</sub>	<b>20.862944</b>
1.12VEk/F <sub>yw</sub>	<b>60.313846</b>
1.40VEk/F <sub>yw</sub>	<b>75.392307</b>

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

$$V_u \leq \phi V_{cr}$$

$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$

$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$

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

$$V_n = V_{cr} = C V_p$$

$$V_p = 0.58 F_{yw} D t_w$$

$$V_p = \text{plastic shear force (kips)}$$

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

$$V_p = 0.58 * 50 * 41.1 * 1.97$$

$$V_p = \boxed{2348.0} \text{ kips}$$

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

$$\phi V_{cr} = 1 * 1 * 2348.0$$

$$\phi V_{cr} = \boxed{2348.0} \text{ kips}$$

$$V_u = \boxed{1804.6} \text{ kips (from LPILE)}$$

$$\boxed{\phantom{000}} \text{ kips (from PYWALL)}$$

$$V_u < \phi V_{cr} \quad \text{OK}$$

### Flexure Capacity Calculation

$$M_u \leq \phi M_n$$

$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$

$$M_u = \text{Moment due to the factored loads}$$

$$M_n = \text{Nominal flexural resistance of a section}$$

$$S_x = \text{Elastic section modulus about the x-axis}$$

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

$$\phi M_n = 1 * 50 * 2460$$

$$\phi M_n = \boxed{123000} \text{ in*kips}$$

$$M_u = \boxed{120753} \text{ in*kips (from LPILE)}$$

$$M_u = \boxed{\phantom{000}} \text{ in*kips (from PYWALL)}$$

$$M_u < \phi M_n \quad \text{OK}$$

### Deflection Criteria

Pile Length Above Rock = <b>45.8</b> ft	Exposed Wall Height = <b>42</b> ft
Pile Length Above Rock = <b>549.6</b> in	Exposed Wall Height = <b>504</b> 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

**5.50** in

$\delta = \boxed{5.87}$  in (from LPILE)

1.5% Wall Height - PYWALL

**5.50** in

$\delta = \boxed{\phantom{000}}$  in (from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement

**NO**



## Service Limit Analysis (Span 48-inch Culvert)

=====

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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=====

This copy of LPIle is being used by:

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Use of this program by any entity other than HDR, ,  
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-----

Files Used for Analysis

-----

Path to file locations:  
\\Users\\dmatchis\\OneDrive - HDR, Inc\\WAS-77 Revisions\\

Name of input data file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Culvert Span Service Case.lp11

Name of output report file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Culvert Span Service Case.lp11

Name of plot output file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Culvert Span Service Case.lp11

Name of runtime message file:  
WAS-77-9.58 42' Wall with Hydrostatic Loading Culvert Span Service Case.lp11

-----

Date and Time of Analysis

-----



Date: September 8, 2023

Time: 11:49:30

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

Project Name: WAS-77-9.58

Job Number:

Client: ODOT D10

Engineer: HDR

Description: 42' Wall Service Case (Culvert Span)

-----  
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 = 63.000 ft  
 Depth of ground surface below top of pile = 42.0000 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	54.0000
2	63.000	54.0000

Input Structural Properties for Pile Sections:  
 -----

Pile Section No. 1:

Section 1 is an elastic pile	
Cross-sectional Shape	= Circular Pile
Length of section	= 63.000000 ft
Width of top of section	= 54.000000 in
Width of bottom of section	= 54.000000 in
Top Area	= 192.000000 sq. in
Bottom Area	= 192.000000 sq. in
Moment of Inertia at Top	= 50600. in^4
Moment of Inertia at Bottom	= 50600. 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	=	42.000000 ft
Distance from top of pile to bottom of layer	=	45.800000 ft
Effective unit weight at top of layer	=	82.600000 pcf
Effective unit weight at bottom of layer	=	82.600000 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 2 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	45.800000 ft
Distance from top of pile to bottom of layer	=	48.700000 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	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	64.000000 %
RQD of rock at bottom of layer	=	64.000000 %
k <sub>rm</sub> of rock at top of layer	=	0.0005000
k <sub>rm</sub> of rock at bottom of layer	=	0.0005000

Layer 3 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	48.700000 ft
Distance from top of pile to bottom of layer	=	55.200000 ft
Effective unit weight at top of layer	=	160.000000 pcf

Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	1150. psi
Uniaxial compressive strength at bottom of layer	=	1150. psi
Initial modulus of rock at top of layer	=	179800. psi
Initial modulus of rock at bottom of layer	=	179800. psi
RQD of rock at top of layer	=	100.000000 %
RQD of rock at bottom of layer	=	100.000000 %
k rm of rock at top of layer	=	0.0005000
k rm of rock at bottom of layer	=	0.0005000

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	55.200000 ft
Distance from top of pile to bottom of layer	=	57.900000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	1150. psi
Uniaxial compressive strength at bottom of layer	=	1150. psi
Initial modulus of rock at top of layer	=	179800. psi
Initial modulus of rock at bottom of layer	=	179800. psi
RQD of rock at top of layer	=	91.000000 %
RQD of rock at bottom of layer	=	91.000000 %
k rm of rock at top of layer	=	0.0005000
k rm of rock at bottom of layer	=	0.0005000

Layer 5 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	57.900000 ft
Distance from top of pile to bottom of layer	=	60.300000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	17.000000 %
RQD of rock at bottom of layer	=	17.000000 %
k rm of rock at top of layer	=	0.0005000
k rm of rock at bottom of layer	=	0.0005000

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

Distance from top of pile to top of layer	=	60.300000 ft
Distance from top of pile to bottom of layer	=	100.000000 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	=	330.000000 psi

```

Uniaxial compressive strength at bottom of layer = 330.000000 psi
Initial modulus of rock at top of layer = 37400. psi
Initial modulus of rock at bottom of layer = 37400. psi
RQD of rock at top of layer = 86.000000 %
RQD of rock at bottom of layer = 86.000000 %
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 37.000 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 6, for effective unit weight = 160.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties								
Layer 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	42.0000	82.6000	4000.	--	--	0.00500	--
	w/o Free Water	45.8000	82.6000	4000.	--	--	0.00500	--
2	Weak	45.8000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
	Rock	48.7000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
3	Weak	48.7000	160.0000	--	1150.	100.0000	5.00E-04	179800.
	Rock	55.2000	160.0000	--	1150.	100.0000	5.00E-04	179800.
4	Weak	55.2000	160.0000	--	1150.	91.0000	5.00E-04	179800.
	Rock	57.9000	160.0000	--	1150.	91.0000	5.00E-04	179800.
5	Weak	57.9000	160.0000	--	330.0000	17.0000	5.00E-04	37400.
	Rock	60.3000	160.0000	--	330.0000	17.0000	5.00E-04	37400.
6	Weak	60.3000	150.0000	--	330.0000	86.0000	5.00E-04	37400.
	Rock	100.0000	150.0000	--	330.0000	86.0000	5.00E-04	37400.

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	42.000	0.7300	1.0000
2	45.800	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	0.000
2	504.000	1417.000

-----  
 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  
 -----

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	42.0000	0.00	N.A.	No	0.00	226958.
2	45.8000	3.8000	No	Yes	N.A.	N.A.
3	48.7000	6.7000	No	Yes	N.A.	N.A.
4	55.2000	13.2000	No	Yes	N.A.	N.A.
5	57.9000	15.9000	No	Yes	N.A.	N.A.
6	60.3000	18.3000	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	5.8727	-9.58E-04	1.51E-06	-0.01178	5.11E-07	1.47E+12	0.00	0.00	5.3137
0.6300	5.7836	151.8490	100.4299	-0.01178	0.08103	1.47E+12	0.00	0.00	21.2550
1.2600	5.6946	1518.	341.4616	-0.01178	0.8103	1.47E+12	0.00	0.00	42.5100
1.8900	5.6056	5315.	743.1811	-0.01178	2.8359	1.47E+12	0.00	0.00	63.7650
2.5200	5.5165	12755.	1306.	-0.01178	6.8062	1.47E+12	0.00	0.00	85.0200
3.1500	5.4275	25055.	2029.	-0.01178	13.3694	1.47E+12	0.00	0.00	106.2750
3.7800	5.3385	43429.	2912.	-0.01178	23.1736	1.47E+12	0.00	0.00	127.5300
4.4100	5.2495	69092.	3957.	-0.01178	36.8671	1.47E+12	0.00	0.00	148.7850
5.0400	5.1604	103258.	5162.	-0.01178	55.0981	1.47E+12	0.00	0.00	170.0400
5.6700	5.0714	147143.	6528.	-0.01177	78.5148	1.47E+12	0.00	0.00	191.2950
6.3000	4.9824	201960.	8054.	-0.01177	107.7655	1.47E+12	0.00	0.00	212.5500
6.9300	4.8934	268926.	9742.	-0.01177	143.4982	1.47E+12	0.00	0.00	233.8050
7.5600	4.8044	349255.	11590.	-0.01177	186.3613	1.47E+12	0.00	0.00	255.0600
8.1900	4.7154	444161.	13598.	-0.01177	237.0030	1.47E+12	0.00	0.00	276.3150
8.8200	4.6265	554860.	15767.	-0.01177	296.0714	1.47E+12	0.00	0.00	297.5700
9.4500	4.5375	682566.	18097.	-0.01176	364.2149	1.47E+12	0.00	0.00	318.8250
10.0800	4.4486	828493.	20588.	-0.01176	442.0815	1.47E+12	0.00	0.00	340.0800
10.7100	4.3597	993858.	23239.	-0.01175	530.3195	1.47E+12	0.00	0.00	361.3350
11.3400	4.2709	1179874.	26052.	-0.01175	629.5772	1.47E+12	0.00	0.00	382.5900
11.9700	4.1821	1387757.	29024.	-0.01174	740.5027	1.47E+12	0.00	0.00	403.8450
12.6000	4.0933	1618721.	32158.	-0.01173	863.7442	1.47E+12	0.00	0.00	425.1000
13.2300	4.0046	1873980.	35452.	-0.01173	999.9501	1.47E+12	0.00	0.00	446.3550
13.8600	3.9160	2154751.	38907.	-0.01172	1150.	1.47E+12	0.00	0.00	467.6100
14.4900	3.8275	2462247.	42522.	-0.01170	1314.	1.47E+12	0.00	0.00	488.8650
15.1200	3.7391	2797684.	46298.	-0.01169	1493.	1.47E+12	0.00	0.00	510.1200
15.7500	3.6507	3162276.	50235.	-0.01167	1687.	1.47E+12	0.00	0.00	531.3750
16.3800	3.5625	3557237.	54333.	-0.01166	1898.	1.47E+12	0.00	0.00	552.6300
17.0100	3.4745	3983784.	58591.	-0.01164	2126.	1.47E+12	0.00	0.00	573.8850
17.6400	3.3866	4443130.	63010.	-0.01162	2371.	1.47E+12	0.00	0.00	595.1400
18.2700	3.2989	4936491.	67589.	-0.01159	2634.	1.47E+12	0.00	0.00	616.3950
18.9000	3.2113	5465080.	72330.	-0.01157	2916.	1.47E+12	0.00	0.00	637.6500
19.5300	3.1240	6030114.	77231.	-0.01154	3218.	1.47E+12	0.00	0.00	658.9050
20.1600	3.0369	6632807.	82292.	-0.01150	3539.	1.47E+12	0.00	0.00	680.1600
20.7900	2.9501	7274373.	87515.	-0.01147	3882.	1.47E+12	0.00	0.00	701.4150
21.4200	2.8635	7956027.	92898.	-0.01143	4245.	1.47E+12	0.00	0.00	722.6700
22.0500	2.7773	8678985.	98441.	-0.01139	4631.	1.47E+12	0.00	0.00	743.9250
22.6800	2.6914	9444461.	104146.	-0.01134	5040.	1.47E+12	0.00	0.00	765.1800
23.3100	2.6058	1.03E+07	110011.	-0.01129	5471.	1.47E+12	0.00	0.00	786.4350
23.9400	2.5207	1.11E+07	116037.	-0.01123	5927.	1.47E+12	0.00	0.00	807.6900
24.5700	2.4360	1.20E+07	122223.	-0.01117	6408.	1.47E+12	0.00	0.00	828.9450

25.2000	2.3518	1.30E+07	128570.	-0.01111	6913.	1.47E+12	0.00	0.00	850.2000
25.8300	2.2680	1.40E+07	135078.	-0.01104	7445.	1.47E+12	0.00	0.00	871.4550
26.4600	2.1848	1.50E+07	141747.	-0.01096	8003.	1.47E+12	0.00	0.00	892.7100
27.0900	2.1022	1.61E+07	148576.	-0.01088	8588.	1.47E+12	0.00	0.00	913.9650
27.7200	2.0203	1.72E+07	155566.	-0.01080	9202.	1.47E+12	0.00	0.00	935.2200
28.3500	1.9390	1.84E+07	162716.	-0.01071	9844.	1.47E+12	0.00	0.00	956.4750
28.9800	1.8584	1.97E+07	170028.	-0.01061	10515.	1.47E+12	0.00	0.00	977.7300
29.6100	1.7786	2.10E+07	177500.	-0.01050	11215.	1.47E+12	0.00	0.00	998.9850
30.2400	1.6996	2.24E+07	185132.	-0.01039	11947.	1.47E+12	0.00	0.00	1020.
30.8700	1.6214	2.38E+07	192926.	-0.01027	12709.	1.47E+12	0.00	0.00	1041.
31.5000	1.5442	2.53E+07	200880.	-0.01015	13503.	1.47E+12	0.00	0.00	1063.
32.1300	1.4680	2.69E+07	208995.	-0.01001	14330.	1.47E+12	0.00	0.00	1084.
32.7600	1.3929	2.85E+07	217270.	-0.00987	15189.	1.47E+12	0.00	0.00	1105.
33.3900	1.3188	3.01E+07	225706.	-0.00972	16083.	1.47E+12	0.00	0.00	1127.
34.0200	1.2459	3.19E+07	234303.	-0.00956	17010.	1.47E+12	0.00	0.00	1148.
34.6500	1.1743	3.37E+07	243060.	-0.00939	17973.	1.47E+12	0.00	0.00	1169.
35.2800	1.1039	3.56E+07	251979.	-0.00921	18971.	1.47E+12	0.00	0.00	1190.
35.9100	1.0350	3.75E+07	261057.	-0.00902	20006.	1.47E+12	0.00	0.00	1212.
36.5400	0.9675	3.95E+07	270297.	-0.00883	21077.	1.47E+12	0.00	0.00	1233.
37.1700	0.9016	4.16E+07	279697.	-0.00862	22187.	1.47E+12	0.00	0.00	1254.
37.8000	0.8372	4.37E+07	289258.	-0.00840	23334.	1.47E+12	0.00	0.00	1275.
38.4300	0.7746	4.60E+07	298980.	-0.00817	24520.	1.47E+12	0.00	0.00	1297.
39.0600	0.7138	4.83E+07	308862.	-0.00792	25746.	1.47E+12	0.00	0.00	1318.
39.6900	0.6548	5.06E+07	318905.	-0.00767	27012.	1.47E+12	0.00	0.00	1339.
40.3200	0.5978	5.31E+07	329109.	-0.00740	28319.	1.47E+12	0.00	0.00	1360.
40.9500	0.5429	5.56E+07	339473.	-0.00712	29668.	1.47E+12	0.00	0.00	1382.
41.5800	0.4902	5.82E+07	349998.	-0.00683	31058.	1.47E+12	0.00	0.00	1403.
42.2100	0.4397	6.09E+07	350563.	-0.00652	32491.	1.47E+12	-1489.	25606.	235.8715
42.8400	0.3916	6.35E+07	340207.	-0.00620	33886.	1.47E+12	-1486.	28697.	0.00
43.4700	0.3459	6.60E+07	328997.	-0.00587	35236.	1.47E+12	-1479.	32332.	0.00
44.1000	0.3029	6.85E+07	317854.	-0.00552	36541.	1.47E+12	-1468.	36651.	0.00
44.7300	0.2625	7.08E+07	306814.	-0.00516	37801.	1.47E+12	-1453.	41839.	0.00
45.3600	0.2248	7.31E+07	295910.	-0.00479	39016.	1.47E+12	-1432.	48151.	0.00
45.9900	0.1900	7.53E+07	257187.	-0.00441	40188.	1.47E+12	-8812.	350591.	0.00
46.6200	0.1582	7.70E+07	186171.	-0.00402	41091.	1.47E+12	-9975.	476778.	0.00
47.2500	0.1293	7.81E+07	107014.	-0.00362	41690.	1.47E+12	-10966.	641146.	0.00
47.8800	0.1035	7.86E+07	21059.	-0.00321	41954.	1.47E+12	-11773.	860052.	0.00
48.5100	0.08073	7.84E+07	-70245.	-0.00281	41860.	1.47E+12	-12381.	1159399.	0.00
49.1400	0.06103	7.76E+07	-214867.	-0.00241	41388.	1.47E+12	-25879.	3205458.	0.00
49.7700	0.04436	7.52E+07	-411688.	-0.00201	40126.	1.47E+12	-26191.	4463937.	0.00
50.4000	0.03061	7.13E+07	-608832.	-0.00163	38066.	1.47E+12	-25964.	6413307.	0.00
51.0300	0.01964	6.60E+07	-801892.	-0.00128	35214.	1.47E+12	-25110.	9668089.	0.00
51.6600	0.01123	5.92E+07	-985523.	-9.59E-04	31597.	1.47E+12	-23469.	1.58E+07	0.00
52.2900	0.00514	5.11E+07	-1152268.	-6.74E-04	27263.	1.47E+12	-20643.	3.04E+07	0.00
52.9200	0.00104	4.18E+07	-1286004.	-4.35E-04	22300.	1.47E+12	-14737.	1.08E+08	0.00
53.5500	-0.00144	3.16E+07	-1277596.	-2.46E-04	16888.	1.47E+12	16961.	8.90E+07	0.00
54.1800	-0.00268	2.25E+07	-1134255.	-1.07E-04	11992.	1.47E+12	20960.	5.90E+07	0.00
54.8100	-0.00305	1.45E+07	-968762.	-1.14E-05	7736.	1.47E+12	22822.	5.65E+07	0.00
55.4400	-0.00286	7827043.	-777218.	-4.61E-05	4176.	1.47E+12	27851.	7.37E+07	0.00
56.0700	-0.00235	2747169.	-566704.	-7.34E-05	1466.	1.47E+12	27840.	8.94E+07	0.00

56.7000	-0.00175	-741524.	-359241.	7.85E-05	395.6749	1.47E+12	27044.	1.17E+08	0.00
57.3300	-0.00117	-2684561.	-160460.	6.97E-05	1432.	1.47E+12	25544.	1.65E+08	0.00
57.9600	-6.93E-04	-3167686.	-18836.	5.46E-05	1690.	1.47E+12	11923.	1.30E+08	0.00
58.5900	-3.41E-04	-2969357.	49341.	3.88E-05	1584.	1.47E+12	6113.	1.35E+08	0.00
59.2200	-1.06E-04	-2421655.	79873.	2.49E-05	1292.	1.47E+12	1964.	1.41E+08	0.00
59.8500	3.58E-05	-1761682.	84765.	1.42E-05	940.0281	1.47E+12	-670.0666	1.41E+08	0.00
60.4800	1.09E-04	-1140006.	74556.	6.69E-06	608.3035	1.47E+12	-2031.	1.41E+08	0.00
61.1100	1.37E-04	-634395.	57199.	2.12E-06	338.5111	1.47E+12	-2561.	1.41E+08	0.00
61.7400	1.41E-04	-275163.	37578.	-2.26E-07	146.8260	1.47E+12	-2629.	1.41E+08	0.00
62.3700	1.34E-04	-66214.	18199.	-1.10E-06	35.3317	1.47E+12	-2497.	1.41E+08	0.00
63.0000	1.24E-04	0.00	0.00	-1.28E-06	0.00	1.47E+12	-2317.	7.07E+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	=	5.87266852 inches
Computed slope at pile head	=	-0.01177651 radians
Maximum bending moment	=	78625690. inch-lbs
Maximum shear force	=	-1286004. lbs
Depth of maximum bending moment	=	47.88000000 feet below pile head
Depth of maximum shear force	=	52.92000000 feet below pile head
Number of iterations	=	30
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 feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
63.00000	5.87266852	78625690.	-1286004.
59.85000	5.91249521	79195664.	-1289126.
56.70000	5.96979522	78871099.	-1348148.

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	5.8727	-0.01178	-1286004.	7.86E+07

Maximum pile-head deflection = 5.8726685227 inches  
Maximum pile-head rotation = -0.0117765060 radians = -0.674744 deg.

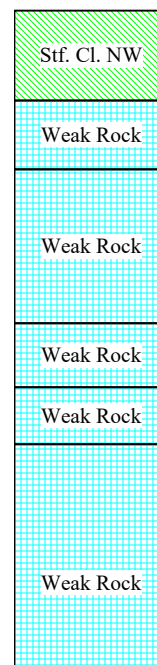
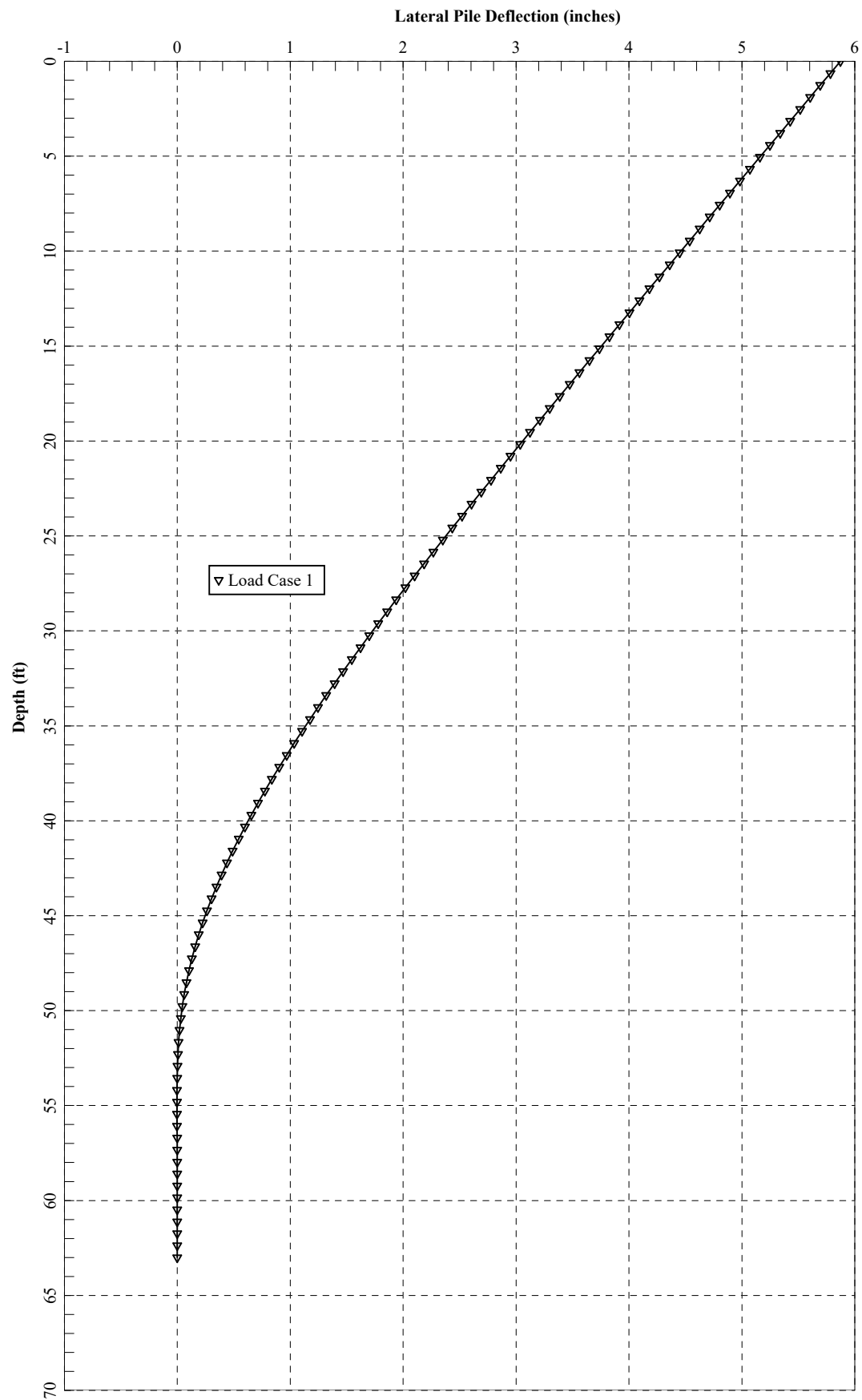
-----  
Summary of Warning Messages  
-----

The following warning was reported 2025 times

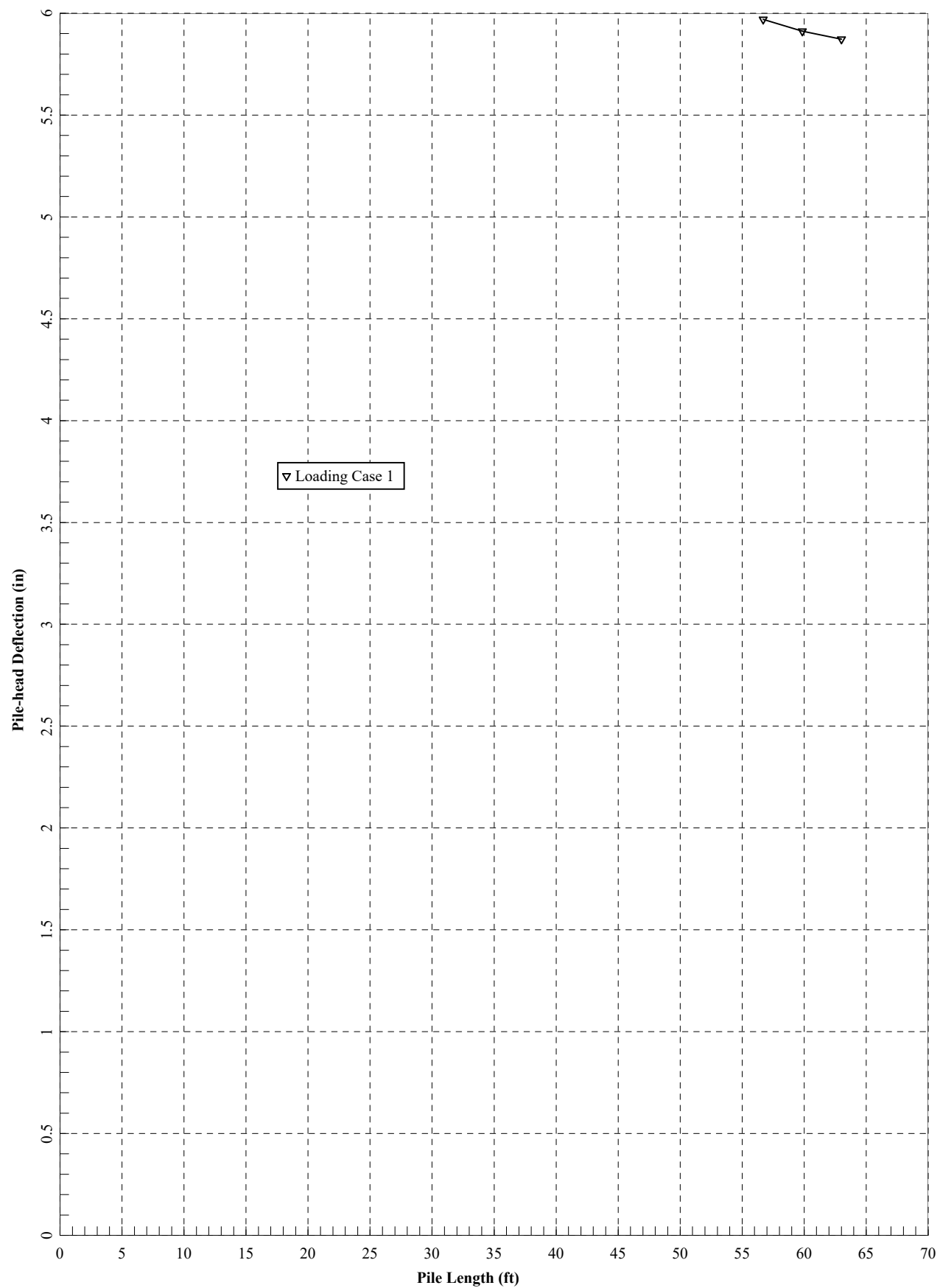
\*\*\*\* Warning \*\*\*\*

An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.









## Strength Limit Analysis (Culvert Span)

=====

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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Files Used for Analysis

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Path to file locations:

\Users\dmachis\OneDrive - HDR, Inc\WAS-77 Revisions\

Name of input data file:

WAS-77-9.58 42' Wall with Hydrostatic Loading Culvert Span Strength Case.lp11

Name of output report file:

WAS-77-9.58 42' Wall with Hydrostatic Loading Culvert Span Strength Case.lp11

Name of plot output file:

WAS-77-9.58 42' Wall with Hydrostatic Loading Culvert Span Strength Case.lp11

Name of runtime message file:

WAS-77-9.58 42' Wall with Hydrostatic Loading Culvert Span Strength Case.lp11

-----

Date and Time of Analysis

-----

Date: September 8, 2023

Time: 11:46:31

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

Project Name: WAS-77-9.58

Job Number:

Client: ODOT D10

Engineer: HDR

Description: 42' Wall Strength Case (Culvert Span)

-----  
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 = 63.000 ft  
Depth of ground surface below top of pile = 42.0000 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	54.0000
2	63.000	54.0000

Input Structural Properties for Pile Sections:  
-----

Pile Section No. 1:

Section 1 is an elastic pile  
Cross-sectional Shape = Circular Pile  
Length of section = 63.000000 ft  
Width of top of section = 54.000000 in  
Width of bottom of section = 54.000000 in  
Top Area = 192.000000 sq. in  
Bottom Area = 192.000000 sq. in  
Moment of Inertia at Top = 50600. in^4  
Moment of Inertia at Bottom = 50600. in^4  
Elastic Modulus = 29000000. psi

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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	=	42.000000	ft
Distance from top of pile to bottom of layer	=	45.800000	ft
Effective unit weight at top of layer	=	82.600000	pcf
Effective unit weight at bottom of layer	=	82.600000	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 2 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	45.800000	ft
Distance from top of pile to bottom of layer	=	48.700000	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	=	330.000000	psi
Uniaxial compressive strength at bottom of layer	=	330.000000	psi
Initial modulus of rock at top of layer	=	37400.	psi
Initial modulus of rock at bottom of layer	=	37400.	psi
RQD of rock at top of layer	=	64.000000	%
RQD of rock at bottom of layer	=	64.000000	%
k <sub>rm</sub> of rock at top of layer	=	0.0005000	
k <sub>rm</sub> of rock at bottom of layer	=	0.0005000	

Layer 3 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	48.700000	ft
Distance from top of pile to bottom of layer	=	55.200000	ft
Effective unit weight at top of layer	=	160.000000	pcf
Effective unit weight at bottom of layer	=	160.000000	pcf
Uniaxial compressive strength at top of layer	=	1150.	psi
Uniaxial compressive strength at bottom of layer	=	1150.	psi
Initial modulus of rock at top of layer	=	179800.	psi
Initial modulus of rock at bottom of layer	=	179800.	psi
RQD of rock at top of layer	=	100.000000	%
RQD of rock at bottom of layer	=	100.000000	%
k <sub>rm</sub> of rock at top of layer	=	0.0005000	
k <sub>rm</sub> of rock at bottom of layer	=	0.0005000	

Layer 4 is weak rock, p-y criteria by Reese, 1997



Distance from top of pile to top of layer	=	55.200000 ft
Distance from top of pile to bottom of layer	=	57.900000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	1150. psi
Uniaxial compressive strength at bottom of layer	=	1150. psi
Initial modulus of rock at top of layer	=	179800. psi
Initial modulus of rock at bottom of layer	=	179800. psi
RQD of rock at top of layer	=	91.000000 %
RQD of rock at bottom of layer	=	91.000000 %
k <sub>rm</sub> of rock at top of layer	=	0.0005000
k <sub>rm</sub> of rock at bottom of layer	=	0.0005000

Layer 5 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	57.900000 ft
Distance from top of pile to bottom of layer	=	60.300000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	17.000000 %
RQD of rock at bottom of layer	=	17.000000 %
k <sub>rm</sub> of rock at top of layer	=	0.0005000
k <sub>rm</sub> of rock at bottom of layer	=	0.0005000

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

Distance from top of pile to top of layer	=	60.300000 ft
Distance from top of pile to bottom of layer	=	100.000000 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	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	86.000000 %
RQD of rock at bottom of layer	=	86.000000 %
k <sub>rm</sub> of rock at top of layer	=	0.0005000
k <sub>rm</sub> of rock at bottom of layer	=	0.0005000

(Depth of the lowest soil layer extends 37.000 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 6, for effective unit weight = 160.00 pcf

This data may be erroneous. Please check your data.

-----  
Summary of Input Soil Properties  
-----

Layer 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	42.0000	82.6000	4000.	--	--	0.00500	--
	w/o Free Water	45.8000	82.6000	4000.	--	--	0.00500	--
2	Weak	45.8000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
	Rock	48.7000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
3	Weak	48.7000	160.0000	--	1150.	100.0000	5.00E-04	179800.
	Rock	55.2000	160.0000	--	1150.	100.0000	5.00E-04	179800.
4	Weak	55.2000	160.0000	--	1150.	91.0000	5.00E-04	179800.
	Rock	57.9000	160.0000	--	1150.	91.0000	5.00E-04	179800.
5	Weak	57.9000	160.0000	--	330.0000	17.0000	5.00E-04	37400.
	Rock	60.3000	160.0000	--	330.0000	17.0000	5.00E-04	37400.
6	Weak	60.3000	150.0000	--	330.0000	86.0000	5.00E-04	37400.
	Rock	100.0000	150.0000	--	330.0000	86.0000	5.00E-04	37400.

-----  
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	42.000	0.7300	1.0000
2	45.800	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	0.000
2	504.000	2126.000

-----  
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  
-----

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	42.0000	0.00	N.A.	No	0.00	226958.
2	45.8000	3.8000	No	Yes	N.A.	N.A.
3	48.7000	6.7000	No	Yes	N.A.	N.A.
4	55.2000	13.2000	No	Yes	N.A.	N.A.
5	57.9000	15.9000	No	Yes	N.A.	N.A.
6	60.3000	18.3000	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	9.4241	-0.00169	-3.02E-06	-0.01863	9.00E-07	1.47E+12	0.00	0.00	7.9725
0.6300	9.2832	227.8287	150.6804	-0.01863	0.1216	1.47E+12	0.00	0.00	31.8900
1.2600	9.1423	2278.	512.3128	-0.01863	1.2157	1.47E+12	0.00	0.00	63.7800
1.8900	9.0015	7974.	1115.	-0.01863	4.2549	1.47E+12	0.00	0.00	95.6700
2.5200	8.8606	19138.	1959.	-0.01863	10.2118	1.47E+12	0.00	0.00	127.5600
3.1500	8.7198	37592.	3044.	-0.01863	20.0588	1.47E+12	0.00	0.00	159.4500
3.7800	8.5789	65159.	4370.	-0.01863	34.7686	1.47E+12	0.00	0.00	191.3400
4.4100	8.4381	103662.	5937.	-0.01863	55.3137	1.47E+12	0.00	0.00	223.2300
5.0400	8.2972	154923.	7745.	-0.01863	82.6666	1.47E+12	0.00	0.00	255.1200
5.6700	8.1564	220766.	9794.	-0.01863	117.8000	1.47E+12	0.00	0.00	287.0100
6.3000	8.0156	303012.	12085.	-0.01863	161.6862	1.47E+12	0.00	0.00	318.9000
6.9300	7.8748	403484.	14616.	-0.01863	215.2980	1.47E+12	0.00	0.00	350.7900
7.5600	7.7340	524006.	17389.	-0.01862	279.6078	1.47E+12	0.00	0.00	382.6800
8.1900	7.5932	666398.	20402.	-0.01862	355.5881	1.47E+12	0.00	0.00	414.5700

8.8200	7.4524	832485.	23657.	-0.01862	444.2116	1.47E+12	0.00	0.00	446.4600
9.4500	7.3117	1024089.	27153.	-0.01861	546.4508	1.47E+12	0.00	0.00	478.3500
10.0800	7.1710	1243033.	30889.	-0.01861	663.2782	1.47E+12	0.00	0.00	510.2400
10.7100	7.0304	1491138.	34867.	-0.01860	795.6664	1.47E+12	0.00	0.00	542.1300
11.3400	6.8898	1770228.	39086.	-0.01859	944.5879	1.47E+12	0.00	0.00	574.0200
11.9700	6.7493	2082125.	43547.	-0.01858	1111.	1.47E+12	0.00	0.00	605.9100
12.6000	6.6089	2428652.	48248.	-0.01857	1296.	1.47E+12	0.00	0.00	637.8000
13.2300	6.4685	2811632.	53190.	-0.01856	1500.	1.47E+12	0.00	0.00	669.6900
13.8600	6.3283	3232887.	58374.	-0.01854	1725.	1.47E+12	0.00	0.00	701.5800
14.4900	6.1882	3694240.	63798.	-0.01852	1971.	1.47E+12	0.00	0.00	733.4700
15.1200	6.0483	4197513.	69464.	-0.01850	2240.	1.47E+12	0.00	0.00	765.3600
15.7500	5.9085	4744529.	75370.	-0.01848	2532.	1.47E+12	0.00	0.00	797.2500
16.3800	5.7689	5337111.	81518.	-0.01845	2848.	1.47E+12	0.00	0.00	829.1400
17.0100	5.6295	5977082.	87907.	-0.01842	3189.	1.47E+12	0.00	0.00	861.0300
17.6400	5.4903	6666263.	94537.	-0.01839	3557.	1.47E+12	0.00	0.00	892.9200
18.2700	5.3514	7406478.	101408.	-0.01835	3952.	1.47E+12	0.00	0.00	924.8100
18.9000	5.2128	8199549.	108520.	-0.01831	4375.	1.47E+12	0.00	0.00	956.7000
19.5300	5.0745	9047299.	115873.	-0.01827	4828.	1.47E+12	0.00	0.00	988.5900
20.1600	4.9366	9951551.	123467.	-0.01822	5310.	1.47E+12	0.00	0.00	1020.
20.7900	4.7990	1.09E+07	131303.	-0.01817	5824.	1.47E+12	0.00	0.00	1052.
21.4200	4.6619	1.19E+07	139379.	-0.01811	6369.	1.47E+12	0.00	0.00	1084.
22.0500	4.5252	1.30E+07	147697.	-0.01804	6948.	1.47E+12	0.00	0.00	1116.
22.6800	4.3890	1.42E+07	156255.	-0.01797	7561.	1.47E+12	0.00	0.00	1148.
23.3100	4.2534	1.54E+07	165055.	-0.01790	8209.	1.47E+12	0.00	0.00	1180.
23.9400	4.1184	1.67E+07	174096.	-0.01782	8893.	1.47E+12	0.00	0.00	1212.
24.5700	3.9841	1.80E+07	183378.	-0.01773	9614.	1.47E+12	0.00	0.00	1244.
25.2000	3.8504	1.94E+07	192901.	-0.01763	10372.	1.47E+12	0.00	0.00	1276.
25.8300	3.7175	2.09E+07	202665.	-0.01753	11170.	1.47E+12	0.00	0.00	1307.
26.4600	3.5854	2.25E+07	212670.	-0.01741	12007.	1.47E+12	0.00	0.00	1339.
27.0900	3.4542	2.41E+07	222916.	-0.01729	12886.	1.47E+12	0.00	0.00	1371.
27.7200	3.3239	2.59E+07	233404.	-0.01716	13806.	1.47E+12	0.00	0.00	1403.
28.3500	3.1947	2.77E+07	244132.	-0.01703	14769.	1.47E+12	0.00	0.00	1435.
28.9800	3.0665	2.96E+07	255102.	-0.01688	15775.	1.47E+12	0.00	0.00	1467.
29.6100	2.9395	3.15E+07	266312.	-0.01672	16827.	1.47E+12	0.00	0.00	1499.
30.2400	2.8137	3.36E+07	277764.	-0.01655	17924.	1.47E+12	0.00	0.00	1531.
30.8700	2.6892	3.57E+07	289457.	-0.01638	19068.	1.47E+12	0.00	0.00	1563.
31.5000	2.5661	3.80E+07	301391.	-0.01619	20259.	1.47E+12	0.00	0.00	1594.
32.1300	2.4444	4.03E+07	313566.	-0.01598	21500.	1.47E+12	0.00	0.00	1626.
32.7600	2.3244	4.27E+07	325982.	-0.01577	22789.	1.47E+12	0.00	0.00	1658.
33.3900	2.2060	4.52E+07	338639.	-0.01554	24130.	1.47E+12	0.00	0.00	1690.
34.0200	2.0894	4.78E+07	351537.	-0.01530	25521.	1.47E+12	0.00	0.00	1722.
34.6500	1.9746	5.05E+07	364676.	-0.01505	26966.	1.47E+12	0.00	0.00	1754.
35.2800	1.8618	5.33E+07	378057.	-0.01478	28464.	1.47E+12	0.00	0.00	1786.
35.9100	1.7511	5.63E+07	391678.	-0.01450	30016.	1.47E+12	0.00	0.00	1818.
36.5400	1.6426	5.93E+07	405541.	-0.01420	31624.	1.47E+12	0.00	0.00	1850.
37.1700	1.5363	6.24E+07	419644.	-0.01389	33288.	1.47E+12	0.00	0.00	1882.
37.8000	1.4325	6.56E+07	433989.	-0.01356	35009.	1.47E+12	0.00	0.00	1913.
38.4300	1.3313	6.89E+07	448575.	-0.01321	36789.	1.47E+12	0.00	0.00	1945.
39.0600	1.2328	7.24E+07	463402.	-0.01285	38628.	1.47E+12	0.00	0.00	1977.
39.6900	1.1370	7.60E+07	478470.	-0.01247	40528.	1.47E+12	0.00	0.00	2009.
40.3200	1.0443	7.96E+07	493779.	-0.01207	42489.	1.47E+12	0.00	0.00	2041.
40.9500	0.9546	8.34E+07	509329.	-0.01165	44512.	1.47E+12	0.00	0.00	2073.
41.5800	0.8682	8.73E+07	525121.	-0.01121	46598.	1.47E+12	0.00	0.00	2105.

42.2100	0.7851	9.14E+07	527907.	-0.01075	48748.	1.47E+12	-1721.	16576.	353.8904
42.8400	0.7057	9.53E+07	516228.	-0.01027	50857.	1.47E+12	-1722.	18449.	0.00
43.4700	0.6299	9.92E+07	503222.	-0.00976	52913.	1.47E+12	-1719.	20626.	0.00
44.1000	0.5580	1.03E+08	490259.	-0.00924	54917.	1.47E+12	-1711.	23175.	0.00
44.7300	0.4902	1.07E+08	477374.	-0.00870	56869.	1.47E+12	-1698.	26190.	0.00
45.3600	0.4264	1.10E+08	464604.	-0.00815	58769.	1.47E+12	-1680.	29792.	0.00
45.9900	0.3670	1.14E+08	418983.	-0.00757	60617.	1.47E+12	-10388.	214002.	0.00
46.6200	0.3120	1.16E+08	335031.	-0.00698	62149.	1.47E+12	-11821.	286456.	0.00
47.2500	0.2615	1.19E+08	240915.	-0.00637	63320.	1.47E+12	-13077.	378064.	0.00
47.8800	0.2156	1.20E+08	138015.	-0.00576	64093.	1.47E+12	-14145.	495894.	0.00
48.5100	0.1745	1.21E+08	27803.	-0.00514	64434.	1.47E+12	-15012.	650485.	0.00
49.1400	0.1380	1.21E+08	-148891.	-0.00451	64317.	1.47E+12	-31733.	1738506.	0.00
49.7700	0.1062	1.19E+08	-391992.	-0.00390	63232.	1.47E+12	-32580.	2318968.	0.00
50.4000	0.07905	1.15E+08	-639559.	-0.00330	61154.	1.47E+12	-32914.	3147854.	0.00
51.0300	0.05635	1.09E+08	-887511.	-0.00272	58072.	1.47E+12	-32682.	4384818.	0.00
51.6600	0.03789	1.01E+08	-1131261.	-0.00218	53994.	1.47E+12	-31802.	6346008.	0.00
52.2900	0.02337	9.17E+07	-1365403.	-0.00168	48945.	1.47E+12	-30140.	9751726.	0.00
52.9200	0.01242	8.05E+07	-1582926.	-0.00124	42978.	1.47E+12	-27406.	1.67E+07	0.00
53.5500	0.00461	6.78E+07	-1772310.	-8.58E-04	36174.	1.47E+12	-22696.	3.72E+07	0.00
54.1800	-5.62E-04	5.37E+07	-1804564.	-5.45E-04	28679.	1.47E+12	14163.	1.90E+08	0.00
54.8100	-0.00364	4.05E+07	-1660894.	-3.03E-04	21615.	1.47E+12	23845.	4.95E+07	0.00
55.4400	-0.00514	2.86E+07	-1448838.	-1.25E-04	15279.	1.47E+12	32254.	4.75E+07	0.00
56.0700	-0.00552	1.86E+07	-1196694.	-2.83E-06	9926.	1.47E+12	34450.	4.72E+07	0.00
56.7000	-0.00518	1.05E+07	-932318.	7.22E-05	5624.	1.47E+12	35490.	5.18E+07	0.00
57.3300	-0.00443	4505508.	-663407.	1.11E-04	2404.	1.47E+12	35650.	6.09E+07	0.00
57.9600	-0.00350	508918.	-442937.	1.24E-04	271.5570	1.47E+12	22675.	4.89E+07	0.00
58.5900	-0.00256	-2191697.	-274760.	1.20E-04	1169.	1.47E+12	21816.	6.45E+07	0.00
59.2200	-0.00169	-3645450.	-114956.	1.05E-04	1945.	1.47E+12	20460.	9.13E+07	0.00
59.8500	-9.75E-04	-3929834.	30064.	8.50E-05	2097.	1.47E+12	17905.	1.39E+08	0.00
60.4800	-4.09E-04	-3190876.	123950.	6.67E-05	1703.	1.47E+12	6932.	1.28E+08	0.00
61.1100	3.35E-05	-2055715.	147787.	5.32E-05	1097.	1.47E+12	-626.0309	1.41E+08	0.00
61.7400	3.95E-04	-956334.	119431.	4.54E-05	510.2967	1.47E+12	-6876.	1.31E+08	0.00
62.3700	7.20E-04	-249918.	63250.	4.23E-05	133.3557	1.47E+12	-7987.	8.39E+07	0.00
63.0000	0.00104	0.00	0.00	4.17E-05	0.00	1.47E+12	-8746.	3.19E+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	=	9.42405547 inches
Computed slope at pile head	=	-0.01863139 radians
Maximum bending moment	=	120753460. inch-lbs
Maximum shear force	=	-1804564. lbs
Depth of maximum bending moment	=	48.51000000 feet below pile head
Depth of maximum shear force	=	54.18000000 feet below pile head
Number of iterations	=	31
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 feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
63.00000	9.42405547	120753460.	-1804564.
59.85000	9.46556104	121543416.	-1801653.
56.70000	11.21033423	120117020.	-2132397.

-----  
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	Load Type 2	Load Type 1	Load Type 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	9.4241	-0.01863	-1804564.	1.21E+08

Maximum pile-head deflection = 9.4240554677 inches  
Maximum pile-head rotation = -0.0186313947 radians = -1.067500 deg.

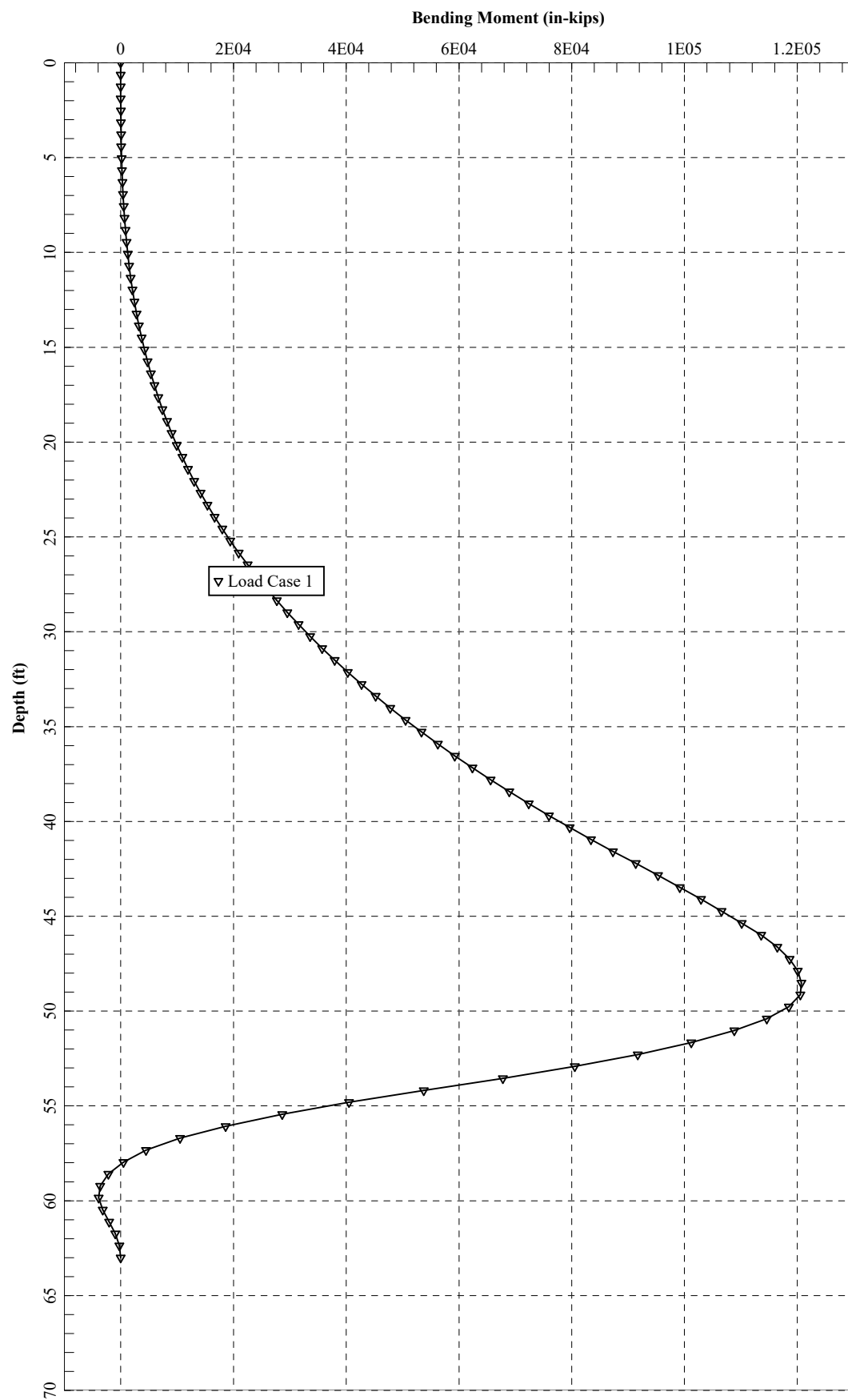
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Summary of Warning Messages  
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The following warning was reported 2178 times

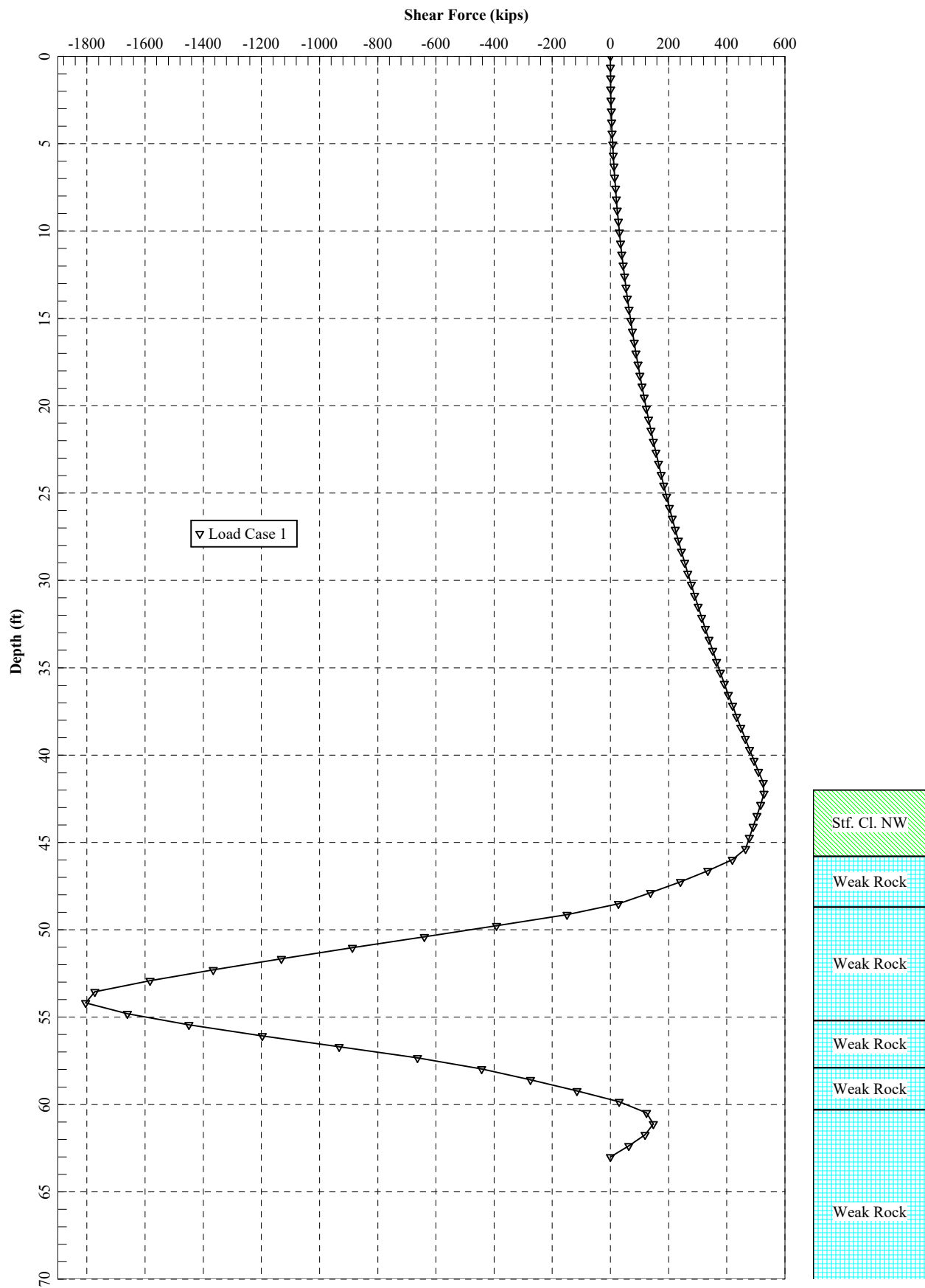
\*\*\*\* Warning \*\*\*\*

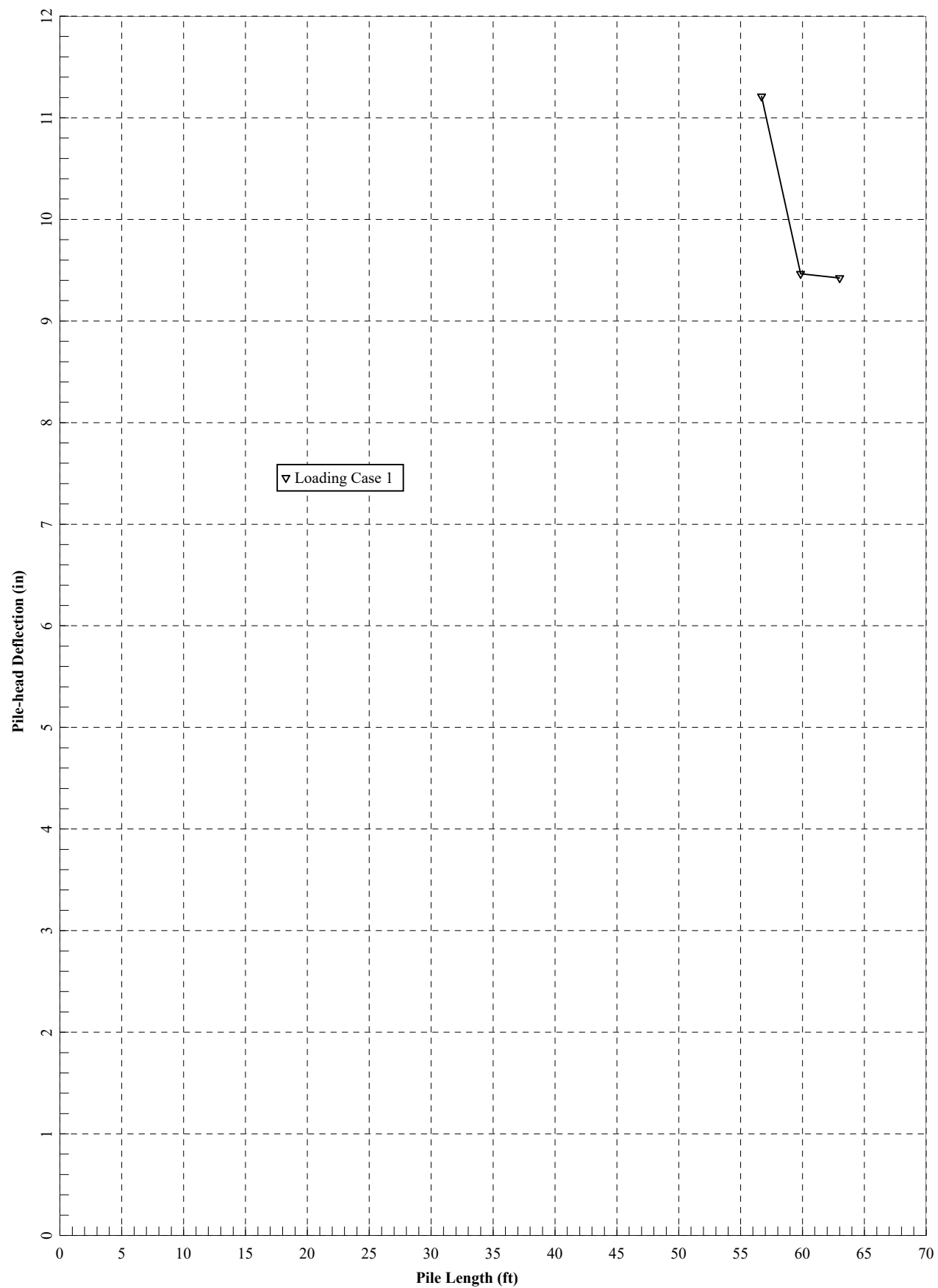
An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.



Stf. Cl. NW
Weak Rock
Weak Rock
Weak Rock
Weak Rock
Weak Rock







## **Shoring Suite Analyses (Soldier Pile and Lagging Wall with Tiebacks)**





## Earth Pressure Determination

## Geometry

Elevation (ft)			Horiz. Distance from C/L (ft)		
Top of Backfill =	865.0	at Bottom of Embankment	Start of Wall Backfill =	50.0	at Bottom of Embankment
Top of Wall =	856.0	at C/L of Wall	Wall =	0.0	at C/L of Wall
Existing Ground Surface =	857.0	at C/L of Wall			
Bottom of Wall =	814.0	at C/L of Wall	Backfill Slope Angle =	5.6	H:1V
Groundwater =	848.5	at C/L of Wall		10.2	degrees

## Wall Loading Profile (B-005-0-23)

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	856.0	5.8	115	23	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	1.7	65	21	115
Layer 1 Soft to Medium Stiff Cohesive	848.5	3.3	65	21	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	10.0	115	23	140
Layer 3 Stiff to Very Stiff Cohesive	835.2	20.0	175	25	135
Hard Cohesive	815.2	1.2	250	28	145
Bottom of Wall/Maintenance Bench	814.0				
Weighted Value		42.0	140	24	85

## Earth Pressure Coefficients

	Deg	
Shear Resistance, $\Phi$ =	26	
Wall Friction, $\delta^A$ =	0.0	
Wall Slope, $\theta$ =	90	
Backfill Slope, $\beta$ =	10.20	
Revised Backfill Slope, $\beta$ =	10.20	
Backfill Condition	INFINITE	
Horz. Backslope Dist.	50.0	feet (C/L of Wall - Edge of Shoulder)
Wall Height (H)	42.0	feet (Top of Wall - Maintenance Bench)
Slope Height (h)	9.0	feet (Top of Backfill - Top of Wall)
$I$ =	6.12	degrees

### Notes:

- Wall friction neglected
- Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).
- The wall retained soil will consist of existing cohesive overburden. Using the soil layer thicknesses and respective soil parameters, a weighted average was determined and assumed for the entire profile ( $c' = 140$  psf and  $\phi' = 24^\circ$ ). The parameters were converted to equivalent soil strength parameters  $c' = 0$  psf and  $\phi' = 26^\circ$  for checking tieback lengths based on a 1 degree increase in friction angle for every 50 psf decrease in cohesion up to 150 psf (Ref: Hall's Thesis).

## Shoring Suite Design Profile

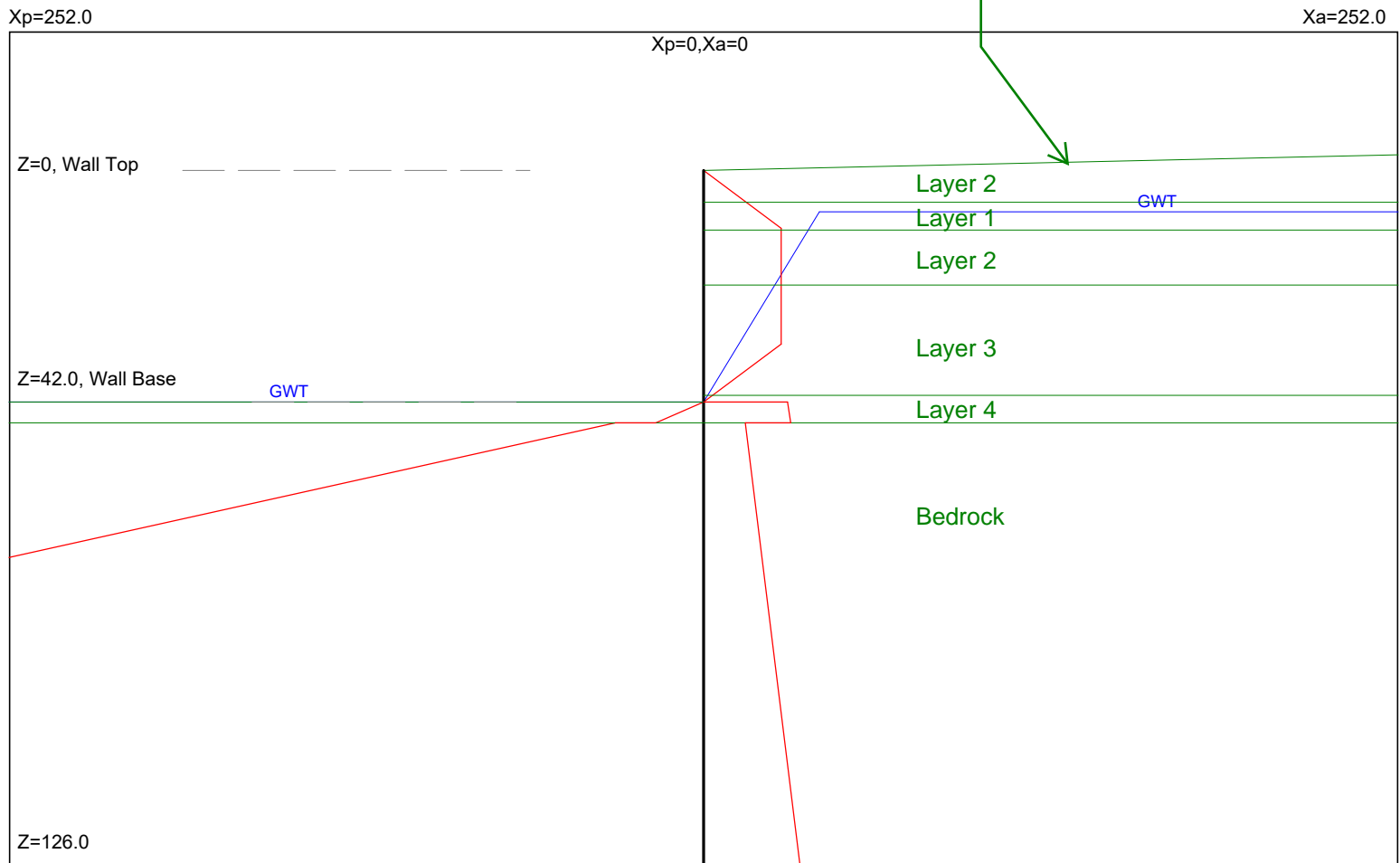
	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	856.0	0.0	0	25	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	5.8	0	22	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	10.8	0	25	140
Layer 3 Stiff to Very Stiff Cohesive	835.2	20.8	0	28	135
Layer 4 Hard Cohesive	815.2	40.8	0	31	145
Bedrock	810.2	45.8	0	45	150

Depths referenced below the top of wall. Friction angles reflect adjustments made per Hall's Thesis. Bedrock modeled as very dense gravel.

Earth pressures generated using service loading.

**WAS-77-9.58**

5.6H:1V Backslope



<EarthPres> CIVILTECH SOFTWARE www.civiltech.com \* Licensed to 4324324234 3424343  
 UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf  
 Date: 9/6/2023 File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Wall Tieback.ep8

### \* INPUT DATA \*

Wall Height=42.0 Total Soil Types= 5

Soil No.	Weight	Saturate	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
2	140.0	145.0	25	0.0	11	1	2. Medium St
3	135.0	140.0	28	0.0	24	1	3. Stiff to
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
5	150.0	155.0	45	0.0	100	5	Bedrock

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.	Description
1	0.0	0.0	-9.0	800.0	2	2. Medium St
2	5.8	0.0	5.8	800.0	1	1. Soft to M
3	10.8	0.0	10.8	800.0	2	2. Medium St
4	20.8	0.0	20.8	800.0	3	3. Stiff to
5	40.8	0.0	40.8	800.0	4	4. Hard Cohe
6	45.8	0.0	45.8	800.0	5	Bedrock

Water Table at Active Side:

Point	Z-water	X-water
1	42.0	0.0
2	7.5	42.0
3	7.5	800.0

Bedrock modeled as dense gravel to generate active pressures.

### Soil Layers in Front of Wall

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.	Description
1	42.0	0.0	42.0	800.0	4	4. Hard Cohe
2	45.8	0.0	45.8	800.0	5	Bedrock

### Water Depth in Front of Wall

Water Table at Passive Side:

Point	Z-water	X-water
1	42.0	0.0
2	42.0	800.0

Wall Friction Options: 1.\* No wall friction

Wall Batter Angle = 0

Apparent Pressure Conversion: 1.\* Default (Terzaghi and Peck)\*

Water Density = 62.4

Water Pressure: 1.\* No seepage at wall tip

### \* OUTPUT RESULTS \*

Total Force above Base= 44.25 per one linear foot (or meter) width along wall height

Total Static Force above Base= 44.25. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Driving Pressure above Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Coef.
0.00	0.00	10.50	1.69	0.1606	1.1468
10.50	1.69	31.50	1.69	0.0000	0.0000
31.50	1.69	42.00	0.00	-0.1606	-1.1893

Driving Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Ka or Ko
42.00	1.82	45.80	1.89	0.0179	0.2043
45.80	0.90	126.00	2.09	0.0148	0.1597

Passive Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pp1	Z2	Pp2	Slope	Kp
42.00	0.00	45.80	1.04	0.274	3.1247
45.80	1.92	126.00	45.25	0.540	5.8355

Passive pressures below 45.8 feet manually adjusted in shoring module to reflect claystone strength.

UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

Date: 9/6/2023 File Name: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Wall Tieback.ep8

\*\*\*\*\*

EARTH PRESSURE ANALYSIS SUMMARY  
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Date: 9/6/2023 File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Wall  
Tieback.ep8

Title 1: WAS-77-9.58  
Title 2:

Input data: \*\*\*\*\*

Wall Height = 42.00  
Depth of Ground at Active Side = 0.00  
Depth of Ground at Passive Side = 42.00  
Apparent Pressure Envelope: 4. 2-Trapezoid Envelope (Braced, Stiff Clay)  
Pressure Type: 1.\* Active, Ka  
Earthquake Loading Apply to: 1. No Earthq. Loads  
Earthquake Horizontal Acceleration, Kh = 0  
Earthquake Vertical Acceleration, Kv = 0  
Calculation Methods: 1.\* Numerical Solution (Wedge Analysis)  
Wall Friction Options: 1.\* No wall friction  
Wall Batter Angle = 0  
Apparent Pressure Conversion: 1.\* Default (Terzaghi and Peck)\*  
Water Density = 62.4  
Water Pressure: 1.\* No seepage at wall tip  
User's Settings  
Ignore Passive from Depth = 0  
Multiplier of Active Pressure = 1  
Multiplier of Passive Pressure = 1  
Multiplier of Water Pressure = 1  
Multiplier of Earthq. Pressure = 1  
Estimated Embedment: Shallow: 3H  
Program's Settings  
Max. Height, Hmax = 400.00  
Analysis Segment, dz = 1.05  
No. of Active Segment at H, nz0 = 5  
No. of Active Segment at Hmax, nz = 7  
No. of Passive Segment, nzp = 2  
Active Depth at H, Zh = 42.00  
Active Depth at Hmax, Z = 400.00  
Passive Depth at Hmax, Zp = 400.00  
Max. Pressure = 196.25

Total Soil Types= 5

Soil	Weight	W(S)	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
>	115.0	120.0	22.0	0.0	5	1	Converted
2	140.0	145.0	25	0.0	11	1	2. Medium St
>	140.0	145.0	25.0	0.0	11	1	Converted
3	135.0	140.0	28	0.0	24	1	3. Stiff to
>	135.0	140.0	28.0	0.0	24	1	Converted
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
>	145.0	150.0	31.0	0.0	65	1	Converted
5	150.0	155.0	45	0.0	100	5	Bedrock

Soil Type: 1 Equivalent Clay; 2 Clay; 3 Silt; 4 Sand; 5 Gravel

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.
1	0.0	0.0	-9.0	800.0	2
2	5.8	0.0	5.8	800.0	1
3	10.8	0.0	10.8	800.0	2
4	20.8	0.0	20.8	800.0	3
5	40.8	0.0	40.8	800.0	4
6	45.8	0.0	45.8	800.0	5

Water Table at Active Side:

Point	Z-water	X-water
1	42.0	0.0
2	7.5	42.0
3	7.5	800.0

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.
1	42.0	0.0	42.0	800.0	4
2	45.8	0.0	45.8	800.0	5

Water Table at Passive Side:

Point	Z-water	X-water
1	42.0	0.0
2	42.0	800.0

Output data: \*\*\*\*\*

Total Force above Base= 44.25 per one linear foot (or meter) width along wall height

Static Force above Base= 44.25. Distributed in Apparent Envelope along wall height.  
Ignore soil layers and water line

Apparent Pressure above Base - Output to Shoring

Active/At-Rest Force above Base, Ea = 44.25

No	Z1	P1	Z2	P2	Slope	Coef.
0	0.0	0.00	10.5	1.69	0.1606	1.1468
1	10.5	1.69	31.5	1.69	0.0000	0.0000

2            31.5       1.69       42.0       0.00       -0.1606 -1.1893

Driving Pressure below Base - Output to Shoring

No           Z1           P1           Z2           P2           Slope    Ka or Ko

0           42.0       1.82       45.8       1.89       0.0179 0.2043

1           45.8       0.85       400.0      6.59       0.0162 0.1747

Passive Pressure below Base - Output to Shoring

No           Z1           P1           Z2           P2           Slope    Kp

0           42.0       0.00       45.8       1.04       0.2737 3.1247

1           45.8       0.91       400.0      196.25    0.5515 5.9557

Passive pressures below 45.8 feet manually adjusted in shoring module to reflect claystone strength.

\*\*\*\*\*

DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

Z, Xa, Xp - Coordinates of ground lines

Z- Depth measured from wall top

Xa - Distance measure from wall to active side.

Xp - Distance measure from wall to passive side

Z1, P1, Z2, P2 - Four values to define a pressure diagram

Z1- Top depth of the diagram

P1- Top pressure of the diagram

Z2- Bottom depth of the diagram

P2- Bottom pressure of the diagram

Slope -  $(P2-P1)/(Z2-Z1)$ , Slope of the diagram. It also called Equivalent fluid density.

Coef. - Pressure Coefficient = Slope/Unit Weight

Ka - Active Earth Pressure Coefficient

Ko - At-Rest Earth Pressure Coefficient

Kp - Passive Earth Pressure Coefficient



## Steel Beam and Cross-Section Properties

Assumed Pile Shape **HP 14x73**

### Pile Availability

AISC Member Producers	<b>3</b>
Non-Member Producers	<b>0</b>

### Shaft Geometry

Shaft Diameter	<b>30</b>	in
Longest Beam Dimension	<b>19.952945</b>	in
Clear Distance	<b>5.0235277</b>	in

### Steel Beam Geometry

Beam Depth (D)	<b>13.6</b>	in
Web Thickness (t <sub>w</sub> )	<b>0.505</b>	in
Flange Width (B <sub>f</sub> )	<b>14.6</b>	in
Flange Thickness (t <sub>f</sub> )	<b>0.505</b>	in
Area of Steel (A <sub>s</sub> )	<b>21.4</b>	in <sup>2</sup>

### Steel Properties

Yield Strength of Steel	<b>50</b>	ksi
Moment of Inertia (I <sub>xx</sub> ) of Steel	<b>729</b>	in <sup>4</sup>
Modulus of Elasticity of Steel (E)	<b>29000</b>	ksi
Modulus of Elasticity of Steel (E)	<b>29000000</b>	psi
EI (Steel Only)	<b>2.114E+10</b>	lb*in <sup>2</sup>
Section Modulus (S <sub>x</sub> )	<b>107</b>	in <sup>3</sup>
Section Modulus (Z <sub>x</sub> )	<b>118</b>	in <sup>3</sup>
Shear-Buckling Coefficient (k)	<b>5</b>	
Ratio of Shear-Buckling Resistance (C)	<b>1</b>	
D/t <sub>w</sub>	<b>26.930693</b>	
1.12VEk/F <sub>yw</sub>	<b>60.313846</b>	
1.40VEk/F <sub>yw</sub>	<b>75.392307</b>	

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

$$V_u \leq \phi V_{cr}$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$
$$V_{cr} = \text{shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)}$$
$$V_n = V_{cr} = C V_p$$
$$V_p = 0.58 F_{yw} D t_w$$
$$V_p = \text{plastic shear force (kips)}$$
$$C = \text{ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6}$$
$$V_p = 0.58 * 50 * 13.6 * 0.505$$
$$V_p = \boxed{199.2} \text{ kips}$$
$$\phi V_{cr} = \phi * C * V_p$$
$$\phi V_{cr} = 1 * 1 * 199.2$$
$$\phi V_{cr} = \boxed{199.2} \text{ kips}$$
$$V_u = \boxed{99.42} \text{ kips (from Shoring Suite)}$$
$$\boxed{\phantom{000}} \text{ kips (from PYWALL)}$$
$$V_u < \phi V_{cr} \quad \text{OK}$$

### Flexure Capacity Calculation

$$M_u \leq \phi M_n$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$M_u = \text{Moment due to the factored loads}$$
$$M_n = \text{Nominal flexural resistance of a section}$$
$$S_x = \text{Elastic section modulus about the x-axis}$$
$$\phi M_n = \phi * F_y * S_x$$
$$\phi M_n = 1 * 50 * 107$$
$$\phi M_n = \boxed{5350} \text{ in*kips}$$
$$M_u = \boxed{2866.7} \text{ in*kips (from Shoring Suite)}$$
$$M_u = \boxed{\phantom{000}} \text{ in*kips (from PYWALL)}$$
$$M_u < \phi M_n \quad \text{OK}$$

### Deflection Criteria

Pile Length Above Rock =	<b>45.8</b>	ft	Exposed Wall Height =	<b>42</b>	ft
Pile Length Above Rock =	<b>549.6</b>	in	Exposed Wall Height =	<b>504</b>	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

**5.496**

in

$\delta = \boxed{0.3}$  in (from LPILE)

1.5% Wall Height - PYWALL

in

$\delta = \boxed{\phantom{000}}$  in (from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement

**NO**

## Tieback Loading Computations

Design Tieback Load, TF1 = 197.8 kips / shaft  
 Design Tieback Load, TF2 = 127.6 kips / shaft  
 Design Tieback Load, TF3 = 154.7 kips / shaft

Horizontal values determined from Shoring Suite calculations.

### 1) Determine Tiebacks

Strands

0.6 GUTS per strand = 35.2 kips per strand (FHWA-NHI-07-071: Table 8-16)

(GUTS = guranteed ultimate tensile strength)

Tieback	Inclin.	Required Anchor Load**	Strands	
No.	deg	kips	Required	Selected
1	20	210.5	6.0	6.0
2	20	135.8	3.9	4.0
3	20	164.6	4.7	5.0

\*\*Required Anchor Load = (TF) / [Cos (Inclin. Angle)]

### 2) Check Pull-Out Capacity and Bond Length

Pullout Resistance Factor  $\phi_{pr}$  = 0.7 Per AASHTO LRFD Table 11.5.7-1 for "Pullout resistance of anchors, cohesive soils"

Soil Friction Angle  $\phi$  = 26

Table 8-16. Properties of 0.6 in. Diameter Prestressing Steel Strands (ASTM A416, Grade 270).

Number of 0.6 in. diameter strands	Cross section area (in. <sup>2</sup> )	Ultimate strength (=GUTS) (kips)	Prestressing force		
			0.8 $f_{pu}A_{ps}$ (kips)	0.7 $f_{pu}A_{ps}$ (kips)	0.6 $f_{pu}A_{ps}$ (kips)
1	0.217	58.6	46.9	41.0	35.2

Tieback	Height Above Bottom of Wall	Tieback Length to Active Wedge	Total Unbonded Length	Ultimate Bond Strength	Tieback Drill Hole Diameter	Surface Area per Foot of Tieback	Allowable Bond Strength per Foot of Tieback	Required Anchor Load	Required Bond Length	Total Tieback Length
No.	ft	ft	ft	ksf	in	in <sup>2</sup> /ft	kips/ft	kips	ft	ft
1	32	17.4	32	3	9	339.3	4.95	210.5	43	75
2	22	11.9	26	3	9	339.3	4.95	135.8	27	54
3	12	6.5	21	3	9	339.3	4.95	164.6	33	55

Total unbonded length = Tieback length to active wedge + greater of 5 feet or H/3, with a 15 foot minimum, per AASHTO LRFD Figure 11.9.1-1

Ultimate bond strength per AASHTO LRFD Table C11.9.4.2-1. Tieback lengths assume entire bond length is in clay.

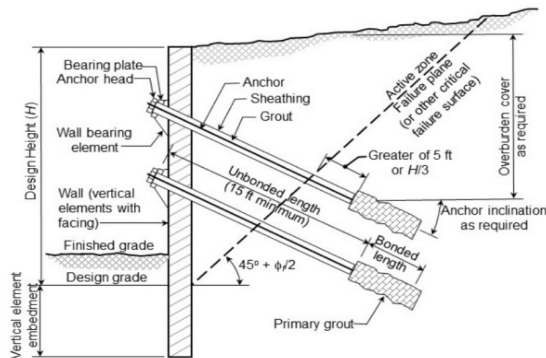


Figure 11.9.1-1—Anchored Wall Nomenclature and Anchor Embedment Guidelines

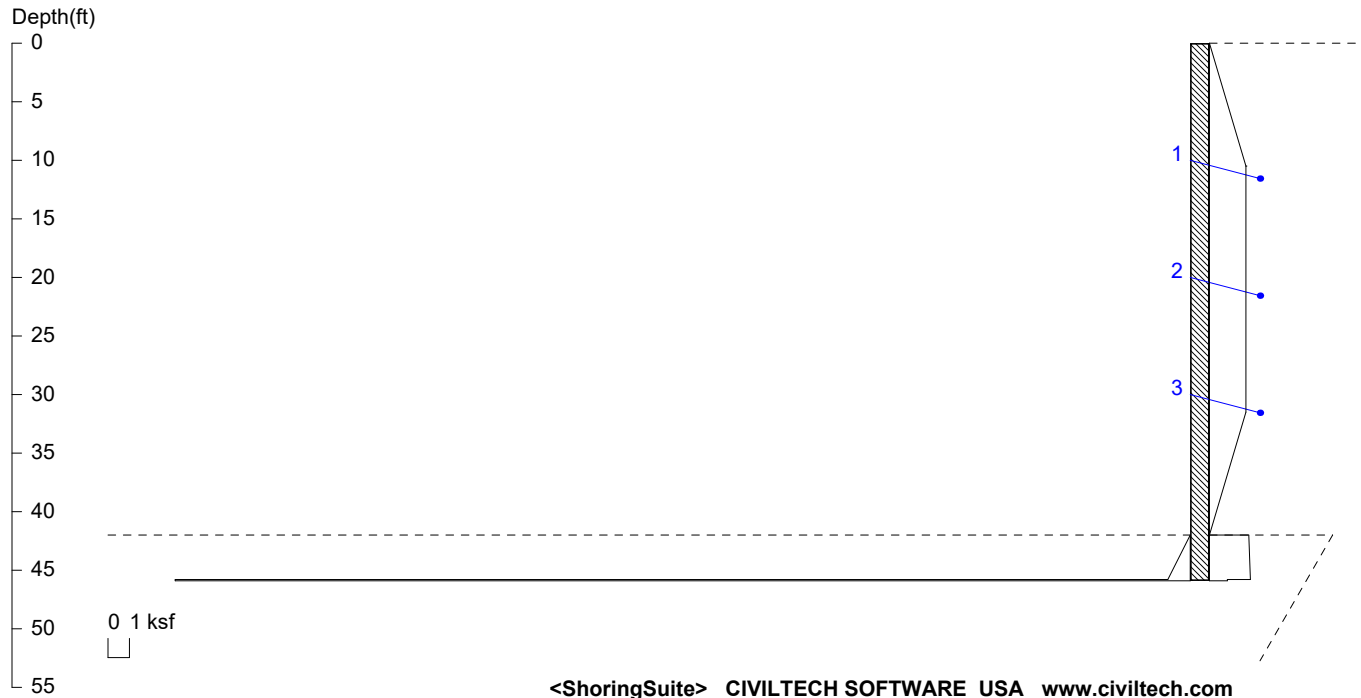
Table C11.9.4.2-1—Presumptive Ultimate Unit Bond Stress for Anchors in Cohesive Soils

Anchor/Soil Type (Grout Pressure)	Soil Stiffness or Unconfined Compressive Strength (tsf)	Presumptive Ultimate Unit Bond Stress, $\tau_u$ (ksf)
Gravity Grouted Anchors (<50 psi)		
Silt-Clay Mixtures	Stiff to Very Stiff 1.0–4.0	0.6 to 1.5
Pressure Grouted Anchors (50 psi–400 psi)		
High Plasticity Clay	Stiff 1.0–2.5 V. Stiff 2.5–4.0	0.6 to 2 1.5 to 3.6
Medium Plasticity Clay	Stiff 1.0–2.5 V. Stiff 2.5–4.0	2.0 to 5.2 2.9 to 7.3
Medium Plasticity Sandy Silt	V. Stiff 2.5–4.0	5.8 to 7.9



## Service Limit Analysis (Soldier Pile and Lagging Wall with Tiebacks)

# WAS-77-9.58



Licensed to 4324324234 3424343

Date: 9/7/2023

File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Main Wall Tieback Service.sh8

Wall Height=42.0

Pile Diameter=2.5

Pile Spacing=6.0

Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=3.90 (5~10ft is recommended!!!) Min. Pile Length=45.90

MOMENT IN PILE: Max. Moment=160.02 per Pile Spacing=6.0 at Depth=10.01

## PILE SELECTION:

Request Min. Section Modulus = 38.4 in<sup>3</sup>/pile=629.32 cm<sup>3</sup>/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X73 has Section Modulus = 107.0 in<sup>3</sup>/pile=1753.41 cm<sup>3</sup>/pile. It is greater than Min. Requirements!

Top Deflection = 0.30(in) based on E (ksi)=29000.00 and I (in<sup>4</sup>)/pile=729.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L_free	Fixed Length
1. Tieback	10.0	20.0	6.0	140.3*	131.9	48.0	25.5	28.4
2. Tieback	20.0	20.0	6.0	89.4	84.0	30.6	20.4	18.1
3. Tieback	30.0	20.0	6.0	111.2	104.5	38.0	15.3	22.5

\* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

## DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE):

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	10.50	1.686	0.160554
10.50	1.686	31.50	1.686	0.000000
31.50	1.686	42.00	0.000	-0.16055
*	Below	Base		
42.00	1.822	45.80	1.890	0.017893
45.80	0.823	252.0	4.227	0.016508

## PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		

42.00	0.000	45.80	1.040	0.273724
45.80	47	252.0	47	0.0000

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	42.00	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	42.00	5.00

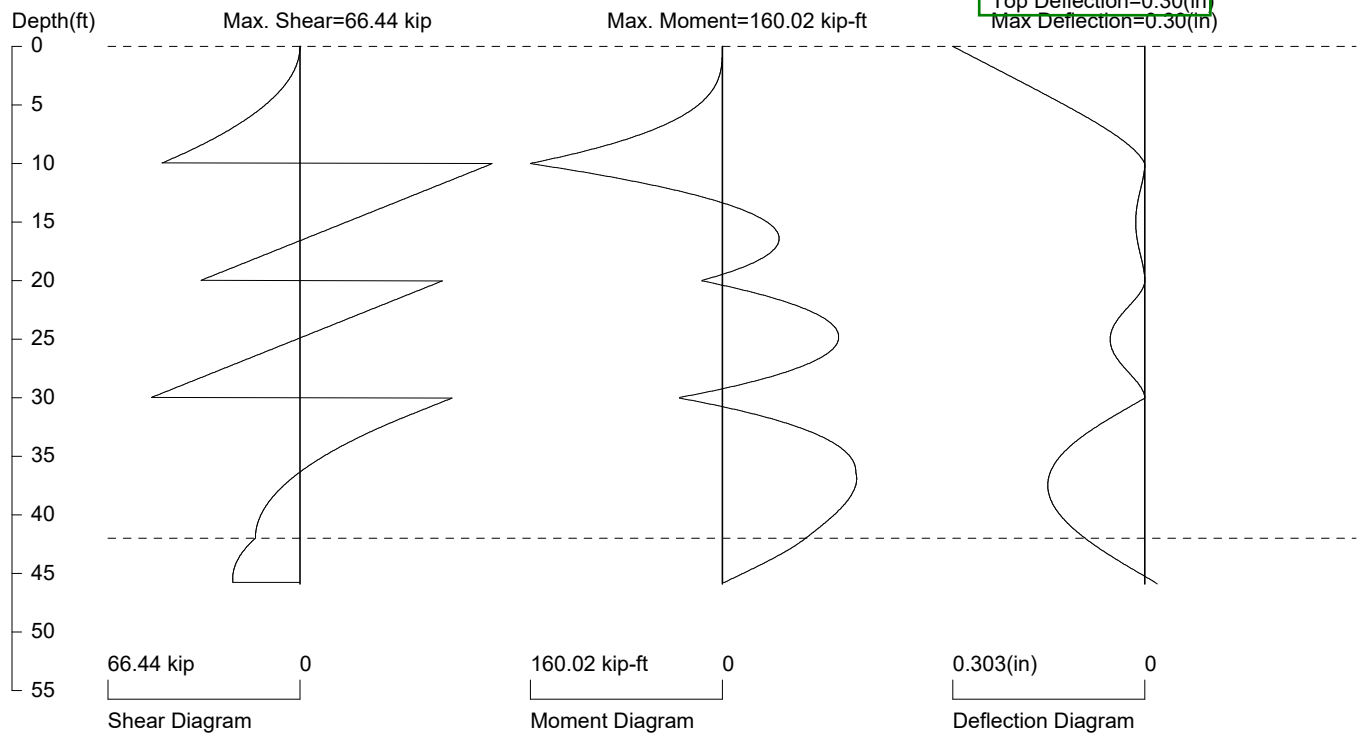
Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft  
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft<sup>3</sup>; Deflection - in

# WAS-77-9.58



Pile head deflection =



## PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14X73: E (ksi)=29000.0, I (in<sup>4</sup>)/pile=729.0

File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Main Wall Tieback Service.sh8

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\*\*\*\*\*

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ShoringSuite Software is developed by CivilTech Software, Bellevue, WA, USA.

The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf, Pres. Slope - kip/ft<sup>3</sup>, Deflection - in

-----  
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Date: 9/7/2023 File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Main Wall Tieback Service.sh8

Title: WAS-77-9.58

Subtitle:

\*\*\*\*\*INPUT DATA\*\*\*\*\*

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 42.00

Pile Diameter: 2.50

Pile Spacing: 6.00

Factor of Safety (F.S.): 1.00

As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback



Top Brace Increase (Multi-Bracing): Add 15%\*

No-Load Zone:

Vertical Depth for No-Load Zone: 42.00

H-Distance (Input H/V ratio) for No-Load Zone: 0.25

Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes

Friction at Pile Tip: No

Pile Properties:

Steel Strength, Fy: 50 ksi = 345 MPa

Allowable Fb/Fy: 1

Elastic Module, E: 29000.00

Moment of Inertia, I: 729.00

User Input Pile: HP14X73

\* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) \*

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	10.50	1.686	0.160554
3	10.50	1.686	31.50	1.686	0.000000
4	31.50	1.686	42.00	0.000	-0.16055
5	*	Below	Base		
6	42.00	1.822	45.80	1.890	0.017893
7	45.80	0.823	252.0	4.227	0.016508

\* PASSIVE PRESSURE \*

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	42.00	0.000	45.80	1.040	0.273724
3	45.80	47	252.0	47	0.0000

\* ACTIVE SPACE \*

No.	Z depth	Spacing
1	0.00	6.00
2	42.00	2.50

\* PASSIVE SPACE \*

No.	Z depth	Spacing
1	42.00	5.00

Hole diameter in feet  
(9 inches).

Allowable bond strength =  
resistance factor \* ultimate  
bond strength =  $0.7 \times 3$  ksf

\* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR\*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	10.00	20.0	6.00	0.75	2.10	Tieback
2	20.00	20.0	6.00	0.75	2.10	Tieback
3	30.00	20.0	6.00	0.75	2.10	Tieback

\*For Tieback: Input1 = Diameter; Input2 = Bond Strength

\*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

\*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

\*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

\*\*\*\*\*CALCULATION\*\*\*\*\*

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

\* CALCULATE REQUEST EMBEDMENT \*

```

| <-- D1=30.00
|
==|== D2=42.00
|
| D3=45.90

```

D1 - TOP DEPTH

R1 - TOP REACTION

D2 - EXCAVATION BASE

D3 - PILE TIP

TOTAL REACTION: R1 = 52.17  
TOTAL PRESSURES ACTING ON WALL = 52.17  
Total Reactions = Total Pressures, OK!  
The Calculated Embedment, Yend = 3.90

-----MULTIPLE BRACE / TIEBACK CASE-----  
\*\* Use the calculated embedment, Yend = 3.90 for graphics and analysis.

NUMBER OF BRACE LEVEL= 3

\* CANTILEVER SPAN, N0.0 \*

	D1=0.00	
<--	D2=10.00	R2=48.17, with Cantilever Moment=160.55

D1 - TOP DEPTH  
D2 - BOTTOM DEPTH                      R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 48.17  
TOTAL PRESSURES ACTING ON WALL = 48.17  
Total Reactions = Total Pressures, OK!

---

BRACE NO.1 AT DEPTH = 10.00  
R2 of Cantilever Span                      } Sum of Reaction = Brace Load = 114.68  
R1 of Span No.1

---

\* MIDDLE SPAN NO.1 \*

<--	D1=10.00	R1=66.52, with Cantilever Moment=160.55
<--	D2=20.00	R2=34.52

D1 - TOP DEPTH                      R1 - TOP REACTION  
D2 - BOTTOM DEPTH                R2 - BOTTOM REACTION

TOTAL REACTION:  $R1+R2 = 101.04$   
TOTAL PRESSURES ACTING ON WALL =  $101.04$   
Total Reactions = Total Pressures,      OK!

---

BRACE NO.2 AT DEPTH =  $20.00$   
R2 of Span No.1  
R1 of Last Span                      } Sum of Reaction = Brace Load =  $84.00$

---

\* LAST SPAN \*

| <-- D1= $20.00$                       R1= $49.48$   
|  
| <-- D2= $30.00$                       R2= $104.52$   
|  
| D3= $45.90$

D1 - TOP DEPTH                      R1 - TOP REACTION  
D2 - LAST BRACE DEPTH          R2 - LAST BRACE REACTION  
D3 - BOTTOM DEPTH

TOTAL REACTION:  $R1+R2 = 154.00$   
TOTAL PRESSURES ACTING ON WALL =  $154.00$   
Total Reactions  $\geq$  Total Pressures,      OK!

---

BRACE NO.3 AT DEPTH =  $30.00$   
R2 of Last Span = Brace Load =  $104.52$

---

\*\*\*\*\*RESULTS\*\*\*\*\*

\* EMBEDMENT \*

MINIMUM EMBEDMENT = 3.90 (5~10ft recommended!!!), TOTAL MINIMUM PILE LENGTH = 45.90

\* MOMENT IN PILE (per pile spacing)\*

Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	10.00	160.02	47.30	16.39
2	20.00	17.19	96.86	24.76
3	30.00	35.70	111.90	36.92

Overall Maximum Moment = 160.02 at 10.01

Maximum Shear = 66.44

Moment and Shear are per pile spacing: 6.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 114.68 to 131.89

\* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR\*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	10.00	20.0	6.00	131.89	48.00	140.35
2	20.00	20.0	6.00	84.00	30.57	89.40
3	30.00	20.0	6.00	104.52	38.04	111.23

No.	DEPTH	Free length	Brace Type
1	10.00	25.48	Tieback, Bond length = 28.36
2	20.00	20.40	Tieback, Bond length = 18.07
3	30.00	15.33	Tieback, Bond length = 22.48

\* VERTICAL LOADING \*

Vertical Loading from Braces = 116.62

Vertical Loading from External Load = 0.00

Total Vertical Loading = 116.62

\*\*\*\*\*SPECIFIED PILE \*\*\*\*\*

Overall Maximum Moment = 160.02 at 10.01

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 38.40 in<sup>3</sup>/pile = 629.32 cm<sup>3</sup>/pile,  $F_y = 50 \text{ ksi} = 345 \text{ MPa}$ ,  $F_b/F_y = 1$

HP14X73 has been found in Soldier Pile list!

(English Units):

Area= 21.4 in. Depth= 13.6 in. Width= 14.6 in. Height= 14 in.

Flange thickness= 0.505 in. Web thickness= 0.505 in.

$I_x = 729 \text{ in}^4/\text{pile}$   $S_x = 107 \text{ in}^3/\text{pile}$   $I_y = 261 \text{ in}^4/\text{pile}$   $S_y = 35.8 \text{ in}^3/\text{pile}$

(Metric Units):

$I_x = 303.41 \times 100 \text{ cm}^4/\text{pile}$   $S_x = 1753.41 \text{ cm}^3/\text{pile}$   $I_y = 108.63 \times 100 \text{ cm}^4/\text{pile}$   $S_y = 586.65 \text{ cm}^3/\text{pile}$

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X73 is capable to support the shoring!

Top deflection = 0.303(in)

Max. deflection = 0.303(in)

\*\*\*\*\* LAGGING SIZE ESTIMATION \*\*\*\*\*

Max. Pressure above base = 1.69

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 0.84

Pile Spacing = 6.0, Max. Moment in lagging = 3.79

For 4"x12" Timber, Section Modules  $S = 23.47 \text{ in}^3$ . The request allowable bending strength,  $f_b = M/S = 1.94$

For 6"x12" Timber, Section Modules  $S = 57.98 \text{ in}^3$ . The request allowable bending strength,  $f_b = M/S = 0.79$

If 30% loading is used for lagging design, Design Pressure = 0.51

Pile Spacing = 6.0, Max. Moment in lagging = 2.28

For 4"x12" Timber, Section Modules  $S = 23.47 \text{ in}^3$ . The request allowable bending strength,  $f_b = M/S = 1.16$

For 6"x12" Timber, Section Modules  $S = 57.98 \text{ in}^3$ . The request allowable bending strength,  $f_b = M/S = 0.47$

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi





## Strength Limit Analysis (Soldier Pile and Lagging Wall with Tiebacks)

# WAS-77-9.58



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Date: 9/7/2023

File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Main Wall Tieback Stren

Anchor loads and lengths

Wall Height=42.0 Pile Diameter=2.5 Pile Spacing=6.0 Wall Type: 2. Soldier File, Drilled

PILE LENGTH: Min. Embedment=3.97 (5~10ft is recommended!!!) Min. Pile Length=45.97

MOMENT IN PILE: Max. Moment=238.89 per Pile Spacing=6.0 at Depth=9.97

## PILE SELECTION:

Request Min. Section Modulus = 57.3 in<sup>3</sup>/pile=939.53 cm<sup>3</sup>/pile, F<sub>y</sub>= 50 ksi = 345 MPa, F<sub>b</sub>/F<sub>y</sub>=1

HP14X102 has Section Modulus = 150.0 in<sup>3</sup>/pile=2458.05 cm<sup>3</sup>/pile. It is greater than Min. Requirements!

Top Deflection = 0.32(in) based on E (ksi)=29000.00 and I (in<sup>4</sup>)/pile=1050.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	Unbonded Length	Bonded Length
1. Tieback	10.0	20.0	6.0	210.5*	197.8	72.0	25.5	42.5
2. Tieback	20.0	20.0	6.0	135.8	127.6	46.4	20.4	27.4
3. Tieback	30.0	20.0	6.0	164.6	154.7	56.3	15.3	33.3

\* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE): Pressures below will be multiplied by a Factor =1.5

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	10.50	1.686	0.160554
10.50	1.686	31.50	1.686	0.000000
31.50	1.686	42.00	0.000	-0.16055
*	Below	Base		
42.00	1.822	45.80	1.890	0.017893
45.80	0.823	252.0	4.227	0.016508

Applied 1.5 load factor for active earth pressures.

## PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		

42.00	0.000	45.80	1.040	0.273724
45.80	47	252.0	47	0.0000

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	42.00	2.50

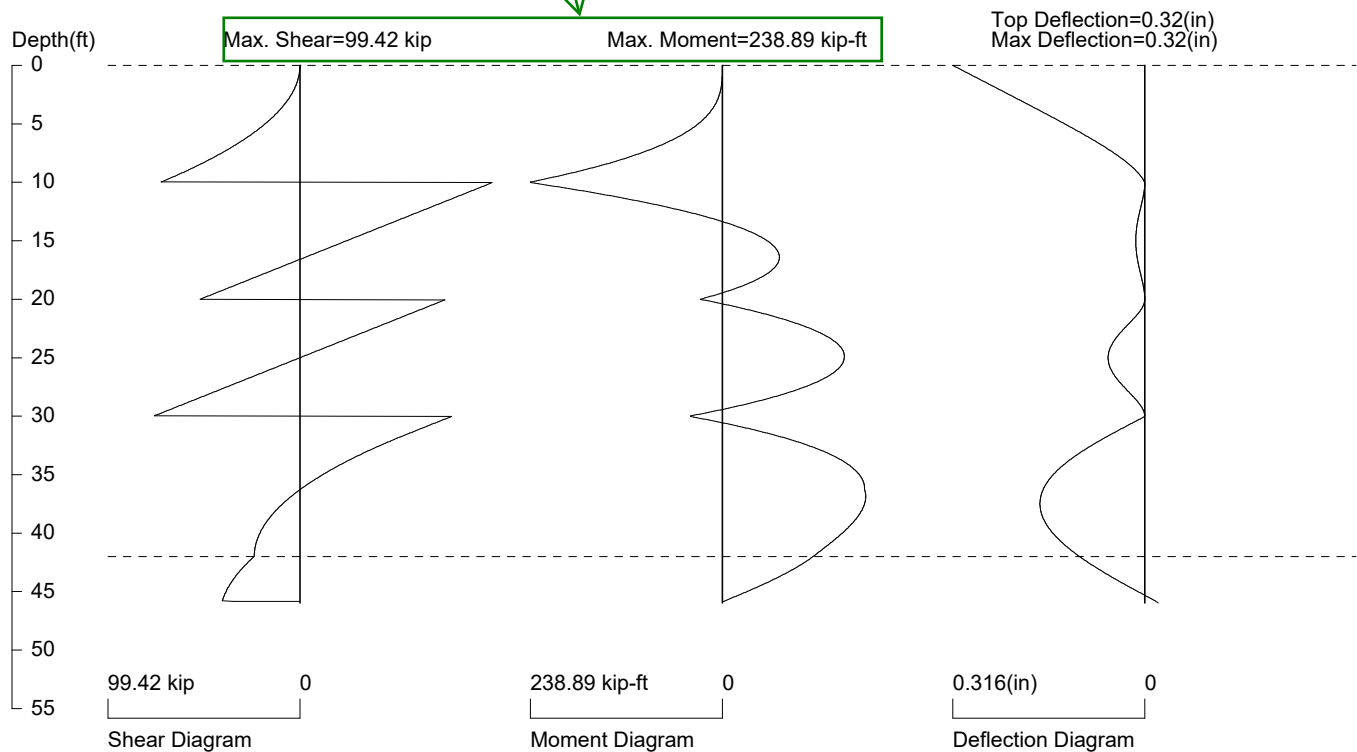
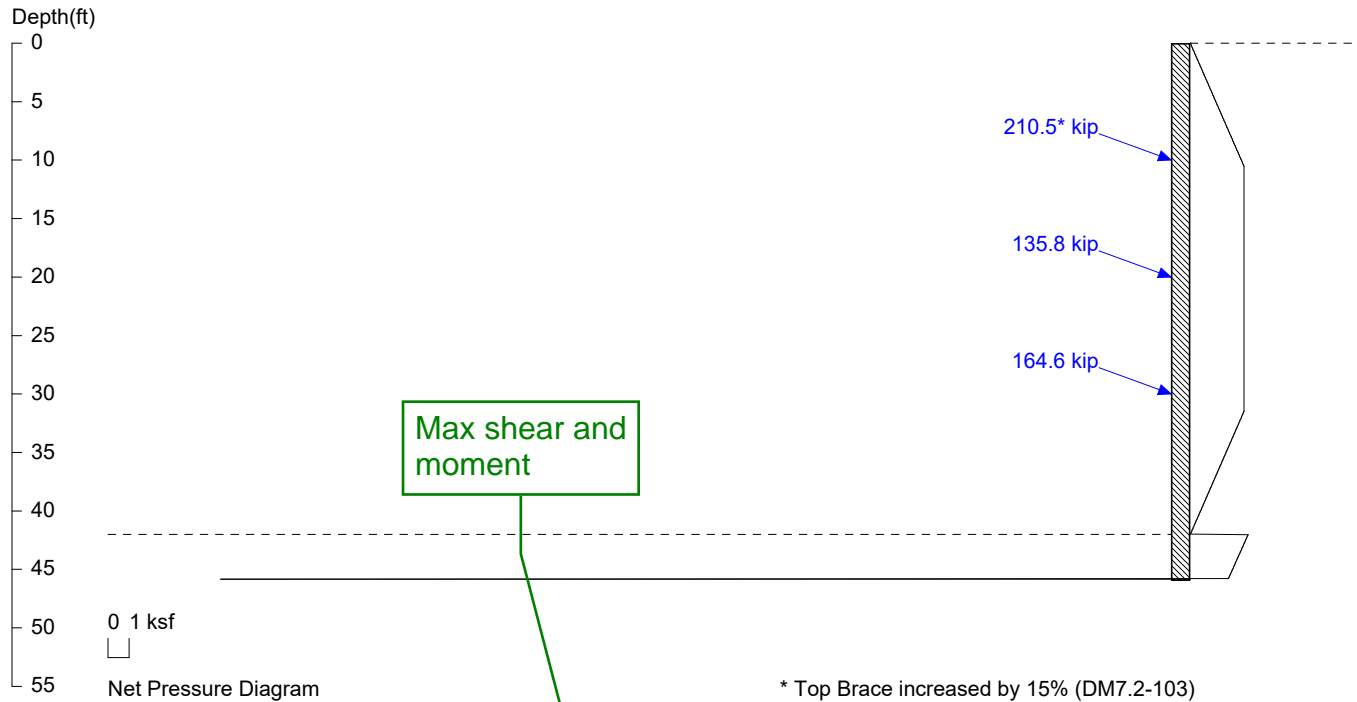
PASSIVE SPACING:

No.	Z depth	Spacing
1	42.00	5.00

Passive pressure for bedrock  
adjusted to 47 ksf based on an  
unconfined strength of 330 psi.

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft  
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft<sup>3</sup>; Deflection - in

# WAS-77-9.58



## PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14X102: E (ksi)=29000.0, I (in<sup>4</sup>)/pile=1050.0

File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Main Wall Tieback Strength.sh8

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The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf,  
Pres. Slope - kip/ft<sup>3</sup>, Deflection - in

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Date: 9/7/2023 File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Main Wall Tieback Strength.sh8

Title: WAS-77-9.58

Subtitle:

\*\*\*\*\*INPUT DATA\*\*\*\*\*

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 42.00

Pile Diameter: 2.50

Pile Spacing: 6.00

Factor of Safety (F.S.): 1.00  
 As Continuous Span Beam  
 Lateral Support Type (Braces): 3. Tieback  
 Top Brace Increase (Multi-Bracing): Add 15%\*  
 No-Load Zone:  
   Vertical Depth for No-Load Zone: 42.00  
   H-Distance (Input H/V ratio) for No-Load Zone: 0.25  
   Angle from H. Line for No-Load Zone: 60.00  
 Embedment Option: 1. Yes  
   Friction at Pile Tip: No  
 Pile Properties:  
   Steel Strength, Fy: 50 ksi = 345 MPa  
   Allowable Fb/Fy: 1  
   Elastic Module, E: 29000.00  
   Moment of Inertia, I: 1050.0  
   User Input Pile: HP14X102

\* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) \*

The pressures below will be multiplied by a Factor =1.5

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
-----					
1	*	Above	Base		
2	0.000	0.000	10.50	1.686	0.160554
3	10.50	1.686	31.50	1.686	0.000000
4	31.50	1.686	42.00	0.000	-0.16055
5	*	Below	Base		
6	42.00	1.822	45.80	1.890	0.017893
7	45.80	0.823	252.0	4.227	0.016508
-----					

\* PASSIVE PRESSURE \*

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
-----					
1	*	Below	Base		
2	42.00	0.000	45.80	1.040	0.273724
3	45.80	47	252.0	47	0.0000

-----

\* ACTIVE SPACE \*

No.	Z depth	Spacing
1	0.00	6.00
2	42.00	2.50

-----

\* PASSIVE SPACE \*

No.	Z depth	Spacing
1	42.00	5.00

-----

Hole diameter in feet  
(9 inches).

Allowable bond strength =  
resistance factor \* ultimate  
bond strength = 0.7\*3 ksf

\* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR\*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	10.00	20.0	6.00	0.75	2.10	Tieback
2	20.00	20.0	6.00	0.75	2.10	Tieback
3	30.00	20.0	6.00	0.75	2.10	Tieback

-----

\*For Tieback: Input1 = Diameter; Input2 = Bond Strength

\*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

\*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

\*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

\*\*\*\*\*CALCULATION\*\*\*\*\*

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

\* CALCULATE REQUEST EMBEDMENT \*



```

| <-- D1=30.00
|
==|== D2=42.00
|
|      D3=45.97

```

D1 - TOP DEPTH                      R1 - TOP REACTION  
 D2 - EXCAVATION BASE  
 D3 - PILE TIP

TOTAL REACTION: R1 = 78.76  
 TOTAL PRESSURES ACTING ON WALL = 78.76  
 Total Reactions = Total Pressures,      OK!  
 The Calculated Embedment, Yend = 3.97

-----MULTIPLE BRACE / TIEBACK CASE-----  
 \*\* Use the calculated embedment, Yend = 3.97 for graphics and analysis.

NUMBER OF BRACE LEVEL= 3

\* CANTILEVER SPAN, N0.0 \*

```

|      D1=0.00
|
|
| <-- D2=10.00                      R2=72.25, with Cantilever Moment=240.83

```

D1 - TOP DEPTH  
 D2 - BOTTOM DEPTH                      R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 72.25  
 TOTAL PRESSURES ACTING ON WALL = 72.25  
 Total Reactions = Total Pressures,      OK!

---

BRACE NO.1 AT DEPTH = 10.00

R2 of Cantilever Span

} Sum of Reaction = Brace Load = 172.02

R1 of Span No.1

---

\* MIDDLE SPAN NO.1 \*

|<-- D1=10.00 R1=99.77, with Cantilever Moment=240.83

|

|<-- D2=20.00 R2=51.78

D1 - TOP DEPTH

R1 - TOP REACTION

D2 - BOTTOM DEPTH

R2 - BOTTOM REACTION

TOTAL REACTION: R1+R2 = 151.56

TOTAL PRESSURES ACTING ON WALL = 151.56

Total Reactions = Total Pressures, OK!

---

BRACE NO.2 AT DEPTH = 20.00

R2 of Span No.1

} Sum of Reaction = Brace Load = 127.60

R1 of Last Span

---

\* LAST SPAN \*

|<-- D1=20.00 R1=75.82

|

|<-- D2=30.00 R2=154.69

|

| D3=45.97

D1 - TOP DEPTH                      R1 - TOP REACTION  
D2 - LAST BRACE DEPTH      R2 - LAST BRACE REACTION  
D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 230.50  
TOTAL PRESSURES ACTING ON WALL = 230.50  
Total Reactions >= Total Pressures,      OK!

---

BRACE NO.3 AT DEPTH = 30.00  
R2 of Last Span = Brace Load = 154.69

---

\*\*\*\*\*RESULTS\*\*\*\*\*

\* EMBEDMENT \*

MINIMUM EMBEDMENT = 3.97 (5~10ft recommended!!!),    TOTAL MINIMUM PILE LENGTH = 45.97

\* MOMENT IN PILE (per pile spacing)\*

Pile Spacing:    sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	10.00	238.42	70.88	16.42
2	20.00	27.63	151.68	24.86
3	30.00	39.91	178.31	36.87

Overall Maximum Moment = 238.89 at 9.97

Maximum Shear = 99.42

Moment and Shear are per pile spacing: 6.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 172.02 to 197.83

\* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR\*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	10.00	20.0	6.00	197.83	72.00	210.52
2	20.00	20.0	6.00	127.60	46.44	135.79
3	30.00	20.0	6.00	154.69	56.30	164.61

No.	DEPTH	Free length	Brace Type
1	10.00	25.48	Tieback, Bond length = 42.55
2	20.00	20.40	Tieback, Bond length = 27.44
3	30.00	15.33	Tieback, Bond length = 33.27

\* VERTICAL LOADING \*

Vertical Loading from Braces = 174.75

Vertical Loading from External Load = 0.00

Total Vertical Loading = 174.75

\*\*\*\*\*SPECIFIED PILE \*\*\*\*\*

Overall Maximum Moment = 238.89 at 9.97

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 57.33 in<sup>3</sup>/pile = 939.53 cm<sup>3</sup>/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X102 has been found in Soldier Pile list!

(English Units):

Area= 30 in. Depth= 14 in. Width= 14.8 in. Height= 14 in.

Flange thickness= 0.705 in. Web thickness= 0.705 in.

Ix= 1050 in<sup>4</sup>/pile Sx= 150 in<sup>3</sup>/pile Iy= 380 in<sup>4</sup>/pile Sy= 51.4 in<sup>3</sup>/pile

(Metric Units):

Ix= 437.01 x100cm<sup>4</sup>/pile Sx= 2458.05 cm<sup>3</sup>/pile Iy= 158.16 x100cm<sup>4</sup>/pile Sy= 842.29 cm<sup>3</sup>/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X102 is capable to support the shoring!

Top deflection = 0.316(in)

Max. deflection = 0.316(in)

\*\*\*\*\* LAGGING SIZE ESTIMATION \*\*\*\*\*

Max. Pressure above base = 2.53

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 1.26

Pile Spacing =6.0, Max. Moment in lagging = 5.69

For 4"x12" Timber, Section Modules  $S=23.47 \text{ in}^3$ . The request allowable bending strength,  $fb=M/S=2.91$

For 6"x12" Timber, Section Modules  $S=57.98 \text{ in}^3$ . The request allowable bending strength,  $fb=M/S=1.18$

If 30% loading is used for lagging design, Design Pressure = 0.76

Pile Spacing =6.0, Max. Moment in lagging = 3.41

For 4"x12" Timber, Section Modules  $S=23.47 \text{ in}^3$ . The request allowable bending strength,  $fb=M/S=1.75$

For 6"x12" Timber, Section Modules  $S=57.98 \text{ in}^3$ . The request allowable bending strength,  $fb=M/S=0.71$

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

\*\*\*\*\*PRESSURE, LOAD, SHEAR, MOMENT, AND DEFLECTION v.s. DEPTH\*\*\*\*\*

The shear and moment are per single soldier pile (secant/tangent pile) or one foot of sheet pile (concrete wall). The deflection is based on users input pile below:

User Input Pile: HP14X102

Elastic Module,  $E \text{ (ksi)}= 29000.00$

Moment of Inertia,  $I \text{ (in}^4\text{)}/\text{pile}= 1050.0$

PRESS. - Sum of all pressures (Net pressure). (Active) direction is positive

LOAD - Liner load (force per unit depth) = Pressures multiply by acting space

No	DEPTH	PRESS.	LOAD	SHEAR	MOMENT	DEFLECTION
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	ft	ksf	kip/ft	kip	kip-ft	in
1	0.00	0.00	0.00	0.00	0.00	0.316
2	0.05	0.01	0.07	0.00	0.00	0.314
3	0.10	0.02	0.15	0.01	0.00	0.312
4	0.15	0.04	0.22	0.02	0.00	0.310
5	0.20	0.05	0.30	0.03	0.00	0.308
6	0.26	0.06	0.37	0.05	0.00	0.306
7	0.31	0.07	0.44	0.07	0.01	0.304
8	0.36	0.09	0.52	0.09	0.01	0.302
9	0.41	0.10	0.59	0.12	0.02	0.300
10	0.46	0.11	0.67	0.15	0.02	0.299
11	0.51	0.12	0.74	0.19	0.03	0.297
12	0.56	0.14	0.81	0.23	0.04	0.295
13	0.61	0.15	0.89	0.27	0.06	0.293
14	0.66	0.16	0.96	0.32	0.07	0.291
15	0.72	0.17	1.03	0.37	0.09	0.289
16	0.77	0.18	1.11	0.43	0.11	0.287
17	0.82	0.20	1.18	0.48	0.13	0.285
18	0.87	0.21	1.26	0.55	0.16	0.283
19	0.92	0.22	1.33	0.61	0.19	0.281
20	0.97	0.23	1.40	0.68	0.22	0.280
21	1.02	0.25	1.48	0.76	0.26	0.278
22	1.07	0.26	1.55	0.83	0.30	0.276
23	1.13	0.27	1.63	0.91	0.34	0.274
24	1.18	0.28	1.70	1.00	0.39	0.272
25	1.23	0.30	1.77	1.09	0.45	0.270
26	1.28	0.31	1.85	1.18	0.50	0.268
27	1.33	0.32	1.92	1.28	0.57	0.266
28	1.38	0.33	2.00	1.38	0.63	0.264
29	1.43	0.34	2.07	1.48	0.71	0.262
30	1.48	0.36	2.14	1.59	0.79	0.261
31	1.53	0.37	2.22	1.70	0.87	0.259
32	1.59	0.38	2.29	1.82	0.96	0.257
33	1.64	0.39	2.36	1.94	1.06	0.255
34	1.69	0.41	2.44	2.06	1.16	0.253

35	1.74	0.42	2.51	2.18	1.27	0.251
36	1.79	0.43	2.59	2.32	1.38	0.249
37	1.84	0.44	2.66	2.45	1.50	0.247
38	1.89	0.46	2.73	2.59	1.63	0.245
39	1.94	0.47	2.81	2.73	1.77	0.243
40	1.99	0.48	2.88	2.87	1.91	0.242
41	2.05	0.49	2.96	3.02	2.06	0.240
42	2.10	0.51	3.03	3.18	2.22	0.238
43	2.15	0.52	3.10	3.33	2.39	0.236
44	2.20	0.53	3.18	3.49	2.56	0.234
45	2.25	0.54	3.25	3.66	2.74	0.232
46	2.30	0.55	3.33	3.83	2.94	0.230
47	2.35	0.57	3.40	4.00	3.14	0.228
48	2.40	0.58	3.47	4.17	3.34	0.226
49	2.45	0.59	3.55	4.35	3.56	0.225
50	2.51	0.60	3.62	4.54	3.79	0.223
51	2.56	0.62	3.70	4.72	4.03	0.221
52	2.61	0.63	3.77	4.92	4.27	0.219
53	2.66	0.64	3.84	5.11	4.53	0.217
54	2.71	0.65	3.92	5.31	4.80	0.215
55	2.76	0.67	3.99	5.51	5.07	0.213
56	2.81	0.68	4.06	5.72	5.36	0.211
57	2.86	0.69	4.14	5.93	5.66	0.209
58	2.92	0.70	4.21	6.14	5.97	0.208
59	2.97	0.71	4.29	6.36	6.29	0.206
60	3.02	0.73	4.36	6.58	6.62	0.204
61	3.07	0.74	4.43	6.80	6.96	0.202
62	3.12	0.75	4.51	7.03	7.31	0.200
63	3.17	0.76	4.58	7.26	7.68	0.198
64	3.22	0.78	4.66	7.50	8.06	0.196
65	3.27	0.79	4.73	7.74	8.45	0.194
66	3.32	0.80	4.80	7.98	8.85	0.192
67	3.38	0.81	4.88	8.23	9.26	0.191
68	3.43	0.83	4.95	8.48	9.69	0.189
69	3.48	0.84	5.03	8.74	10.13	0.187
70	3.53	0.85	5.10	9.00	10.58	0.185



71	3.58	0.86	5.17	9.26	11.05	0.183
72	3.63	0.87	5.25	9.53	11.53	0.181
73	3.68	0.89	5.32	9.80	12.03	0.179
74	3.73	0.90	5.39	10.07	12.53	0.177
75	3.78	0.91	5.47	10.35	13.06	0.176
76	3.84	0.92	5.54	10.63	13.59	0.174
77	3.89	0.94	5.62	10.92	14.14	0.172
78	3.94	0.95	5.69	11.20	14.71	0.170
79	3.99	0.96	5.76	11.50	15.29	0.168
80	4.04	0.97	5.84	11.79	15.88	0.166
81	4.09	0.99	5.91	12.09	16.50	0.164
82	4.14	1.00	5.99	12.40	17.12	0.162
83	4.19	1.01	6.06	12.71	17.76	0.161
84	4.24	1.02	6.13	13.02	18.42	0.159
85	4.30	1.03	6.21	13.33	19.10	0.157
86	4.35	1.05	6.28	13.65	19.79	0.155
87	4.40	1.06	6.36	13.98	20.49	0.153
88	4.45	1.07	6.43	14.30	21.22	0.151
89	4.50	1.08	6.50	14.63	21.96	0.150
90	4.55	1.10	6.58	14.97	22.71	0.148
91	4.60	1.11	6.65	15.31	23.49	0.146
92	4.65	1.12	6.73	15.65	24.28	0.144
93	4.71	1.13	6.80	16.00	25.09	0.142
94	4.76	1.15	6.87	16.35	25.91	0.140
95	4.81	1.16	6.95	16.70	26.76	0.139
96	4.86	1.17	7.02	17.06	27.62	0.137
97	4.91	1.18	7.09	17.42	28.50	0.135
98	4.96	1.19	7.17	17.78	29.40	0.133
99	5.01	1.21	7.24	18.15	30.32	0.131
100	5.06	1.22	7.32	18.52	31.26	0.129
101	5.11	1.23	7.39	18.90	32.22	0.128
102	5.17	1.24	7.46	19.28	33.19	0.126
103	5.22	1.26	7.54	19.66	34.19	0.124
104	5.27	1.27	7.61	20.05	35.21	0.122
105	5.32	1.28	7.69	20.44	36.24	0.121
106	5.37	1.29	7.76	20.84	37.30	0.119

107	5.42	1.31	7.83	21.23	38.37	0.117
108	5.47	1.32	7.91	21.64	39.47	0.115
109	5.52	1.33	7.98	22.04	40.59	0.113
110	5.57	1.34	8.06	22.45	41.72	0.112
111	5.63	1.35	8.13	22.87	42.88	0.110
112	5.68	1.37	8.20	23.28	44.06	0.108
113	5.73	1.38	8.28	23.71	45.26	0.106
114	5.78	1.39	8.35	24.13	46.49	0.105
115	5.83	1.40	8.42	24.56	47.73	0.103
116	5.88	1.42	8.50	24.99	49.00	0.101
117	5.93	1.43	8.57	25.43	50.29	0.099
118	5.98	1.44	8.65	25.87	51.60	0.098
119	6.04	1.45	8.72	26.31	52.94	0.096
120	6.09	1.47	8.79	26.76	54.29	0.094
121	6.14	1.48	8.87	27.21	55.67	0.093
122	6.19	1.49	8.94	27.67	57.08	0.091
123	6.24	1.50	9.02	28.13	58.50	0.089
124	6.29	1.52	9.09	28.59	59.95	0.088
125	6.34	1.53	9.16	29.06	61.43	0.086
126	6.39	1.54	9.24	29.53	62.93	0.084
127	6.44	1.55	9.31	30.00	64.45	0.083
128	6.50	1.56	9.39	30.48	65.99	0.081
129	6.55	1.58	9.46	30.96	67.57	0.079
130	6.60	1.59	9.53	31.45	69.16	0.078
131	6.65	1.60	9.61	31.94	70.78	0.076
132	6.70	1.61	9.68	32.43	72.43	0.074
133	6.75	1.63	9.76	32.93	74.10	0.073
134	6.80	1.64	9.83	33.43	75.80	0.071
135	6.85	1.65	9.90	33.93	77.52	0.070
136	6.90	1.66	9.98	34.44	79.27	0.068
137	6.96	1.68	10.05	34.95	81.04	0.066
138	7.01	1.69	10.12	35.47	82.84	0.065
139	7.06	1.70	10.20	35.99	84.67	0.063
140	7.11	1.71	10.27	36.51	86.53	0.062
141	7.16	1.72	10.35	37.04	88.41	0.060
142	7.21	1.74	10.42	37.57	90.31	0.059

143	7.26	1.75	10.49	38.11	92.25	0.057
144	7.31	1.76	10.57	38.65	94.21	0.056
145	7.36	1.77	10.64	39.19	96.20	0.054
146	7.42	1.79	10.72	39.73	98.22	0.053
147	7.47	1.80	10.79	40.28	100.27	0.051
148	7.52	1.81	10.86	40.84	102.34	0.050
149	7.57	1.82	10.94	41.40	104.44	0.049
150	7.62	1.84	11.01	41.96	106.58	0.047
151	7.67	1.85	11.09	42.52	108.74	0.046
152	7.72	1.86	11.16	43.09	110.93	0.044
153	7.77	1.87	11.23	43.66	113.14	0.043
154	7.83	1.88	11.31	44.24	115.39	0.042
155	7.88	1.90	11.38	44.82	117.67	0.040
156	7.93	1.91	11.45	45.40	119.98	0.039
157	7.98	1.92	11.53	45.99	122.31	0.037
158	8.03	1.93	11.60	46.58	124.68	0.036
159	8.08	1.95	11.68	47.18	127.08	0.035
160	8.13	1.96	11.75	47.78	129.51	0.034
161	8.18	1.97	11.82	48.38	131.97	0.032
162	8.23	1.98	11.90	48.99	134.45	0.031
163	8.29	2.00	11.97	49.60	136.98	0.030
164	8.34	2.01	12.05	50.21	139.53	0.029
165	8.39	2.02	12.12	50.83	142.11	0.027
166	8.44	2.03	12.19	51.45	144.73	0.026
167	8.49	2.04	12.27	52.08	147.37	0.025
168	8.54	2.06	12.34	52.71	150.05	0.024
169	8.59	2.07	12.42	53.34	152.77	0.023
170	8.64	2.08	12.49	53.98	155.51	0.022
171	8.69	2.09	12.56	54.62	158.29	0.021
172	8.75	2.11	12.64	55.26	161.10	0.020
173	8.80	2.12	12.71	55.91	163.94	0.018
174	8.85	2.13	12.79	56.56	166.82	0.017
175	8.90	2.14	12.86	57.22	169.73	0.016
176	8.95	2.16	12.93	57.88	172.67	0.015
177	9.00	2.17	13.01	58.54	175.65	0.014
178	9.05	2.18	13.08	59.21	178.66	0.014

179	9.10	2.19	13.15	59.88	181.70	0.013
180	9.15	2.20	13.23	60.55	184.78	0.012
181	9.21	2.22	13.30	61.23	187.90	0.011
182	9.26	2.23	13.38	61.91	191.04	0.010
183	9.31	2.24	13.45	62.60	194.23	0.009
184	9.36	2.25	13.52	63.29	197.45	0.008
185	9.41	2.27	13.60	63.98	200.70	0.007
186	9.46	2.28	13.67	64.68	203.99	0.007
187	9.51	2.29	13.75	65.38	207.32	0.006
188	9.56	2.30	13.82	66.09	210.68	0.005
189	9.62	2.32	13.89	66.79	214.08	0.005
190	9.67	2.33	13.97	67.51	217.51	0.004
191	9.72	2.34	14.04	68.22	220.98	0.003
192	9.77	2.35	14.12	68.94	224.49	0.003
193	9.82	2.36	14.19	69.67	228.03	0.002
194	9.87	2.38	14.26	70.39	231.62	0.002
195	9.92	2.39	14.34	71.13	235.24	0.001
196	9.97	2.40	14.41	71.86	238.89	0.000
197	10.02	2.41	14.48	-99.42	238.42	0.000
198	10.08	2.43	14.56	-98.68	233.49	0.000
199	10.13	2.44	14.63	-97.93	228.60	0.000
200	10.18	2.45	14.71	-97.18	223.75	0.000
201	10.23	2.46	14.78	-96.43	218.94	0.000
202	10.28	2.48	14.85	-95.67	214.16	0.000
203	10.33	2.49	14.93	-94.91	209.43	0.000
204	10.38	2.50	15.00	-94.15	204.73	0.000
205	10.43	2.51	15.08	-93.38	200.07	0.000
206	10.48	2.52	15.15	-92.60	195.45	0.000
207	10.54	2.53	15.17	-91.83	190.88	0.001
208	10.59	2.53	15.17	-91.05	186.34	0.001
209	10.64	2.53	15.17	-90.28	181.84	0.001
210	10.69	2.53	15.17	-89.50	177.38	0.001
211	10.74	2.53	15.17	-88.72	172.96	0.001
212	10.79	2.53	15.17	-87.95	168.58	0.001
213	10.84	2.53	15.17	-87.17	164.24	0.001
214	10.89	2.53	15.17	-86.40	159.94	0.002

215	10.94	2.53	15.17	-85.62	155.68	0.002
216	11.00	2.53	15.17	-84.84	151.46	0.002
217	11.05	2.53	15.17	-84.07	147.28	0.002
218	11.10	2.53	15.17	-83.29	143.14	0.002
219	11.15	2.53	15.17	-82.52	139.03	0.002
220	11.20	2.53	15.17	-81.74	134.97	0.003
221	11.25	2.53	15.17	-80.96	130.95	0.003
222	11.30	2.53	15.17	-80.19	126.97	0.003
223	11.35	2.53	15.17	-79.41	123.02	0.003
224	11.41	2.53	15.17	-78.64	119.12	0.003
225	11.46	2.53	15.17	-77.86	115.26	0.004
226	11.51	2.53	15.17	-77.08	111.43	0.004
227	11.56	2.53	15.17	-76.31	107.65	0.004
228	11.61	2.53	15.17	-75.53	103.90	0.004
229	11.66	2.53	15.17	-74.75	100.20	0.004
230	11.71	2.53	15.17	-73.98	96.53	0.005
231	11.76	2.53	15.17	-73.20	92.91	0.005
232	11.81	2.53	15.17	-72.43	89.32	0.005
233	11.87	2.53	15.17	-71.65	85.77	0.005
234	11.92	2.53	15.17	-70.87	82.27	0.006
235	11.97	2.53	15.17	-70.10	78.80	0.006
236	12.02	2.53	15.17	-69.32	75.37	0.006
237	12.07	2.53	15.17	-68.55	71.99	0.006
238	12.12	2.53	15.17	-67.77	68.64	0.007
239	12.17	2.53	15.17	-66.99	65.33	0.007
240	12.22	2.53	15.17	-66.22	62.06	0.007
241	12.27	2.53	15.17	-65.44	58.83	0.007
242	12.33	2.53	15.17	-64.67	55.64	0.007
243	12.38	2.53	15.17	-63.89	52.49	0.008
244	12.43	2.53	15.17	-63.11	49.38	0.008
245	12.48	2.53	15.17	-62.34	46.31	0.008
246	12.53	2.53	15.17	-61.56	43.28	0.008
247	12.58	2.53	15.17	-60.79	40.29	0.009
248	12.63	2.53	15.17	-60.01	37.34	0.009
249	12.68	2.53	15.17	-59.23	34.43	0.009
250	12.73	2.53	15.17	-58.46	31.56	0.009

251	12.79	2.53	15.17	-57.68	28.73	0.010
252	12.84	2.53	15.17	-56.91	25.94	0.010
253	12.89	2.53	15.17	-56.13	23.18	0.010
254	12.94	2.53	15.17	-55.35	20.47	0.010
255	12.99	2.53	15.17	-54.58	17.80	0.010
256	13.04	2.53	15.17	-53.80	15.16	0.011
257	13.09	2.53	15.17	-53.03	12.57	0.011
258	13.14	2.53	15.17	-52.25	10.02	0.011
259	13.20	2.53	15.17	-51.47	7.50	0.011
260	13.25	2.53	15.17	-50.70	5.03	0.011
261	13.30	2.53	15.17	-49.92	2.59	0.012
262	13.35	2.53	15.17	-49.15	0.20	0.012
263	13.40	2.53	15.17	-48.37	-2.16	0.012
264	13.45	2.53	15.17	-47.59	-4.47	0.012
265	13.50	2.53	15.17	-46.82	-6.75	0.012
266	13.55	2.53	15.17	-46.04	-8.99	0.012
267	13.60	2.53	15.17	-45.26	-11.18	0.013
268	13.66	2.53	15.17	-44.49	-13.34	0.013
269	13.71	2.53	15.17	-43.71	-15.46	0.013
270	13.76	2.53	15.17	-42.94	-17.54	0.013
271	13.81	2.53	15.17	-42.16	-19.57	0.013
272	13.86	2.53	15.17	-41.38	-21.57	0.013
273	13.91	2.53	15.17	-40.61	-23.53	0.013
274	13.96	2.53	15.17	-39.83	-25.45	0.014
275	14.01	2.53	15.17	-39.06	-27.33	0.014
276	14.06	2.53	15.17	-38.28	-29.17	0.014
277	14.12	2.53	15.17	-37.50	-30.97	0.014
278	14.17	2.53	15.17	-36.73	-32.73	0.014
279	14.22	2.53	15.17	-35.95	-34.45	0.014
280	14.27	2.53	15.17	-35.18	-36.13	0.014
281	14.32	2.53	15.17	-34.40	-37.77	0.014
282	14.37	2.53	15.17	-33.62	-39.37	0.014
283	14.42	2.53	15.17	-32.85	-40.93	0.014
284	14.47	2.53	15.17	-32.07	-42.46	0.015
285	14.52	2.53	15.17	-31.30	-43.94	0.015
286	14.58	2.53	15.17	-30.52	-45.38	0.015

287	14.63	2.53	15.17	-29.74	-46.78	0.015
288	14.68	2.53	15.17	-28.97	-48.15	0.015
289	14.73	2.53	15.17	-28.19	-49.47	0.015
290	14.78	2.53	15.17	-27.42	-50.75	0.015
291	14.83	2.53	15.17	-26.64	-52.00	0.015
292	14.88	2.53	15.17	-25.86	-53.20	0.015
293	14.93	2.53	15.17	-25.09	-54.37	0.015
294	14.99	2.53	15.17	-24.31	-55.49	0.015
295	15.04	2.53	15.17	-23.54	-56.58	0.015
296	15.09	2.53	15.17	-22.76	-57.62	0.015
297	15.14	2.53	15.17	-21.98	-58.63	0.015
298	15.19	2.53	15.17	-21.21	-59.60	0.015
299	15.24	2.53	15.17	-20.43	-60.52	0.015
300	15.29	2.53	15.17	-19.65	-61.41	0.015
301	15.34	2.53	15.17	-18.88	-62.26	0.015
302	15.39	2.53	15.17	-18.10	-63.07	0.015
303	15.45	2.53	15.17	-17.33	-63.83	0.015
304	15.50	2.53	15.17	-16.55	-64.56	0.015
305	15.55	2.53	15.17	-15.77	-65.25	0.015
306	15.60	2.53	15.17	-15.00	-65.90	0.014
307	15.65	2.53	15.17	-14.22	-66.51	0.014
308	15.70	2.53	15.17	-13.45	-67.08	0.014
309	15.75	2.53	15.17	-12.67	-67.61	0.014
310	15.80	2.53	15.17	-11.89	-68.10	0.014
311	15.85	2.53	15.17	-11.12	-68.55	0.014
312	15.91	2.53	15.17	-10.34	-68.96	0.014
313	15.96	2.53	15.17	-9.57	-69.33	0.014
314	16.01	2.53	15.17	-8.79	-69.66	0.014
315	16.06	2.53	15.17	-8.01	-69.95	0.014
316	16.11	2.53	15.17	-7.24	-70.21	0.013
317	16.16	2.53	15.17	-6.46	-70.42	0.013
318	16.21	2.53	15.17	-5.69	-70.59	0.013
319	16.26	2.53	15.17	-4.91	-70.72	0.013
320	16.31	2.53	15.17	-4.13	-70.82	0.013
321	16.37	2.53	15.17	-3.36	-70.87	0.013
322	16.42	2.53	15.17	-2.58	-70.88	0.013



323	16.47	2.53	15.17	-1.81	-70.86	0.012
324	16.52	2.53	15.17	-1.03	-70.79	0.012
325	16.57	2.53	15.17	-0.25	-70.69	0.012
326	16.62	2.53	15.17	0.52	-70.53	0.012
327	16.67	2.53	15.17	1.30	-70.33	0.012
328	16.72	2.53	15.17	2.07	-70.09	0.012
329	16.78	2.53	15.17	2.85	-69.82	0.011
330	16.83	2.53	15.17	3.63	-69.50	0.011
331	16.88	2.53	15.17	4.40	-69.15	0.011
332	16.93	2.53	15.17	5.18	-68.75	0.011
333	16.98	2.53	15.17	5.95	-68.31	0.011
334	17.03	2.53	15.17	6.73	-67.84	0.010
335	17.08	2.53	15.17	7.51	-67.32	0.010
336	17.13	2.53	15.17	8.28	-66.77	0.010
337	17.18	2.53	15.17	9.06	-66.18	0.010
338	17.24	2.53	15.17	9.84	-65.54	0.010
339	17.29	2.53	15.17	10.61	-64.87	0.009
340	17.34	2.53	15.17	11.39	-64.15	0.009
341	17.39	2.53	15.17	12.16	-63.40	0.009
342	17.44	2.53	15.17	12.94	-62.61	0.009
343	17.49	2.53	15.17	13.72	-61.78	0.008
344	17.54	2.53	15.17	14.49	-60.90	0.008
345	17.59	2.53	15.17	15.27	-59.99	0.008
346	17.64	2.53	15.17	16.04	-59.04	0.008
347	17.70	2.53	15.17	16.82	-58.05	0.007
348	17.75	2.53	15.17	17.60	-57.02	0.007
349	17.80	2.53	15.17	18.37	-55.95	0.007
350	17.85	2.53	15.17	19.15	-54.84	0.007
351	17.90	2.53	15.17	19.92	-53.69	0.007
352	17.95	2.53	15.17	20.70	-52.50	0.006
353	18.00	2.53	15.17	21.48	-51.27	0.006
354	18.05	2.53	15.17	22.25	-50.00	0.006
355	18.10	2.53	15.17	23.03	-48.69	0.006
356	18.16	2.53	15.17	23.80	-47.34	0.005
357	18.21	2.53	15.17	24.58	-45.95	0.005
358	18.26	2.53	15.17	25.36	-44.53	0.005

359	18.31	2.53	15.17	26.13	-43.06	0.005
360	18.36	2.53	15.17	26.91	-41.55	0.004
361	18.41	2.53	15.17	27.68	-40.01	0.004
362	18.46	2.53	15.17	28.46	-38.42	0.004
363	18.51	2.53	15.17	29.24	-36.79	0.004
364	18.57	2.53	15.17	30.01	-35.13	0.004
365	18.62	2.53	15.17	30.79	-33.42	0.003
366	18.67	2.53	15.17	31.56	-31.68	0.003
367	18.72	2.53	15.17	32.34	-29.89	0.003
368	18.77	2.53	15.17	33.12	-28.07	0.003
369	18.82	2.53	15.17	33.89	-26.20	0.003
370	18.87	2.53	15.17	34.67	-24.30	0.002
371	18.92	2.53	15.17	35.44	-22.35	0.002
372	18.97	2.53	15.17	36.22	-20.37	0.002
373	19.03	2.53	15.17	37.00	-18.35	0.002
374	19.08	2.53	15.17	37.77	-16.28	0.002
375	19.13	2.53	15.17	38.55	-14.18	0.002
376	19.18	2.53	15.17	39.33	-12.04	0.001
377	19.23	2.53	15.17	40.10	-9.86	0.001
378	19.28	2.53	15.17	40.88	-7.64	0.001
379	19.33	2.53	15.17	41.65	-5.37	0.001
380	19.38	2.53	15.17	42.43	-3.07	0.001
381	19.43	2.53	15.17	43.21	-0.73	0.001
382	19.49	2.53	15.17	43.98	1.65	0.001
383	19.54	2.53	15.17	44.76	4.07	0.000
384	19.59	2.53	15.17	45.53	6.53	0.000
385	19.64	2.53	15.17	46.31	9.03	0.000
386	19.69	2.53	15.17	47.09	11.57	0.000
387	19.74	2.53	15.17	47.86	14.14	0.000
388	19.79	2.53	15.17	48.64	16.76	0.000
389	19.84	2.53	15.17	49.41	19.42	0.000
390	19.89	2.53	15.17	50.19	22.12	0.000
391	19.95	2.53	15.17	50.97	24.86	0.000
392	20.00	2.53	15.17	51.74	27.63	0.000
393	20.05	2.53	15.17	-75.08	24.23	0.000
394	20.10	2.53	15.17	-74.31	20.51	0.000

395	20.15	2.53	15.17	-73.53	16.83	0.000
396	20.20	2.53	15.17	-72.75	13.20	0.000
397	20.25	2.53	15.17	-71.98	9.60	0.001
398	20.30	2.53	15.17	-71.20	6.04	0.001
399	20.36	2.53	15.17	-70.43	2.52	0.001
400	20.41	2.53	15.17	-69.65	-0.96	0.001
401	20.46	2.53	15.17	-68.87	-4.40	0.002
402	20.51	2.53	15.17	-68.10	-7.80	0.002
403	20.56	2.53	15.17	-67.32	-11.16	0.003
404	20.61	2.53	15.17	-66.55	-14.48	0.003
405	20.66	2.53	15.17	-65.77	-17.76	0.004
406	20.71	2.53	15.17	-64.99	-21.00	0.004
407	20.76	2.53	15.17	-64.22	-24.20	0.005
408	20.82	2.53	15.17	-63.44	-27.36	0.005
409	20.87	2.53	15.17	-62.67	-30.48	0.006
410	20.92	2.53	15.17	-61.89	-33.56	0.007
411	20.97	2.53	15.17	-61.11	-36.60	0.007
412	21.02	2.53	15.17	-60.34	-39.61	0.008
413	21.07	2.53	15.17	-59.56	-42.57	0.009
414	21.12	2.53	15.17	-58.78	-45.49	0.010
415	21.17	2.53	15.17	-58.01	-48.38	0.010
416	21.22	2.53	15.17	-57.23	-51.22	0.011
417	21.28	2.53	15.17	-56.46	-54.02	0.012
418	21.33	2.53	15.17	-55.68	-56.79	0.013
419	21.38	2.53	15.17	-54.90	-59.51	0.014
420	21.43	2.53	15.17	-54.13	-62.20	0.014
421	21.48	2.53	15.17	-53.35	-64.84	0.015
422	21.53	2.53	15.17	-52.58	-67.45	0.016
423	21.58	2.53	15.17	-51.80	-70.02	0.017
424	21.63	2.53	15.17	-51.02	-72.54	0.018
425	21.68	2.53	15.17	-50.25	-75.03	0.019
426	21.74	2.53	15.17	-49.47	-77.48	0.020
427	21.79	2.53	15.17	-48.70	-79.88	0.021
428	21.84	2.53	15.17	-47.92	-82.25	0.022
429	21.89	2.53	15.17	-47.14	-84.58	0.023
430	21.94	2.53	15.17	-46.37	-86.87	0.024

431	21.99	2.53	15.17	-45.59	-89.12	0.025
432	22.04	2.53	15.17	-44.82	-91.32	0.025
433	22.09	2.53	15.17	-44.04	-93.49	0.026
434	22.15	2.53	15.17	-43.26	-95.62	0.027
435	22.20	2.53	15.17	-42.49	-97.71	0.028
436	22.25	2.53	15.17	-41.71	-99.76	0.029
437	22.30	2.53	15.17	-40.94	-101.77	0.030
438	22.35	2.53	15.17	-40.16	-103.74	0.031
439	22.40	2.53	15.17	-39.38	-105.67	0.032
440	22.45	2.53	15.17	-38.61	-107.57	0.033
441	22.50	2.53	15.17	-37.83	-109.42	0.034
442	22.55	2.53	15.17	-37.06	-111.23	0.035
443	22.61	2.53	15.17	-36.28	-113.00	0.036
444	22.66	2.53	15.17	-35.50	-114.73	0.037
445	22.71	2.53	15.17	-34.73	-116.43	0.038
446	22.76	2.53	15.17	-33.95	-118.08	0.038
447	22.81	2.53	15.17	-33.18	-119.69	0.039
448	22.86	2.53	15.17	-32.40	-121.27	0.040
449	22.91	2.53	15.17	-31.62	-122.80	0.041
450	22.96	2.53	15.17	-30.85	-124.30	0.042
451	23.01	2.53	15.17	-30.07	-125.75	0.043
452	23.07	2.53	15.17	-29.29	-127.16	0.044
453	23.12	2.53	15.17	-28.52	-128.54	0.044
454	23.17	2.53	15.17	-27.74	-129.88	0.045
455	23.22	2.53	15.17	-26.97	-131.17	0.046
456	23.27	2.53	15.17	-26.19	-132.43	0.047
457	23.32	2.53	15.17	-25.41	-133.64	0.047
458	23.37	2.53	15.17	-24.64	-134.82	0.048
459	23.42	2.53	15.17	-23.86	-135.96	0.049
460	23.48	2.53	15.17	-23.09	-137.06	0.050
461	23.53	2.53	15.17	-22.31	-138.11	0.050
462	23.58	2.53	15.17	-21.53	-139.13	0.051
463	23.63	2.53	15.17	-20.76	-140.11	0.051
464	23.68	2.53	15.17	-19.98	-141.05	0.052
465	23.73	2.53	15.17	-19.21	-141.95	0.053
466	23.78	2.53	15.17	-18.43	-142.81	0.053

467	23.83	2.53	15.17	-17.65	-143.63	0.054
468	23.88	2.53	15.17	-16.88	-144.41	0.054
469	23.94	2.53	15.17	-16.10	-145.15	0.055
470	23.99	2.53	15.17	-15.33	-145.85	0.055
471	24.04	2.53	15.17	-14.55	-146.51	0.056
472	24.09	2.53	15.17	-13.77	-147.13	0.056
473	24.14	2.53	15.17	-13.00	-147.71	0.057
474	24.19	2.53	15.17	-12.22	-148.25	0.057
475	24.24	2.53	15.17	-11.45	-148.75	0.058
476	24.29	2.53	15.17	-10.67	-149.22	0.058
477	24.34	2.53	15.17	-9.89	-149.64	0.058
478	24.40	2.53	15.17	-9.12	-150.02	0.059
479	24.45	2.53	15.17	-8.34	-150.37	0.059
480	24.50	2.53	15.17	-7.57	-150.67	0.059
481	24.55	2.53	15.17	-6.79	-150.93	0.059
482	24.60	2.53	15.17	-6.01	-151.16	0.059
483	24.65	2.53	15.17	-5.24	-151.34	0.060
484	24.70	2.53	15.17	-4.46	-151.49	0.060
485	24.75	2.53	15.17	-3.69	-151.59	0.060
486	24.80	2.53	15.17	-2.91	-151.66	0.060
487	24.86	2.53	15.17	-2.13	-151.68	0.060
488	24.91	2.53	15.17	-1.36	-151.67	0.060
489	24.96	2.53	15.17	-0.58	-151.62	0.060
490	25.01	2.53	15.17	0.20	-151.52	0.060
491	25.06	2.53	15.17	0.97	-151.46	0.060
492	25.11	2.53	15.17	1.75	-151.36	0.060
493	25.16	2.53	15.17	2.52	-151.22	0.060
494	25.21	2.53	15.17	3.30	-151.04	0.060
495	25.27	2.53	15.17	4.08	-150.82	0.060
496	25.32	2.53	15.17	4.85	-150.55	0.060
497	25.37	2.53	15.17	5.63	-150.25	0.060
498	25.42	2.53	15.17	6.40	-149.91	0.059
499	25.47	2.53	15.17	7.18	-149.53	0.059
500	25.52	2.53	15.17	7.96	-149.12	0.059
501	25.57	2.53	15.17	8.73	-148.66	0.059
502	25.62	2.53	15.17	9.51	-148.16	0.059

503	25.67	2.53	15.17	10.28	-147.62	0.058
504	25.73	2.53	15.17	11.06	-147.04	0.058
505	25.78	2.53	15.17	11.84	-146.42	0.058
506	25.83	2.53	15.17	12.61	-145.76	0.057
507	25.88	2.53	15.17	13.39	-145.07	0.057
508	25.93	2.53	15.17	14.16	-144.33	0.056
509	25.98	2.53	15.17	14.94	-143.55	0.056
510	26.03	2.53	15.17	15.72	-142.74	0.055
511	26.08	2.53	15.17	16.49	-141.88	0.055
512	26.13	2.53	15.17	17.27	-140.99	0.054
513	26.19	2.53	15.17	18.04	-140.05	0.054
514	26.24	2.53	15.17	18.82	-139.08	0.053
515	26.29	2.53	15.17	19.60	-138.06	0.053
516	26.34	2.53	15.17	20.37	-137.01	0.052
517	26.39	2.53	15.17	21.15	-135.91	0.051
518	26.44	2.53	15.17	21.92	-134.78	0.051
519	26.49	2.53	15.17	22.70	-133.60	0.050
520	26.54	2.53	15.17	23.48	-132.39	0.050
521	26.59	2.53	15.17	24.25	-131.14	0.049
522	26.65	2.53	15.17	25.03	-129.85	0.048
523	26.70	2.53	15.17	25.81	-128.51	0.047
524	26.75	2.53	15.17	26.58	-127.14	0.047
525	26.80	2.53	15.17	27.36	-125.73	0.046
526	26.85	2.53	15.17	28.13	-124.28	0.045
527	26.90	2.53	15.17	28.91	-122.79	0.044
528	26.95	2.53	15.17	29.69	-121.26	0.044
529	27.00	2.53	15.17	30.46	-119.69	0.043
530	27.06	2.53	15.17	31.24	-118.08	0.042
531	27.11	2.53	15.17	32.01	-116.43	0.041
532	27.16	2.53	15.17	32.79	-114.74	0.040
533	27.21	2.53	15.17	33.57	-113.01	0.039
534	27.26	2.53	15.17	34.34	-111.24	0.038
535	27.31	2.53	15.17	35.12	-109.43	0.038
536	27.36	2.53	15.17	35.89	-107.58	0.037
537	27.41	2.53	15.17	36.67	-105.69	0.036
538	27.46	2.53	15.17	37.45	-103.76	0.035

539	27.52	2.53	15.17	38.22	-101.80	0.034
540	27.57	2.53	15.17	39.00	-99.79	0.033
541	27.62	2.53	15.17	39.77	-97.74	0.032
542	27.67	2.53	15.17	40.55	-95.66	0.031
543	27.72	2.53	15.17	41.33	-93.53	0.030
544	27.77	2.53	15.17	42.10	-91.37	0.029
545	27.82	2.53	15.17	42.88	-89.16	0.028
546	27.87	2.53	15.17	43.65	-86.91	0.027
547	27.92	2.53	15.17	44.43	-84.63	0.026
548	27.98	2.53	15.17	45.21	-82.31	0.025
549	28.03	2.53	15.17	45.98	-79.94	0.025
550	28.08	2.53	15.17	46.76	-77.54	0.024
551	28.13	2.53	15.17	47.53	-75.09	0.023
552	28.18	2.53	15.17	48.31	-72.61	0.022
553	28.23	2.53	15.17	49.09	-70.09	0.021
554	28.28	2.53	15.17	49.86	-67.52	0.020
555	28.33	2.53	15.17	50.64	-64.92	0.019
556	28.38	2.53	15.17	51.41	-62.28	0.018
557	28.44	2.53	15.17	52.19	-59.60	0.017
558	28.49	2.53	15.17	52.97	-56.88	0.016
559	28.54	2.53	15.17	53.74	-54.12	0.015
560	28.59	2.53	15.17	54.52	-51.31	0.014
561	28.64	2.53	15.17	55.30	-48.47	0.014
562	28.69	2.53	15.17	56.07	-45.59	0.013
563	28.74	2.53	15.17	56.85	-42.67	0.012
564	28.79	2.53	15.17	57.62	-39.71	0.011
565	28.85	2.53	15.17	58.40	-36.71	0.010
566	28.90	2.53	15.17	59.18	-33.68	0.010
567	28.95	2.53	15.17	59.95	-30.60	0.009
568	29.00	2.53	15.17	60.73	-27.48	0.008
569	29.05	2.53	15.17	61.50	-24.32	0.007
570	29.10	2.53	15.17	62.28	-21.12	0.007
571	29.15	2.53	15.17	63.06	-17.89	0.006
572	29.20	2.53	15.17	63.83	-14.61	0.005
573	29.25	2.53	15.17	64.61	-11.29	0.005
574	29.31	2.53	15.17	65.38	-7.93	0.004

575	29.36	2.53	15.17	66.16	-4.54	0.004
576	29.41	2.53	15.17	66.94	-1.10	0.003
577	29.46	2.53	15.17	67.71	2.37	0.003
578	29.51	2.53	15.17	68.49	5.89	0.002
579	29.56	2.53	15.17	69.26	9.44	0.002
580	29.61	2.53	15.17	70.04	13.04	0.001
581	29.66	2.53	15.17	70.82	16.67	0.001
582	29.71	2.53	15.17	71.59	20.35	0.001
583	29.77	2.53	15.17	72.37	24.06	0.001
584	29.82	2.53	15.17	73.14	27.81	0.000
585	29.87	2.53	15.17	73.92	31.61	0.000
586	29.92	2.53	15.17	74.70	35.44	0.000
587	29.97	2.53	15.17	75.47	39.31	0.000
588	30.02	2.53	15.17	-78.44	39.91	0.000
589	30.07	2.53	15.17	-77.66	35.95	0.002
590	30.12	2.53	15.17	-76.89	32.02	0.004
591	30.17	2.53	15.17	-76.11	28.14	0.006
592	30.23	2.53	15.17	-75.33	24.29	0.007
593	30.28	2.53	15.17	-74.56	20.48	0.009
594	30.33	2.53	15.17	-73.78	16.72	0.011
595	30.38	2.53	15.17	-73.01	12.99	0.013
596	30.43	2.53	15.17	-72.23	9.30	0.015
597	30.48	2.53	15.17	-71.45	5.65	0.017
598	30.53	2.53	15.17	-70.68	2.04	0.019
599	30.58	2.53	15.17	-69.90	-1.53	0.021
600	30.64	2.53	15.17	-69.13	-5.05	0.022
601	30.69	2.53	15.17	-68.35	-8.54	0.024
602	30.74	2.53	15.17	-67.57	-11.99	0.026
603	30.79	2.53	15.17	-66.80	-15.40	0.028
604	30.84	2.53	15.17	-66.02	-18.77	0.030
605	30.89	2.53	15.17	-65.25	-22.10	0.032
606	30.94	2.53	15.17	-64.47	-25.40	0.034
607	30.99	2.53	15.17	-63.69	-28.65	0.036
608	31.04	2.53	15.17	-62.92	-31.86	0.037
609	31.10	2.53	15.17	-62.14	-35.03	0.039
610	31.15	2.53	15.17	-61.37	-38.16	0.041



611	31.20	2.53	15.17	-60.59	-41.26	0.043
612	31.25	2.53	15.17	-59.81	-44.31	0.045
613	31.30	2.53	15.17	-59.04	-47.32	0.047
614	31.35	2.53	15.17	-58.26	-50.29	0.048
615	31.40	2.53	15.17	-57.48	-53.23	0.050
616	31.45	2.53	15.17	-56.71	-56.12	0.052
617	31.50	2.53	15.17	-55.93	-58.98	0.054
618	31.56	2.52	15.09	-55.16	-61.79	0.056
619	31.61	2.50	15.02	-54.39	-64.57	0.057
620	31.66	2.49	14.95	-53.62	-67.30	0.059
621	31.71	2.48	14.87	-52.86	-70.00	0.061
622	31.76	2.47	14.80	-52.10	-72.66	0.063
623	31.81	2.45	14.72	-51.35	-75.28	0.065
624	31.86	2.44	14.65	-50.60	-77.86	0.066
625	31.91	2.43	14.58	-49.85	-80.40	0.068
626	31.96	2.42	14.50	-49.10	-82.90	0.070
627	32.02	2.40	14.43	-48.36	-85.37	0.072
628	32.07	2.39	14.35	-47.63	-87.80	0.073
629	32.12	2.38	14.28	-46.90	-90.19	0.075
630	32.17	2.37	14.21	-46.17	-92.55	0.077
631	32.22	2.36	14.13	-45.44	-94.86	0.078
632	32.27	2.34	14.06	-44.72	-97.14	0.080
633	32.32	2.33	13.99	-44.00	-99.38	0.082
634	32.37	2.32	13.91	-43.29	-101.59	0.083
635	32.43	2.31	13.84	-42.58	-103.76	0.085
636	32.48	2.29	13.76	-41.88	-105.89	0.087
637	32.53	2.28	13.69	-41.17	-107.99	0.088
638	32.58	2.27	13.62	-40.48	-110.05	0.090
639	32.63	2.26	13.54	-39.78	-112.08	0.092
640	32.68	2.24	13.47	-39.09	-114.07	0.093
641	32.73	2.23	13.39	-38.40	-116.03	0.095
642	32.78	2.22	13.32	-37.72	-117.95	0.096
643	32.83	2.21	13.25	-37.04	-119.83	0.098
644	32.89	2.20	13.17	-36.37	-121.68	0.100
645	32.94	2.18	13.10	-35.69	-123.50	0.101
646	32.99	2.17	13.02	-35.03	-125.28	0.103

647	33.04	2.16	12.95	-34.36	-127.03	0.104
648	33.09	2.15	12.88	-33.70	-128.75	0.106
649	33.14	2.13	12.80	-33.04	-130.43	0.107
650	33.19	2.12	12.73	-32.39	-132.07	0.109
651	33.24	2.11	12.65	-31.74	-133.69	0.110
652	33.29	2.10	12.58	-31.10	-135.27	0.111
653	33.35	2.08	12.51	-30.46	-136.82	0.113
654	33.40	2.07	12.43	-29.82	-138.33	0.114
655	33.45	2.06	12.36	-29.18	-139.81	0.116
656	33.50	2.05	12.29	-28.55	-141.26	0.117
657	33.55	2.04	12.21	-27.93	-142.68	0.118
658	33.60	2.02	12.14	-27.30	-144.07	0.120
659	33.65	2.01	12.06	-26.69	-145.42	0.121
660	33.70	2.00	11.99	-26.07	-146.75	0.122
661	33.75	1.99	11.92	-25.46	-148.04	0.124
662	33.81	1.97	11.84	-24.85	-149.30	0.125
663	33.86	1.96	11.77	-24.25	-150.53	0.126
664	33.91	1.95	11.69	-23.65	-151.73	0.128
665	33.96	1.94	11.62	-23.05	-152.90	0.129
666	34.01	1.92	11.55	-22.46	-154.03	0.130
667	34.06	1.91	11.47	-21.87	-155.14	0.131
668	34.11	1.90	11.40	-21.29	-156.22	0.132
669	34.16	1.89	11.32	-20.71	-157.27	0.134
670	34.22	1.88	11.25	-20.13	-158.28	0.135
671	34.27	1.86	11.18	-19.55	-159.27	0.136
672	34.32	1.85	11.10	-18.98	-160.23	0.137
673	34.37	1.84	11.03	-18.42	-161.16	0.138
674	34.42	1.83	10.96	-17.86	-162.06	0.139
675	34.47	1.81	10.88	-17.30	-162.94	0.140
676	34.52	1.80	10.81	-16.74	-163.78	0.141
677	34.57	1.79	10.73	-16.19	-164.60	0.142
678	34.62	1.78	10.66	-15.65	-165.39	0.144
679	34.68	1.76	10.59	-15.10	-166.15	0.145
680	34.73	1.75	10.51	-14.56	-166.88	0.146
681	34.78	1.74	10.44	-14.03	-167.58	0.147
682	34.83	1.73	10.36	-13.50	-168.26	0.147

683	34.88	1.72	10.29	-12.97	-168.91	0.148
684	34.93	1.70	10.22	-12.44	-169.54	0.149
685	34.98	1.69	10.14	-11.92	-170.13	0.150
686	35.03	1.68	10.07	-11.41	-170.70	0.151
687	35.08	1.67	9.99	-10.89	-171.25	0.152
688	35.14	1.65	9.92	-10.38	-171.77	0.153
689	35.19	1.64	9.85	-9.88	-172.26	0.154
690	35.24	1.63	9.77	-9.38	-172.72	0.155
691	35.29	1.62	9.70	-8.88	-173.16	0.155
692	35.34	1.60	9.62	-8.38	-173.58	0.156
693	35.39	1.59	9.55	-7.89	-173.97	0.157
694	35.44	1.58	9.48	-7.41	-174.34	0.158
695	35.49	1.57	9.40	-6.92	-174.68	0.158
696	35.54	1.55	9.33	-6.45	-174.99	0.159
697	35.60	1.54	9.26	-5.97	-175.28	0.160
698	35.65	1.53	9.18	-5.50	-175.55	0.160
699	35.70	1.52	9.11	-5.03	-175.79	0.161
700	35.75	1.51	9.03	-4.57	-176.01	0.162
701	35.80	1.49	8.96	-4.11	-176.21	0.162
702	35.85	1.48	8.89	-3.65	-176.38	0.163
703	35.90	1.47	8.81	-3.20	-176.53	0.163
704	35.95	1.46	8.74	-2.75	-176.66	0.164
705	36.01	1.44	8.66	-2.30	-176.76	0.165
706	36.06	1.43	8.59	-1.86	-176.84	0.165
707	36.11	1.42	8.52	-1.43	-176.90	0.166
708	36.16	1.41	8.44	-0.99	-176.93	0.166
709	36.21	1.39	8.37	-0.56	-176.95	0.167
710	36.26	1.38	8.29	-0.14	-176.94	0.167
711	36.31	1.37	8.22	0.29	-177.17	0.167
712	36.36	1.36	8.15	0.71	-177.38	0.168
713	36.41	1.35	8.07	1.12	-177.56	0.168
714	36.47	1.33	8.00	1.53	-177.73	0.169
715	36.52	1.32	7.93	1.94	-177.87	0.169
716	36.57	1.31	7.85	2.34	-177.99	0.169
717	36.62	1.30	7.78	2.74	-178.10	0.170
718	36.67	1.28	7.70	3.14	-178.18	0.170

719	36.72	1.27	7.63	3.53	-178.24	0.170
720	36.77	1.26	7.56	3.92	-178.28	0.171
721	36.82	1.25	7.48	4.30	-178.31	0.171
722	36.87	1.23	7.41	4.68	-178.31	0.171
723	36.93	1.22	7.33	5.06	-178.29	0.171
724	36.98	1.21	7.26	5.43	-178.26	0.171
725	37.03	1.20	7.19	5.80	-178.20	0.172
726	37.08	1.19	7.11	6.17	-178.13	0.172
727	37.13	1.17	7.04	6.53	-178.04	0.172
728	37.18	1.16	6.96	6.89	-177.93	0.172
729	37.23	1.15	6.89	7.24	-177.80	0.172
730	37.28	1.14	6.82	7.59	-177.65	0.172
731	37.33	1.12	6.74	7.94	-177.49	0.172
732	37.39	1.11	6.67	8.28	-177.31	0.172
733	37.44	1.10	6.60	8.62	-177.11	0.172
734	37.49	1.09	6.52	8.96	-176.89	0.172
735	37.54	1.07	6.45	9.29	-176.66	0.172
736	37.59	1.06	6.37	9.62	-176.41	0.172
737	37.64	1.05	6.30	9.94	-176.14	0.172
738	37.69	1.04	6.23	10.26	-175.85	0.172
739	37.74	1.03	6.15	10.58	-175.55	0.172
740	37.80	1.01	6.08	10.89	-175.24	0.172
741	37.85	1.00	6.00	11.20	-174.91	0.172
742	37.90	0.99	5.93	11.50	-174.56	0.172
743	37.95	0.98	5.86	11.81	-174.20	0.172
744	38.00	0.96	5.78	12.10	-173.82	0.171
745	38.05	0.95	5.71	12.40	-173.42	0.171
746	38.10	0.94	5.63	12.69	-173.01	0.171
747	38.15	0.93	5.56	12.97	-172.59	0.171
748	38.20	0.91	5.49	13.26	-172.15	0.171
749	38.26	0.90	5.41	13.53	-171.70	0.170
750	38.31	0.89	5.34	13.81	-171.23	0.170
751	38.36	0.88	5.26	14.08	-170.75	0.170
752	38.41	0.87	5.19	14.35	-170.26	0.169
753	38.46	0.85	5.12	14.61	-169.75	0.169
754	38.51	0.84	5.04	14.87	-169.23	0.169

755	38.56	0.83	4.97	15.13	-168.70	0.168
756	38.61	0.82	4.90	15.38	-168.15	0.168
757	38.66	0.80	4.82	15.63	-167.59	0.168
758	38.72	0.79	4.75	15.87	-167.02	0.167
759	38.77	0.78	4.67	16.11	-166.43	0.167
760	38.82	0.77	4.60	16.35	-165.83	0.166
761	38.87	0.75	4.53	16.58	-165.22	0.166
762	38.92	0.74	4.45	16.81	-164.60	0.165
763	38.97	0.73	4.38	17.04	-163.97	0.165
764	39.02	0.72	4.30	17.26	-163.33	0.164
765	39.07	0.71	4.23	17.48	-162.67	0.164
766	39.12	0.69	4.16	17.69	-162.00	0.163
767	39.18	0.68	4.08	17.91	-161.33	0.163
768	39.23	0.67	4.01	18.11	-160.64	0.162
769	39.28	0.66	3.93	18.32	-159.94	0.161
770	39.33	0.64	3.86	18.51	-159.23	0.161
771	39.38	0.63	3.79	18.71	-158.51	0.160
772	39.43	0.62	3.71	18.90	-157.78	0.159
773	39.48	0.61	3.64	19.09	-157.04	0.159
774	39.53	0.59	3.57	19.27	-156.29	0.158
775	39.59	0.58	3.49	19.45	-155.54	0.157
776	39.64	0.57	3.42	19.63	-154.77	0.157
777	39.69	0.56	3.34	19.80	-154.00	0.156
778	39.74	0.54	3.27	19.97	-153.21	0.155
779	39.79	0.53	3.20	20.14	-152.42	0.154
780	39.84	0.52	3.12	20.30	-151.62	0.154
781	39.89	0.51	3.05	20.46	-150.81	0.153
782	39.94	0.50	2.97	20.61	-149.99	0.152
783	39.99	0.48	2.90	20.76	-149.16	0.151
784	40.05	0.47	2.83	20.91	-148.33	0.150
785	40.10	0.46	2.75	21.05	-147.49	0.149
786	40.15	0.45	2.68	21.19	-146.64	0.149
787	40.20	0.43	2.60	21.33	-145.79	0.148
788	40.25	0.42	2.53	21.46	-144.93	0.147
789	40.30	0.41	2.46	21.58	-144.06	0.146
790	40.35	0.40	2.38	21.71	-143.19	0.145

791	40.40	0.38	2.31	21.83	-142.31	0.144
792	40.45	0.37	2.23	21.94	-141.42	0.143
793	40.51	0.36	2.16	22.06	-140.53	0.142
794	40.56	0.35	2.09	22.16	-139.63	0.141
795	40.61	0.34	2.01	22.27	-138.73	0.140
796	40.66	0.32	1.94	22.37	-137.82	0.139
797	40.71	0.31	1.87	22.47	-136.90	0.138
798	40.76	0.30	1.79	22.56	-135.98	0.137
799	40.81	0.29	1.72	22.65	-135.06	0.136
800	40.86	0.27	1.64	22.74	-134.13	0.135
801	40.91	0.26	1.57	22.82	-133.20	0.134
802	40.97	0.25	1.50	22.90	-132.26	0.133
803	41.02	0.24	1.42	22.97	-131.32	0.131
804	41.07	0.22	1.35	23.04	-130.38	0.130
805	41.12	0.21	1.27	23.11	-129.43	0.129
806	41.17	0.20	1.20	23.17	-128.48	0.128
807	41.22	0.19	1.13	23.23	-127.53	0.127
808	41.27	0.18	1.05	23.29	-126.57	0.126
809	41.32	0.16	0.98	23.34	-125.61	0.124
810	41.38	0.15	0.90	23.39	-124.65	0.123
811	41.43	0.14	0.83	23.43	-123.69	0.122
812	41.48	0.13	0.76	23.47	-122.72	0.121
813	41.53	0.11	0.68	23.51	-121.75	0.119
814	41.58	0.10	0.61	23.54	-120.78	0.118
815	41.63	0.09	0.54	23.57	-119.81	0.117
816	41.68	0.08	0.46	23.60	-118.83	0.116
817	41.73	0.06	0.39	23.62	-117.86	0.114
818	41.78	0.05	0.31	23.64	-116.88	0.113
819	41.84	0.04	0.24	23.65	-115.91	0.112
820	41.89	0.03	0.17	23.66	-114.93	0.110
821	41.94	0.02	0.09	23.67	-113.95	0.109
822	41.99	0.00	0.02	23.67	-112.97	0.108
823	42.04	2.72	6.78	23.95	-111.99	0.106
824	42.09	2.71	6.71	24.29	-110.99	0.105
825	42.14	2.70	6.65	24.63	-109.97	0.103
826	42.19	2.69	6.58	24.97	-108.94	0.102

827	42.24	2.67	6.51	25.31	-107.88	0.101
828	42.30	2.66	6.45	25.64	-106.81	0.099
829	42.35	2.65	6.38	25.96	-105.73	0.098
830	42.40	2.63	6.31	26.29	-104.62	0.096
831	42.45	2.62	6.25	26.61	-103.50	0.095
832	42.50	2.61	6.18	26.93	-102.37	0.093
833	42.55	2.60	6.11	27.24	-101.21	0.092
834	42.60	2.58	6.05	27.55	-100.05	0.090
835	42.65	2.57	5.98	27.86	-98.86	0.089
836	42.71	2.56	5.91	28.17	-97.66	0.087
837	42.76	2.55	5.85	28.47	-96.45	0.086
838	42.81	2.53	5.78	28.76	-95.22	0.084
839	42.86	2.52	5.72	29.06	-93.97	0.083
840	42.91	2.51	5.65	29.35	-92.71	0.081
841	42.96	2.50	5.58	29.64	-91.43	0.080
842	43.01	2.48	5.52	29.92	-90.14	0.078
843	43.06	2.47	5.45	30.20	-88.84	0.077
844	43.11	2.46	5.38	30.48	-87.52	0.075
845	43.17	2.45	5.32	30.75	-86.19	0.073
846	43.22	2.43	5.25	31.02	-84.84	0.072
847	43.27	2.42	5.18	31.29	-83.48	0.070
848	43.32	2.41	5.12	31.55	-82.11	0.068
849	43.37	2.39	5.05	31.81	-80.72	0.067
850	43.42	2.38	4.98	32.07	-79.32	0.065
851	43.47	2.37	4.92	32.32	-77.90	0.064
852	43.52	2.36	4.85	32.57	-76.48	0.062
853	43.57	2.34	4.78	32.82	-75.04	0.060
854	43.63	2.33	4.72	33.06	-73.59	0.059
855	43.68	2.32	4.65	33.30	-72.12	0.057
856	43.73	2.31	4.58	33.54	-70.65	0.055
857	43.78	2.29	4.52	33.77	-69.16	0.053
858	43.83	2.28	4.45	34.00	-67.66	0.052
859	43.88	2.27	4.38	34.22	-66.15	0.050
860	43.93	2.26	4.32	34.45	-64.62	0.048
861	43.98	2.24	4.25	34.66	-63.09	0.047
862	44.03	2.23	4.18	34.88	-61.54	0.045

863	44.09	2.22	4.12	35.09	-59.98	0.043
864	44.14	2.21	4.05	35.30	-58.42	0.041
865	44.19	2.19	3.98	35.51	-56.84	0.040
866	44.24	2.18	3.92	35.71	-55.25	0.038
867	44.29	2.17	3.85	35.91	-53.65	0.036
868	44.34	2.15	3.78	36.10	-52.05	0.034
869	44.39	2.14	3.72	36.29	-50.43	0.033
870	44.44	2.13	3.65	36.48	-48.80	0.031
871	44.50	2.12	3.59	36.67	-47.16	0.029
872	44.55	2.10	3.52	36.85	-45.51	0.027
873	44.60	2.09	3.45	37.03	-43.86	0.025
874	44.65	2.08	3.39	37.20	-42.19	0.024
875	44.70	2.07	3.32	37.37	-40.52	0.022
876	44.75	2.05	3.25	37.54	-38.83	0.020
877	44.80	2.04	3.19	37.71	-37.14	0.018
878	44.85	2.03	3.12	37.87	-35.44	0.016
879	44.90	2.02	3.05	38.03	-33.73	0.015
880	44.96	2.00	2.99	38.18	-32.02	0.013
881	45.01	1.99	2.92	38.33	-30.30	0.011
882	45.06	1.98	2.85	38.48	-28.56	0.009
883	45.11	1.97	2.79	38.62	-26.82	0.007
884	45.16	1.95	2.72	38.76	-25.08	0.006
885	45.21	1.94	2.65	38.90	-23.33	0.004
886	45.26	1.93	2.59	39.04	-21.56	0.002
887	45.31	1.91	2.52	39.17	-19.80	0.000
888	45.36	1.90	2.45	39.29	-18.02	-0.002
889	45.42	1.89	2.39	39.42	-16.24	-0.004
890	45.47	1.88	2.32	39.54	-14.46	-0.006
891	45.52	1.86	2.25	39.65	-12.67	-0.007
892	45.57	1.85	2.19	39.77	-10.87	-0.009
893	45.62	1.84	2.12	39.88	-9.06	-0.011
894	45.67	1.83	2.05	39.99	-7.25	-0.013
895	45.72	1.81	1.99	40.09	-5.44	-0.015
896	45.77	1.80	1.92	40.19	-3.62	-0.017
897	45.82	-45.76	-231.91	34.49	-1.87	-0.018
898	45.88	-45.76	-231.91	22.63	-0.64	-0.020



899	45.93	-45.76	-231.91	0.00	0.23	-0.022
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The above data can be selected using mouse, then copy and paste into Excel to create graphics



**Shoring Suite Analyses  
(Soldier Pile and Lagging Wall with Tiebacks)  
(Span 48-inch Culvert)**

## Steel Beam and Cross-Section Properties

Assumed Pile Shape **HP 14x73**

### Pile Availability

AISC Member Producers	<b>3</b>
Non-Member Producers	<b>0</b>

### Shaft Geometry

Shaft Diameter	<b>30</b> in
Longest Beam Dimension	<b>19.952945</b> in
Clear Distance	<b>5.0235277</b> in

### Steel Beam Geometry

Beam Depth (D)	<b>13.6</b> in
Web Thickness ( $t_w$ )	<b>0.505</b> in
Flange Width ( $B_f$ )	<b>14.6</b> in
Flange Thickness ( $t_f$ )	<b>0.505</b> in
Area of Steel ( $A_s$ )	<b>21.4</b> in <sup>2</sup>

### Steel Properties

Yield Strength of Steel	<b>50</b> ksi
Moment of Inertia ( $I_{xx}$ ) of Steel	<b>729</b> in <sup>4</sup>
Modulus of Elasticity of Steel (E)	<b>29000</b> ksi
Modulus of Elasticity of Steel (E)	<b>29000000</b> psi
EI (Steel Only)	<b>2.114E+10</b> lb*in <sup>2</sup>
Section Modulus ( $S_x$ )	<b>107</b> in <sup>3</sup>
Section Modulus ( $Z_x$ )	<b>118</b> in <sup>3</sup>
Shear-Buckling Coefficient (k)	<b>5</b>
Ratio of Shear-Buckling Resistance (C)	<b>1</b>
D/ $t_w$	<b>26.930693</b>
1.12VEk/ $F_{yw}$	<b>60.313846</b>
1.40VEk/ $F_{yw}$	<b>75.392307</b>

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

$$V_u \leq \phi V_{cr}$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$
$$V_{cr} = \text{shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)}$$
$$V_n = V_{cr} = C V_p$$
$$V_p = 0.58 F_{yw} D t_w$$
$$V_p = \text{plastic shear force (kips)}$$
$$C = \text{ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6}$$
$$V_p = 0.58 * 50 * 13.6 * 0.505$$
$$V_p = \boxed{199.2} \text{ kips}$$
$$\phi V_{cr} = \phi * C * V_p$$
$$\phi V_{cr} = 1 * 1 * 199.2$$
$$\phi V_{cr} = \boxed{199.2} \text{ kips}$$
$$V_u = \boxed{120.05} \text{ kips (from Shoring Suite)}$$
$$\boxed{\phantom{000}} \text{ kips (from PYWALL)}$$
$$V_u < \phi V_{cr} \quad \text{OK}$$

### Flexure Capacity Calculation

$$M_u \leq \phi M_n$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$M_u = \text{Moment due to the factored loads}$$
$$M_n = \text{Nominal flexural resistance of a section}$$
$$S_x = \text{Elastic section modulus about the x-axis}$$
$$\phi M_n = \phi * F_y * S_x$$
$$\phi M_n = 1 * 50 * 107$$
$$\phi M_n = \boxed{5350} \text{ in*kips}$$
$$M_u = \boxed{3469.2} \text{ in*kips (from Shoring Suite)}$$
$$M_u = \boxed{\phantom{000}} \text{ in*kips (from PYWALL)}$$
$$M_u < \phi M_n \quad \text{OK}$$

### Deflection Criteria

Pile Length Above Rock = <b>45.8</b> ft	Exposed Wall Height = <b>42</b> ft
Pile Length Above Rock = <b>549.6</b> in	Exposed Wall Height = <b>504</b> 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

**5.496** in

$\delta = \boxed{0.37}$  in (from LPILE)

1.5% Wall Height - PYWALL

in

$\delta = \boxed{\phantom{000}}$  in (from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement

**NO**

## Tieback Loading Computations

Design Tieback Load, TF1 = 239.0 kips / shaft  
 Design Tieback Load, TF2 = 154.2 kips / shaft  
 Design Tieback Load, TF3 = 186.4 kips / shaft

Horizontal values determined from Shoring Suite calculations.

### 1) Determine Tiebacks

Strands

0.6 GUTS per strand = 35.2 kips per strand (FHWA-NHI-07-071: Table 8-16)

(GUTS = guranteed ultimate tensile strength)

Tieback	Inclin.	Required Anchor Load**	Strands	
No.	deg	kips	Required	Selected
1	20	254.3	7.2	8.0
2	20	164.1	4.7	5.0
3	20	198.4	5.6	6.0

\*\*Required Anchor Load = (TF) / [Cos (Inclin. Angle)]

### 2) Check Pull-Out Capacity and Bond Length

Pullout Resistance Factor  $\phi_{pr}$  = 0.7 Per AASHTO LRFD Table 11.5.7-1 for "Pullout resistance of anchors, cohesive soils"

Soil Friction Angle  $\phi$  = 26

Table 8-16. Properties of 0.6 in. Diameter Prestressing Steel Strands (ASTM A416, Grade 270).

Number of 0.6 in. diameter strands	Cross section area (in. <sup>2</sup> )	Ultimate strength (=GUTS) (kips)	Prestressing force		
			0.8 $f_{pu}A_{ps}$ (kips)	0.7 $f_{pu}A_{ps}$ (kips)	0.6 $f_{pu}A_{ps}$ (kips)
1	0.217	58.6	46.9	41.0	35.2

Tieback	Height Above Bottom of Wall	Tieback Length to Active Wedge	Total Unbonded Length	Ultimate Bond Strength	Tieback Drill Hole Diameter	Surface Area per Foot of Tieback	Allowable Bond Strength per Foot of Tieback	Required Anchor Load	Required Bond Length	Total Tieback Length
No.	ft	ft	ft	ksf	in	in <sup>2</sup> /ft	kips/ft	kips	ft	ft
1	32	17.3	32	3	9	339.3	4.95	254.3	51	84
2	22	11.9	26	3	9	339.3	4.95	164.1	33	60
3	12	6.5	21	3	9	339.3	4.95	198.4	40	62

Total unbonded length = Tieback length to active wedge + greater of 5 feet or H/3, with a 15 foot minimum, per AASHTO LRFD Figure 11.9.1-1

Ultimate bond strength per AASHTO LRFD Table C11.9.4.2-1. Tieback lengths assume entire bond length is in clay.

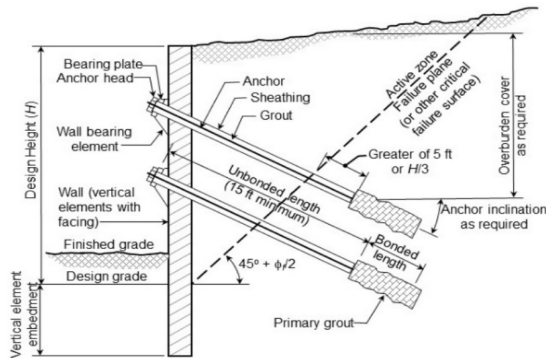


Figure 11.9.1-1—Anchored Wall Nomenclature and Anchor Embedment Guidelines

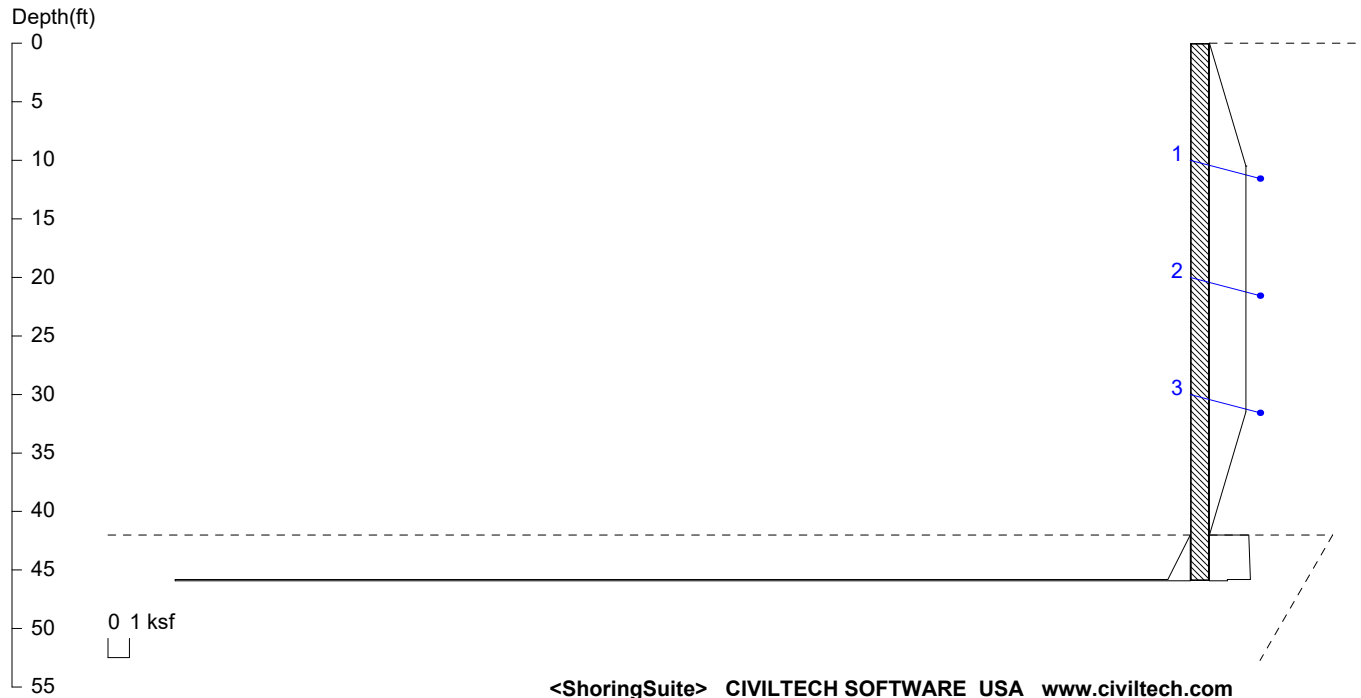
Table C11.9.4.2-1—Presumptive Ultimate Unit Bond Stress for Anchors in Cohesive Soils

Anchor/Soil Type (Grout Pressure)	Soil Stiffness or Unconfined Compressive Strength (tsf)	Presumptive Ultimate Unit Bond Stress, $\tau_u$ (ksf)
Gravity Grouted Anchors (<50 psi)		
Silt-Clay Mixtures	Stiff to Very Stiff 1.0-4.0	0.6 to 1.5
Pressure Grouted Anchors (50 psi-400 psi)		
High Plasticity Clay	Stiff 1.0-2.5 V. Stiff 2.5-4.0	0.6 to 2 1.5 to 3.6
Medium Plasticity Clay	Stiff 1.0-2.5 V. Stiff 2.5-4.0	2.0 to 5.2 2.9 to 7.3
Medium Plasticity Sandy Silt	V. Stiff 2.5-4.0	5.8 to 7.9



## Service Limit Analysis (Span 48-inch Culvert)

# WAS-77-9.58



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Date: 9/8/2023

File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Culvert Span Tieback Service.sh8

Wall Height=42.0

Pile Diameter=2.5

Pile Spacing=7.3

Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=3.92 (5~10ft is recommended!!!) Min. Pile Length=45.92

MOMENT IN PILE: Max. Moment=193.03 per Pile Spacing=7.3 at Depth=10.01

## PILE SELECTION:

Request Min. Section Modulus = 46.3 in<sup>3</sup>/pile=759.17 cm<sup>3</sup>/pile, F<sub>y</sub>= 50 ksi = 345 MPa, F<sub>b</sub>/F<sub>y</sub>=1

HP14X73 has Section Modulus = 107.0 in<sup>3</sup>/pile=1753.41 cm<sup>3</sup>/pile. It is greater than Min. Requirements!

Top Deflection = 0.00(in) based on E (ksi)=29000.00 and I (in<sup>4</sup>)/pile=729.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L <sub>free</sub>	Fixed Length
1. Tieback	10.0	20.0	7.3	169.6*	159.4	58.0	25.5	34.3
2. Tieback	20.0	20.0	7.3	109.3	102.7	37.4	20.4	22.1
3. Tieback	30.0	20.0	7.3	132.0	124.1	45.2	15.3	26.7

\* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

## DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE):

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	10.50	1.686	0.160554
10.50	1.686	31.50	1.686	0.000000
31.50	1.686	42.00	0.000	-0.16055
*	Below	Base		
42.00	1.822	45.80	1.890	0.017893
45.80	0.823	252.0	4.227	0.016508

## PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		

42.00	0.000	45.80	1.040	0.273724
45.80	47	252.0	47	0.0000

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	7.25
2	42.00	2.50

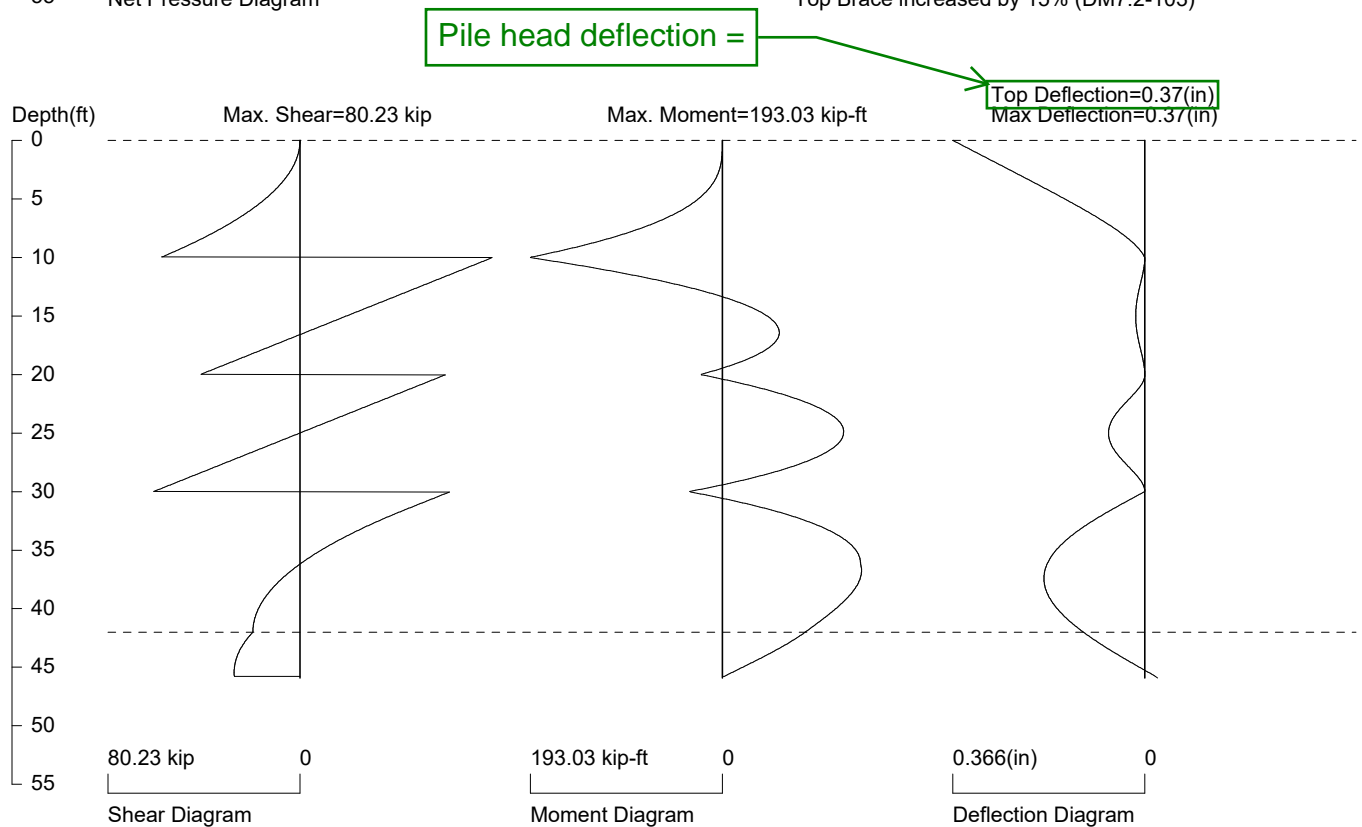
PASSIVE SPACING:

No.	Z depth	Spacing
1	42.00	5.00

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft  
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft<sup>3</sup>; Deflection - in

# WAS-77-9.58



## PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 7.3 foot or meter

User Input Pile, HP14X73: E (ksi)=29000.0, I (in4)/pile=729.0

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SHORING WALL CALCULATION SUMMARY  
The leading shoring design and calculation software  
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\*\*\*\*\*

ShoringSuite Software is developed by CivilTech Software, Bellevue, WA, USA.

The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf, Pres. Slope - kip/ft<sup>3</sup>, Deflection - in

-----  
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Date: 9/8/2023 File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Culvert Span Tieback Service.sh8

Title: WAS-77-9.58

Subtitle:

\*\*\*\*\*INPUT DATA\*\*\*\*\*

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 42.00

Pile Diameter: 2.50

Pile Spacing: 7.25

Factor of Safety (F.S.): 1.00

As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback

Top Brace Increase (Multi-Bracing): Add 15%\*

No-Load Zone:

Vertical Depth for No-Load Zone: 42.00

H-Distance (Input H/V ratio) for No-Load Zone: 0.25

Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes

Friction at Pile Tip: No

Pile Properties:

Steel Strength, Fy: 50 ksi = 345 MPa

Allowable Fb/Fy: 1

Elastic Module, E: 29000.00

Moment of Inertia, I: 729.00

User Input Pile: HP14X73

\* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) \*

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	10.50	1.686	0.160554
3	10.50	1.686	31.50	1.686	0.000000
4	31.50	1.686	42.00	0.000	-0.16055
5	*	Below	Base		
6	42.00	1.822	45.80	1.890	0.017893
7	45.80	0.823	252.0	4.227	0.016508

\* PASSIVE PRESSURE \*

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	42.00	0.000	45.80	1.040	0.273724
3	45.80	47	252.0	47	0.0000

\* ACTIVE SPACE \*

No.	Z depth	Spacing
1	0.00	7.25
2	42.00	2.50

\* PASSIVE SPACE \*

No.	Z depth	Spacing
1	42.00	5.00

Hole diameter in feet  
(9 inches).

Allowable bond strength =  
resistance factor \* ultimate  
bond strength = 0.7\*3 ksf

\* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR\*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	10.00	20.0	7.25	0.75	2.10	Tieback
2	20.00	20.0	7.25	0.75	2.10	Tieback
3	30.00	20.0	7.25	0.75	2.10	Tieback

\*For Tieback: Input1 = Diameter; Input2 = Bond Strength

\*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

\*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

\*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

\*\*\*\*\*CALCULATION\*\*\*\*\*

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

\* CALCULATE REQUEST EMBEDMENT \*

```

| <-- D1=30.00
|
==|== D2=42.00
|
|      D3=45.92

```

D1 - TOP DEPTH

R1 - TOP REACTION

D2 - EXCAVATION BASE

D3 - PILE TIP

TOTAL REACTION: R1 = 62.75  
TOTAL PRESSURES ACTING ON WALL = 62.75  
Total Reactions = Total Pressures, OK!  
The Calculated Embedment, Yend = 3.92

-----MULTIPLE BRACE / TIEBACK CASE-----  
\*\* Use the calculated embedment, Yend = 3.92 for graphics and analysis.

NUMBER OF BRACE LEVEL= 3

\* CANTILEVER SPAN, N0.0 \*

	D1=0.00	
<--	D2=10.00	R2=58.20, with Cantilever Moment=194.00

D1 - TOP DEPTH  
D2 - BOTTOM DEPTH                      R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 58.20  
TOTAL PRESSURES ACTING ON WALL = 58.20  
Total Reactions = Total Pressures, OK!

---

BRACE NO.1 AT DEPTH = 10.00  
R2 of Cantilever Span  
R1 of Span No.1                      } Sum of Reaction = Brace Load = 138.57

---

\* MIDDLE SPAN NO.1 \*

<--	D1=10.00	R1=80.37, with Cantilever Moment=194.00
<--	D2=20.00	R2=41.71

D1 - TOP DEPTH                      R1 - TOP REACTION  
D2 - BOTTOM DEPTH                R2 - BOTTOM REACTION

TOTAL REACTION:  $R1+R2 = 122.09$   
TOTAL PRESSURES ACTING ON WALL = 122.09  
Total Reactions = Total Pressures, OK!

```
BRACE NO.2 AT DEPTH = 20.00
    R2 of Span No.1
    R1 of Last Span
    } Sum of Reaction = Brace Load = 102.71
```

\* LAST SPAN \*

<--	D1=20.00	R1=61.00
<--	D2=30.00	R2=124.06
	D3=45.92	

D1 - TOP DEPTH                      R1 - TOP REACTION  
D2 - LAST BRACE DEPTH          R2 - LAST BRACE REACTION  
D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 185.06  
TOTAL PRESSURES ACTING ON WALL = 185.06  
Total Reactions >= Total Pressures, OK!

BRACE NO.3 AT DEPTH = 30.00  
R2 of Last Span = Brace Load = 124.06

\*\*\*\*\*RESULTS\*\*\*\*\*

\* EMBEDMENT \*

MINIMUM EMBEDMENT = 3.92 (5~10ft recommended!!!), TOTAL MINIMUM PILE LENGTH = 45.92

\* MOMENT IN PILE (per pile spacing)\*

Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	10.00	193.03	57.16	16.40
2	20.00	20.87	121.85	24.88
3	30.00	32.85	139.87	36.73

Overall Maximum Moment = 193.03 at 10.01

Maximum Shear = 80.23

Moment and Shear are per pile spacing: 7.3 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 138.57 to 159.36

\* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR\*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	10.00	20.0	7.25	159.36	58.00	169.59
2	20.00	20.0	7.25	102.71	37.39	109.31
3	30.00	20.0	7.25	124.06	45.15	132.02

No.	DEPTH	Free length	Brace Type
1	10.00	25.48	Tieback, Bond length = 34.27
2	20.00	20.40	Tieback, Bond length = 22.09
3	30.00	15.33	Tieback, Bond length = 26.68

\* VERTICAL LOADING \*

Vertical Loading from Braces = 140.54

Vertical Loading from External Load = 0.00

Total Vertical Loading = 140.54

\*\*\*\*\*SPECIFIED PILE \*\*\*\*\*

Overall Maximum Moment = 193.03 at 10.01

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 46.33 in<sup>3</sup>/pile = 759.17 cm<sup>3</sup>/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X73 has been found in Soldier Pile list!

(English Units):

Area= 21.4 in. Depth= 13.6 in. Width= 14.6 in. Height= 14 in.

Flange thickness= 0.505 in. Web thickness= 0.505 in.

Ix= 729 in<sup>4</sup>/pile Sx= 107 in<sup>3</sup>/pile Iy= 261 in<sup>4</sup>/pile Sy= 35.8 in<sup>3</sup>/pile

(Metric Units):

Ix= 303.41 x100cm<sup>4</sup>/pile Sx= 1753.41 cm<sup>3</sup>/pile Iy= 108.63 x100cm<sup>4</sup>/pile Sy= 586.65 cm<sup>3</sup>/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X73 is capable to support the shoring!

Top deflection = 0.000(in)

Max. deflection = 0.864(in)

\*\*\*\*\* LAGGING SIZE ESTIMATION \*\*\*\*\*

Max. Pressure above base = 1.69

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 0.84

Pile Spacing =7.3, Max. Moment in lagging = 5.54

For 4"x12" Timber, Section Modules S=23.47 in<sup>3</sup>. The request allowable bending strength, fb=M/S=2.83

For 6"x12" Timber, Section Modules S=57.98 in<sup>3</sup>. The request allowable bending strength, fb=M/S=1.15

If 30% loading is used for lagging design, Design Pressure = 0.51

Pile Spacing =7.3, Max. Moment in lagging = 3.32

For 4"x12" Timber, Section Modules S=23.47 in<sup>3</sup>. The request allowable bending strength, fb=M/S=1.70

For 6"x12" Timber, Section Modules S=57.98 in<sup>3</sup>. The request allowable bending strength, fb=M/S=0.69

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi



Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi



## Strength Limit Analysis (Span 48-inch Culvert)

# WAS-77-9.58



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Date: 9/8/2023

File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Culvert Span Tieback St

Anchor loads and lengths

Wall Height=42.0 Pile Diameter=2.5 Pile Spacing=7.3 Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=4.00 (5~10ft is recommended!!!) Min. Pile Length=46.00

MOMENT IN PILE: Max. Moment=289.10 per Pile Spacing=7.3 at Depth=9.98

## PILE SELECTION:

Request Min. Section Modulus = 69.4 in<sup>3</sup>/pile=1137.00 cm<sup>3</sup>/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X73 has Section Modulus = 107.0 in<sup>3</sup>/pile=1753.41 cm<sup>3</sup>/pile. It is greater than Min. Requirements!

Top Deflection = 0.55(in) based on E (ksi)=29000.00 and I (in<sup>4</sup>)/pile=729.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	Unbonded Length	Bonded Length
1. Tieback	10.0	20.0	7.3	254.4*	239.0	87.0	25.5	51.4
2. Tieback	20.0	20.0	7.3	164.1	154.2	56.1	20.4	33.2
3. Tieback	30.0	20.0	7.3	198.4	186.4	67.9	15.3	40.1

\* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

## DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE):

Pressures below will be multiplied by a Factor =1.5

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	10.50	1.686	0.160554
10.50	1.686	31.50	1.686	0.000000
31.50	1.686	42.00	0.000	-0.16055
*	Below	Base		
42.00	1.822	45.80	1.890	0.017893
45.80	0.823	252.0	4.227	0.016508

Applied 1.5 load factor for active earth pressures.

## PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		

42.00	0.000	45.80	1.040	0.273724
45.80	47	252.0	47	0.0000

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	7.25
2	42.00	2.50

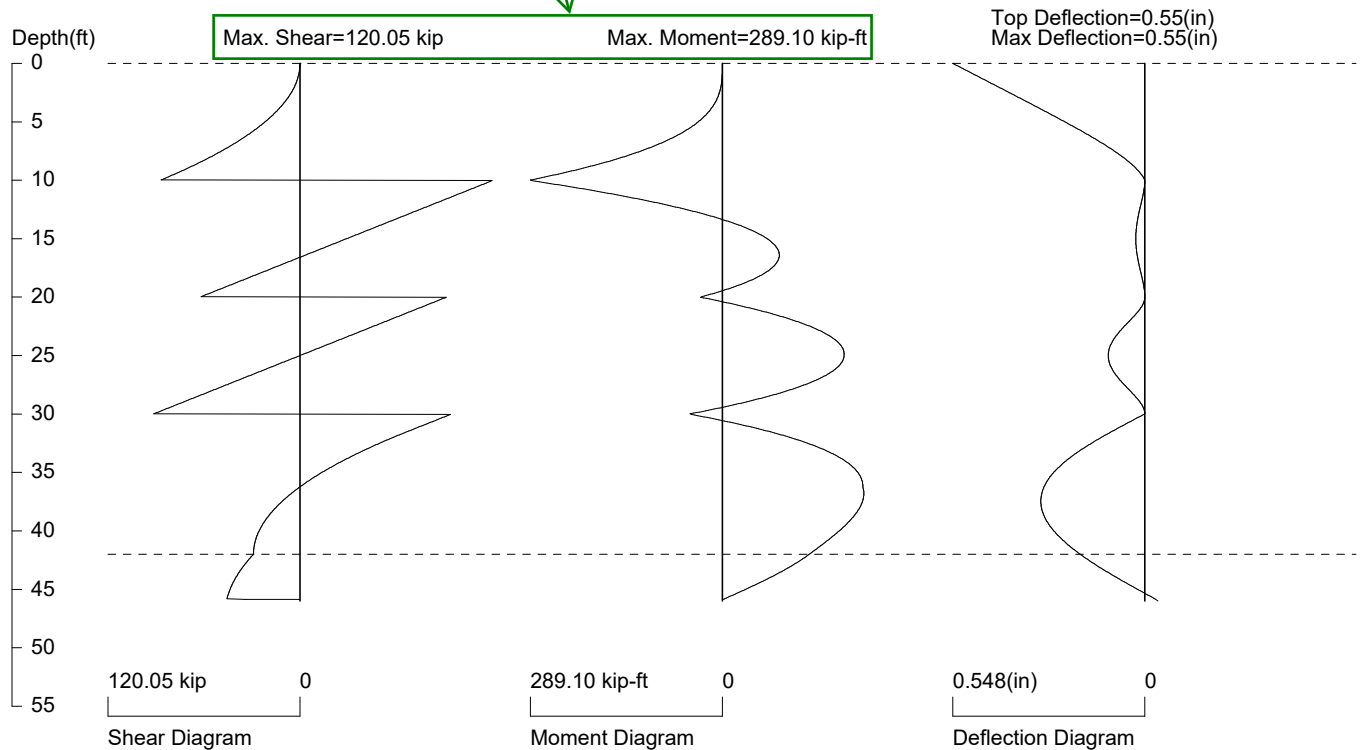
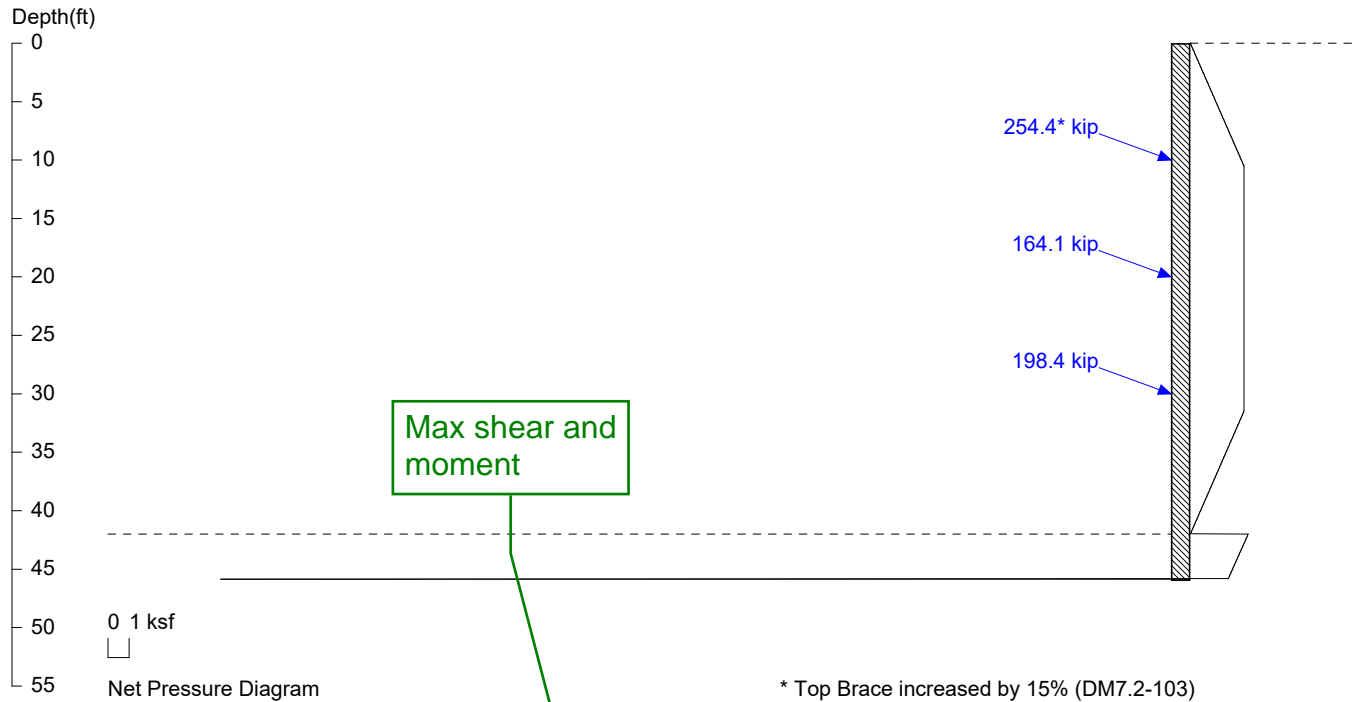
PASSIVE SPACING:

No.	Z depth	Spacing
1	42.00	5.00

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft  
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft<sup>3</sup>; Deflection - in

# WAS-77-9.58



## PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 7.3 foot or meter

User Input Pile, HP14X73: E (ksi)=29000.0, I (in<sup>4</sup>)/pile=729.0

File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Culvert Span Tieback Strength.sh8

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SHORING WALL CALCULATION SUMMARY  
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\*\*\*\*\*

ShoringSuite Software is developed by CivilTech Software, Bellevue, WA, USA.

The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf,  
Pres. Slope - kip/ft<sup>3</sup>, Deflection - in

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Date: 9/8/2023 File: C:\Users\DMATCHIS\Documents\WAS-77-9.58 42' Culvert Span Tieback Strength.sh8

Title: WAS-77-9.58

Subtitle:

\*\*\*\*\*INPUT DATA\*\*\*\*\*

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 42.00

Pile Diameter: 2.50

Pile Spacing: 7.25

Factor of Safety (F.S.): 1.00  
 As Continuous Span Beam  
 Lateral Support Type (Braces): 3. Tieback  
 Top Brace Increase (Multi-Bracing): Add 15%\*  
 No-Load Zone:  
   Vertical Depth for No-Load Zone: 42.00  
   H-Distance (Input H/V ratio) for No-Load Zone: 0.25  
   Angle from H. Line for No-Load Zone: 60.00  
 Embedment Option: 1. Yes  
   Friction at Pile Tip: Limited  
   Limited Tip Friction: 0.00  
 Pile Properties:  
   Steel Strength, Fy: 50 ksi = 345 MPa  
   Allowable Fb/Fy: 1  
   Elastic Module, E: 29000.00  
   Moment of Inertia, I: 729.00  
   User Input Pile: HP14X73

\* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) \*

The pressures below will be multiplied by a Factor =1.5

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
-----					
1	*	Above	Base		
2	0.000	0.000	10.50	1.686	0.160554
3	10.50	1.686	31.50	1.686	0.000000
4	31.50	1.686	42.00	0.000	-0.16055
5	*	Below	Base		
6	42.00	1.822	45.80	1.890	0.017893
7	45.80	0.823	252.0	4.227	0.016508
-----					

\* PASSIVE PRESSURE \*

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
-----					
1	*	Below	Base		
2	42.00	0.000	45.80	1.040	0.273724

3	45.80	47	252.0	47	0.0000
---	-------	----	-------	----	--------

\* ACTIVE SPACE \*

No.	Z depth	Spacing
-----	---------	---------

1	0.00	7.25
2	42.00	2.50

\* PASSIVE SPACE \*

No.	Z depth	Spacing
-----	---------	---------

1	42.00	5.00
---	-------	------

Hole diameter in feet  
(9 inches).

Allowable bond strength =  
resistance factor \* ultimate  
bond strength = 0.7\*3 ksf

\* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR\*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	10.00	20.0	7.25	0.75	2.10	Tieback
2	20.00	20.0	7.25	0.75	2.10	Tieback
3	30.00	20.0	7.25	0.75	2.10	Tieback

\*For Tieback: Input1 = Diameter; Input2 = Bond Strength

\*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

\*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

\*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

\*\*\*\*\*CALCULATION\*\*\*\*\*

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00



\* CALCULATE REQUEST EMBEDMENT \*

```
      | <-- D1=30.00
      |
==|== D2=42.00
      |
      | D3=46.00
```

D1 - TOP DEPTH                      R1 - TOP REACTION  
D2 - EXCAVATION BASE  
D3 - PILE TIP

TOTAL REACTION: R1 = 94.69

TOTAL PRESSURES ACTING ON WALL = 94.69

Total Reactions = Total Pressures,      OK!

The Calculated Embedment, Yend = 4.00

-----MULTIPLE BRACE / TIEBACK CASE-----

\*\* Use the calculated embedment, Yend = 4.00 for graphics and analysis.

NUMBER OF BRACE LEVEL= 3

\* CANTILEVER SPAN, N0.0 \*

```
      | D1=0.00
      |
      |
      | <-- D2=10.00                      R2=87.30, with Cantilever Moment=291.00
```

D1 - TOP DEPTH  
D2 - BOTTOM DEPTH                      R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 87.30

TOTAL PRESSURES ACTING ON WALL = 87.30

Total Reactions = Total Pressures,      OK!

---

BRACE NO.1 AT DEPTH = 10.00  
 R2 of Cantilever Span  
 R1 of Span No.1 } Sum of Reaction = Brace Load = 207.86

---

\* MIDDLE SPAN NO.1 \*

<--	D1=10.00	R1=120.56, with Cantilever Moment=291.00
<--	D2=20.00	R2=62.57

D1 - TOP DEPTH	R1 - TOP REACTION
D2 - BOTTOM DEPTH	R2 - BOTTOM REACTION

TOTAL REACTION: R1+R2 = 183.13  
 TOTAL PRESSURES ACTING ON WALL = 183.13  
 Total Reactions = Total Pressures, OK!

---

BRACE NO.2 AT DEPTH = 20.00  
 R2 of Span No.1  
 R1 of Last Span } Sum of Reaction = Brace Load = 154.19

---

\* LAST SPAN \*

<--	D1=20.00	R1=91.62
<--	D2=30.00	R2=186.42

|  
| D3=46.00

D1 - TOP DEPTH                      R1 - TOP REACTION  
D2 - LAST BRACE DEPTH      R2 - LAST BRACE REACTION  
D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 278.04  
TOTAL PRESSURES ACTING ON WALL = 278.04  
Total Reactions >= Total Pressures,      OK!

---

BRACE NO.3 AT DEPTH = 30.00  
R2 of Last Span = Brace Load = 186.42

---

\*\*\*\*\*RESULTS\*\*\*\*\*

\* EMBEDMENT \*

MINIMUM EMBEDMENT = 4.00 (5~10ft recommended!!!),    TOTAL MINIMUM PILE LENGTH = 46.00

\* MOMENT IN PILE (per pile spacing)\*

Pile Spacing:    sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
-----				
1	10.00	289.10	85.67	16.43
2	20.00	32.88	183.35	24.87
3	30.00	48.59	212.97	36.79
-----				

Overall Maximum Moment = 289.10 at 9.98

Maximum Shear = 120.05

Moment and Shear are per pile spacing: 7.3 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 207.86 to 239.04

\* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR\*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	10.00	20.0	7.25	239.04	87.00	254.38
2	20.00	20.0	7.25	154.19	56.12	164.09
3	30.00	20.0	7.25	186.42	67.85	198.39

No.	DEPTH	Free length	Brace Type
1	10.00	25.48	Tieback, Bond length = 51.41
2	20.00	20.40	Tieback, Bond length = 33.16
3	30.00	15.33	Tieback, Bond length = 40.09

\* VERTICAL LOADING \*

Vertical Loading from Braces = 210.98

Vertical Loading from External Load = 0.00

Total Vertical Loading = 210.98

\*\*\*\*\*SPECIFIED PILE \*\*\*\*\*

Overall Maximum Moment = 289.10 at 9.98

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 69.38 in<sup>3</sup>/pile = 1137.00 cm<sup>3</sup>/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X73 has been found in Soldier Pile list!

(English Units):

Area= 21.4 in. Depth= 13.6 in. Width= 14.6 in. Height= 14 in.

Flange thickness= 0.505 in. Web thickness= 0.505 in.

Ix= 729 in<sup>4</sup>/pile Sx= 107 in<sup>3</sup>/pile Iy= 261 in<sup>4</sup>/pile Sy= 35.8 in<sup>3</sup>/pile

(Metric Units):

Ix= 303.41 x100cm<sup>4</sup>/pile Sx= 1753.41 cm<sup>3</sup>/pile Iy= 108.63 x100cm<sup>4</sup>/pile Sy= 586.65 cm<sup>3</sup>/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X73 is capable to support the shoring!

Top deflection = 0.548(in)

Max. deflection = 0.548(in)

\*\*\*\*\* LAGGING SIZE ESTIMATION \*\*\*\*\*

Max. Pressure above base = 2.53

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 1.26

Pile Spacing = 7.3, Max. Moment in lagging = 8.31

For 4"x12" Timber, Section Modules  $S=23.47 \text{ in}^3$ . The request allowable bending strength,  $fb=M/S=4.25$

For 6"x12" Timber, Section Modules  $S=57.98 \text{ in}^3$ . The request allowable bending strength,  $fb=M/S=1.72$

If 30% loading is used for lagging design, Design Pressure = 0.76

Pile Spacing = 7.3, Max. Moment in lagging = 4.98

For 4"x12" Timber, Section Modules  $S=23.47 \text{ in}^3$ . The request allowable bending strength,  $fb=M/S=2.55$

For 6"x12" Timber, Section Modules  $S=57.98 \text{ in}^3$ . The request allowable bending strength,  $fb=M/S=1.03$

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

\*\*\*\*\*PRESSURE, LOAD, SHEAR, MOMENT, AND DEFLECTION v.s. DEPTH\*\*\*\*\*

The shear and moment are per single soldier pile (secant/tangent pile) or one foot of sheet pile (concrete wall). The deflection is based on users input pile below:

User Input Pile: HP14X73

Elastic Module,  $E \text{ (ksi)}= 29000.00$

Moment of Inertia,  $I \text{ (in}^4\text{)}/\text{pile}= 729.0$

PRESS. - Sum of all pressures (Net pressure). (Active) direction is positive

LOAD - Liner load (force per unit depth) = Pressures multiply by acting space

No	DEPTH ft	PRESS. ksf	LOAD kip/ft	SHEAR kip	MOMENT kip-ft	DEFLECTION in
1	0.00	0.00	0.00	0.00	0.00	0.548
2	0.05	0.01	0.09	0.00	0.00	0.545
3	0.10	0.02	0.18	0.01	0.00	0.541
4	0.15	0.04	0.27	0.02	0.00	0.538
5	0.20	0.05	0.36	0.04	0.00	0.535
6	0.26	0.06	0.45	0.06	0.00	0.532
7	0.31	0.07	0.54	0.08	0.01	0.528
8	0.36	0.09	0.63	0.11	0.01	0.525
9	0.41	0.10	0.71	0.15	0.02	0.522
10	0.46	0.11	0.80	0.19	0.03	0.518
11	0.51	0.12	0.89	0.23	0.04	0.515
12	0.56	0.14	0.98	0.28	0.05	0.512
13	0.61	0.15	1.07	0.33	0.07	0.508
14	0.67	0.16	1.16	0.39	0.09	0.505
15	0.72	0.17	1.25	0.45	0.11	0.502
16	0.77	0.18	1.34	0.51	0.13	0.498
17	0.82	0.20	1.43	0.59	0.16	0.495
18	0.87	0.21	1.52	0.66	0.19	0.492
19	0.92	0.22	1.61	0.74	0.23	0.489
20	0.97	0.23	1.70	0.83	0.27	0.485
21	1.02	0.25	1.79	0.91	0.31	0.482
22	1.07	0.26	1.88	1.01	0.36	0.479
23	1.13	0.27	1.97	1.11	0.42	0.475
24	1.18	0.28	2.05	1.21	0.47	0.472
25	1.23	0.30	2.14	1.32	0.54	0.469
26	1.28	0.31	2.23	1.43	0.61	0.465
27	1.33	0.32	2.32	1.55	0.69	0.462
28	1.38	0.33	2.41	1.67	0.77	0.459
29	1.43	0.35	2.50	1.79	0.86	0.455
30	1.48	0.36	2.59	1.92	0.95	0.452
31	1.54	0.37	2.68	2.06	1.05	0.449
32	1.59	0.38	2.77	2.20	1.16	0.446
33	1.64	0.39	2.86	2.34	1.28	0.442

34	1.69	0.41	2.95	2.49	1.40	0.439
35	1.74	0.42	3.04	2.64	1.53	0.436
36	1.79	0.43	3.13	2.80	1.67	0.432
37	1.84	0.44	3.22	2.96	1.82	0.429
38	1.89	0.46	3.31	3.13	1.97	0.426
39	1.94	0.47	3.40	3.30	2.14	0.422
40	2.00	0.48	3.48	3.48	2.31	0.419
41	2.05	0.49	3.57	3.66	2.50	0.416
42	2.10	0.51	3.66	3.84	2.69	0.413
43	2.15	0.52	3.75	4.03	2.89	0.409
44	2.20	0.53	3.84	4.23	3.10	0.406
45	2.25	0.54	3.93	4.43	3.32	0.403
46	2.30	0.55	4.02	4.63	3.55	0.399
47	2.35	0.57	4.11	4.84	3.80	0.396
48	2.40	0.58	4.20	5.05	4.05	0.393
49	2.46	0.59	4.29	5.27	4.31	0.389
50	2.51	0.60	4.38	5.49	4.59	0.386
51	2.56	0.62	4.47	5.71	4.87	0.383
52	2.61	0.63	4.56	5.95	5.17	0.380
53	2.66	0.64	4.65	6.18	5.48	0.376
54	2.71	0.65	4.74	6.42	5.80	0.373
55	2.76	0.67	4.82	6.67	6.14	0.370
56	2.81	0.68	4.91	6.91	6.49	0.366
57	2.87	0.69	5.00	7.17	6.85	0.363
58	2.92	0.70	5.09	7.43	7.22	0.360
59	2.97	0.71	5.18	7.69	7.61	0.357
60	3.02	0.73	5.27	7.96	8.01	0.353
61	3.07	0.74	5.36	8.23	8.42	0.350
62	3.12	0.75	5.45	8.51	8.85	0.347
63	3.17	0.76	5.54	8.79	9.29	0.343
64	3.22	0.78	5.63	9.07	9.75	0.340
65	3.27	0.79	5.72	9.36	10.22	0.337
66	3.33	0.80	5.81	9.66	10.71	0.334
67	3.38	0.81	5.90	9.96	11.21	0.330
68	3.43	0.83	5.99	10.26	11.73	0.327
69	3.48	0.84	6.08	10.57	12.26	0.324

70	3.53	0.85	6.16	10.88	12.81	0.321
71	3.58	0.86	6.25	11.20	13.37	0.317
72	3.63	0.87	6.34	11.52	13.95	0.314
73	3.68	0.89	6.43	11.85	14.55	0.311
74	3.74	0.90	6.52	12.18	15.17	0.307
75	3.79	0.91	6.61	12.52	15.80	0.304
76	3.84	0.92	6.70	12.86	16.45	0.301
77	3.89	0.94	6.79	13.20	17.12	0.298
78	3.94	0.95	6.88	13.55	17.80	0.294
79	3.99	0.96	6.97	13.91	18.50	0.291
80	4.04	0.97	7.06	14.27	19.22	0.288
81	4.09	0.99	7.15	14.63	19.96	0.285
82	4.14	1.00	7.24	15.00	20.72	0.282
83	4.20	1.01	7.33	15.37	21.50	0.278
84	4.25	1.02	7.42	15.75	22.29	0.275
85	4.30	1.04	7.50	16.13	23.11	0.272
86	4.35	1.05	7.59	16.52	23.94	0.269
87	4.40	1.06	7.68	16.91	24.80	0.265
88	4.45	1.07	7.77	17.30	25.67	0.262
89	4.50	1.08	7.86	17.70	26.57	0.259
90	4.55	1.10	7.95	18.11	27.49	0.256
91	4.61	1.11	8.04	18.52	28.42	0.253
92	4.66	1.12	8.13	18.93	29.38	0.249
93	4.71	1.13	8.22	19.35	30.36	0.246
94	4.76	1.15	8.31	19.77	31.36	0.243
95	4.81	1.16	8.40	20.20	32.38	0.240
96	4.86	1.17	8.49	20.63	33.43	0.237
97	4.91	1.18	8.58	21.07	34.50	0.234
98	4.96	1.20	8.67	21.51	35.58	0.230
99	5.01	1.21	8.76	21.95	36.70	0.227
100	5.07	1.22	8.85	22.40	37.83	0.224
101	5.12	1.23	8.93	22.86	38.99	0.221
102	5.17	1.24	9.02	23.32	40.17	0.218
103	5.22	1.26	9.11	23.78	41.38	0.215
104	5.27	1.27	9.20	24.25	42.60	0.212
105	5.32	1.28	9.29	24.72	43.86	0.209



106	5.37	1.29	9.38	25.20	45.14	0.205
107	5.42	1.31	9.47	25.68	46.44	0.202
108	5.48	1.32	9.56	26.17	47.76	0.199
109	5.53	1.33	9.65	26.66	49.12	0.196
110	5.58	1.34	9.74	27.16	50.49	0.193
111	5.63	1.36	9.83	27.66	51.89	0.190
112	5.68	1.37	9.92	28.16	53.32	0.187
113	5.73	1.38	10.01	28.67	54.78	0.184
114	5.78	1.39	10.10	29.19	56.26	0.181
115	5.83	1.40	10.19	29.71	57.76	0.178
116	5.88	1.42	10.27	30.23	59.30	0.175
117	5.94	1.43	10.36	30.76	60.86	0.172
118	5.99	1.44	10.45	31.29	62.45	0.169
119	6.04	1.45	10.54	31.83	64.06	0.166
120	6.09	1.47	10.63	32.37	65.70	0.163
121	6.14	1.48	10.72	32.92	67.37	0.160
122	6.19	1.49	10.81	33.47	69.07	0.157
123	6.24	1.50	10.90	34.02	70.80	0.154
124	6.29	1.52	10.99	34.58	72.55	0.151
125	6.35	1.53	11.08	35.15	74.34	0.148
126	6.40	1.54	11.17	35.72	76.15	0.145
127	6.45	1.55	11.26	36.29	77.99	0.143
128	6.50	1.57	11.35	36.87	79.86	0.140
129	6.55	1.58	11.44	37.45	81.77	0.137
130	6.60	1.59	11.53	38.04	83.70	0.134
131	6.65	1.60	11.61	38.63	85.66	0.131
132	6.70	1.61	11.70	39.23	87.65	0.128
133	6.75	1.63	11.79	39.83	89.67	0.126
134	6.81	1.64	11.88	40.43	91.73	0.123
135	6.86	1.65	11.97	41.05	93.81	0.120
136	6.91	1.66	12.06	41.66	95.93	0.117
137	6.96	1.68	12.15	42.28	98.08	0.115
138	7.01	1.69	12.24	42.90	100.26	0.112
139	7.06	1.70	12.33	43.53	102.47	0.109
140	7.11	1.71	12.42	44.17	104.71	0.107
141	7.16	1.73	12.51	44.80	106.99	0.104

142	7.21	1.74	12.60	45.45	109.30	0.101
143	7.27	1.75	12.69	46.09	111.64	0.099
144	7.32	1.76	12.78	46.74	114.01	0.096
145	7.37	1.77	12.87	47.40	116.42	0.093
146	7.42	1.79	12.95	48.06	118.86	0.091
147	7.47	1.80	13.04	48.73	121.34	0.088
148	7.52	1.81	13.13	49.40	123.85	0.086
149	7.57	1.82	13.22	50.07	126.39	0.083
150	7.62	1.84	13.31	50.75	128.97	0.081
151	7.68	1.85	13.40	51.43	131.59	0.078
152	7.73	1.86	13.49	52.12	134.24	0.076
153	7.78	1.87	13.58	52.81	136.92	0.074
154	7.83	1.89	13.67	53.51	139.64	0.071
155	7.88	1.90	13.76	54.21	142.40	0.069
156	7.93	1.91	13.85	54.92	145.19	0.067
157	7.98	1.92	13.94	55.63	148.02	0.064
158	8.03	1.93	14.03	56.34	150.88	0.062
159	8.08	1.95	14.12	57.06	153.79	0.060
160	8.14	1.96	14.21	57.79	156.72	0.057
161	8.19	1.97	14.30	58.52	159.70	0.055
162	8.24	1.98	14.38	59.25	162.71	0.053
163	8.29	2.00	14.47	59.99	165.76	0.051
164	8.34	2.01	14.56	60.73	168.85	0.049
165	8.39	2.02	14.65	61.48	171.98	0.047
166	8.44	2.03	14.74	62.23	175.14	0.045
167	8.49	2.05	14.83	62.99	178.35	0.043
168	8.55	2.06	14.92	63.75	181.59	0.041
169	8.60	2.07	15.01	64.52	184.87	0.039
170	8.65	2.08	15.10	65.29	188.19	0.037
171	8.70	2.09	15.19	66.06	191.55	0.035
172	8.75	2.11	15.28	66.84	194.95	0.033
173	8.80	2.12	15.37	67.63	198.40	0.031
174	8.85	2.13	15.46	68.41	201.88	0.029
175	8.90	2.14	15.55	69.21	205.40	0.028
176	8.95	2.16	15.64	70.00	208.96	0.026
177	9.01	2.17	15.72	70.81	212.56	0.024

178	9.06	2.18	15.81	71.61	216.20	0.023
179	9.11	2.19	15.90	72.43	219.89	0.021
180	9.16	2.21	15.99	73.24	223.62	0.019
181	9.21	2.22	16.08	74.06	227.39	0.018
182	9.26	2.23	16.17	74.89	231.20	0.016
183	9.31	2.24	16.26	75.72	235.05	0.015
184	9.36	2.26	16.35	76.55	238.95	0.014
185	9.42	2.27	16.44	77.39	242.88	0.012
186	9.47	2.28	16.53	78.23	246.87	0.011
187	9.52	2.29	16.62	79.08	250.89	0.010
188	9.57	2.30	16.71	79.93	254.96	0.008
189	9.62	2.32	16.80	80.79	259.07	0.007
190	9.67	2.33	16.89	81.65	263.23	0.006
191	9.72	2.34	16.98	82.52	267.43	0.005
192	9.77	2.35	17.06	83.39	271.67	0.004
193	9.82	2.37	17.15	84.27	275.96	0.003
194	9.88	2.38	17.24	85.15	280.30	0.002
195	9.93	2.39	17.33	86.03	284.68	0.001
196	9.98	2.40	17.42	86.92	289.10	0.000
197	10.03	2.42	17.51	-120.05	287.64	0.000
198	10.08	2.43	17.60	-119.15	281.69	0.000
199	10.13	2.44	17.69	-118.25	275.78	0.000
200	10.18	2.45	17.78	-117.34	269.92	0.000
201	10.23	2.46	17.87	-116.43	264.10	0.000
202	10.29	2.48	17.96	-115.51	258.33	0.000
203	10.34	2.49	18.05	-114.59	252.61	0.000
204	10.39	2.50	18.14	-113.66	246.94	0.001
205	10.44	2.51	18.23	-112.73	241.31	0.001
206	10.49	2.53	18.32	-111.80	235.73	0.001
207	10.54	2.53	18.34	-110.86	230.20	0.001
208	10.59	2.53	18.34	-109.92	224.72	0.001
209	10.64	2.53	18.34	-108.98	219.28	0.002
210	10.69	2.53	18.34	-108.05	213.89	0.002
211	10.75	2.53	18.34	-107.11	208.55	0.002
212	10.80	2.53	18.34	-106.17	203.26	0.002
213	10.85	2.53	18.34	-105.23	198.02	0.003

214	10.90	2.53	18.34	-104.29	192.82	0.003
215	10.95	2.53	18.34	-103.35	187.68	0.003
216	11.00	2.53	18.34	-102.42	182.58	0.003
217	11.05	2.53	18.34	-101.48	177.53	0.004
218	11.10	2.53	18.34	-100.54	172.52	0.004
219	11.16	2.53	18.34	-99.60	167.57	0.004
220	11.21	2.53	18.34	-98.66	162.66	0.005
221	11.26	2.53	18.34	-97.73	157.80	0.005
222	11.31	2.53	18.34	-96.79	152.99	0.005
223	11.36	2.53	18.34	-95.85	148.23	0.006
224	11.41	2.53	18.34	-94.91	143.51	0.006
225	11.46	2.53	18.34	-93.97	138.85	0.007
226	11.51	2.53	18.34	-93.03	134.23	0.007
227	11.56	2.53	18.34	-92.10	129.66	0.007
228	11.62	2.53	18.34	-91.16	125.13	0.008
229	11.67	2.53	18.34	-90.22	120.66	0.008
230	11.72	2.53	18.34	-89.28	116.23	0.008
231	11.77	2.53	18.34	-88.34	111.85	0.009
232	11.82	2.53	18.34	-87.40	107.52	0.009
233	11.87	2.53	18.34	-86.47	103.24	0.010
234	11.92	2.53	18.34	-85.53	99.00	0.010
235	11.97	2.53	18.34	-84.59	94.82	0.010
236	12.02	2.53	18.34	-83.65	90.68	0.011
237	12.08	2.53	18.34	-82.71	86.59	0.011
238	12.13	2.53	18.34	-81.78	82.54	0.012
239	12.18	2.53	18.34	-80.84	78.55	0.012
240	12.23	2.53	18.34	-79.90	74.60	0.012
241	12.28	2.53	18.34	-78.96	70.70	0.013
242	12.33	2.53	18.34	-78.02	66.85	0.013
243	12.38	2.53	18.34	-77.08	63.05	0.014
244	12.43	2.53	18.34	-76.15	59.29	0.014
245	12.49	2.53	18.34	-75.21	55.59	0.014
246	12.54	2.53	18.34	-74.27	51.93	0.015
247	12.59	2.53	18.34	-73.33	48.32	0.015
248	12.64	2.53	18.34	-72.39	44.75	0.016
249	12.69	2.53	18.34	-71.46	41.24	0.016

250	12.74	2.53	18.34	-70.52	37.77	0.016
251	12.79	2.53	18.34	-69.58	34.35	0.017
252	12.84	2.53	18.34	-68.64	30.98	0.017
253	12.89	2.53	18.34	-67.70	27.66	0.017
254	12.95	2.53	18.34	-66.76	24.39	0.018
255	13.00	2.53	18.34	-65.83	21.16	0.018
256	13.05	2.53	18.34	-64.89	17.98	0.019
257	13.10	2.53	18.34	-63.95	14.85	0.019
258	13.15	2.53	18.34	-63.01	11.77	0.019
259	13.20	2.53	18.34	-62.07	8.73	0.020
260	13.25	2.53	18.34	-61.13	5.74	0.020
261	13.30	2.53	18.34	-60.20	2.81	0.020
262	13.36	2.53	18.34	-59.26	-0.08	0.021
263	13.41	2.53	18.34	-58.32	-2.93	0.021
264	13.46	2.53	18.34	-57.38	-5.72	0.021
265	13.51	2.53	18.34	-56.44	-8.47	0.021
266	13.56	2.53	18.34	-55.51	-11.17	0.022
267	13.61	2.53	18.34	-54.57	-13.82	0.022
268	13.66	2.53	18.34	-53.63	-16.42	0.022
269	13.71	2.53	18.34	-52.69	-18.98	0.022
270	13.76	2.53	18.34	-51.75	-21.48	0.023
271	13.82	2.53	18.34	-50.81	-23.94	0.023
272	13.87	2.53	18.34	-49.88	-26.35	0.023
273	13.92	2.53	18.34	-48.94	-28.71	0.023
274	13.97	2.53	18.34	-48.00	-31.03	0.024
275	14.02	2.53	18.34	-47.06	-33.30	0.024
276	14.07	2.53	18.34	-46.12	-35.51	0.024
277	14.12	2.53	18.34	-45.18	-37.68	0.024
278	14.17	2.53	18.34	-44.25	-39.81	0.024
279	14.23	2.53	18.34	-43.31	-41.88	0.024
280	14.28	2.53	18.34	-42.37	-43.91	0.025
281	14.33	2.53	18.34	-41.43	-45.89	0.025
282	14.38	2.53	18.34	-40.49	-47.82	0.025
283	14.43	2.53	18.34	-39.56	-49.70	0.025
284	14.48	2.53	18.34	-38.62	-51.53	0.025
285	14.53	2.53	18.34	-37.68	-53.32	0.025

286	14.58	2.53	18.34	-36.74	-55.06	0.025
287	14.63	2.53	18.34	-35.80	-56.75	0.025
288	14.69	2.53	18.34	-34.86	-58.39	0.025
289	14.74	2.53	18.34	-33.93	-59.99	0.026
290	14.79	2.53	18.34	-32.99	-61.53	0.026
291	14.84	2.53	18.34	-32.05	-63.03	0.026
292	14.89	2.53	18.34	-31.11	-64.48	0.026
293	14.94	2.53	18.34	-30.17	-65.89	0.026
294	14.99	2.53	18.34	-29.24	-67.24	0.026
295	15.04	2.53	18.34	-28.30	-68.55	0.026
296	15.10	2.53	18.34	-27.36	-69.80	0.026
297	15.15	2.53	18.34	-26.42	-71.01	0.026
298	15.20	2.53	18.34	-25.48	-72.18	0.026
299	15.25	2.53	18.34	-24.54	-73.29	0.026
300	15.30	2.53	18.34	-23.61	-74.36	0.025
301	15.35	2.53	18.34	-22.67	-75.38	0.025
302	15.40	2.53	18.34	-21.73	-76.35	0.025
303	15.45	2.53	18.34	-20.79	-77.27	0.025
304	15.50	2.53	18.34	-19.85	-78.14	0.025
305	15.56	2.53	18.34	-18.91	-78.97	0.025
306	15.61	2.53	18.34	-17.98	-79.75	0.025
307	15.66	2.53	18.34	-17.04	-80.48	0.025
308	15.71	2.53	18.34	-16.10	-81.16	0.025
309	15.76	2.53	18.34	-15.16	-81.80	0.024
310	15.81	2.53	18.34	-14.22	-82.38	0.024
311	15.86	2.53	18.34	-13.29	-82.92	0.024
312	15.91	2.53	18.34	-12.35	-83.41	0.024
313	15.97	2.53	18.34	-11.41	-83.85	0.024
314	16.02	2.53	18.34	-10.47	-84.25	0.024
315	16.07	2.53	18.34	-9.53	-84.59	0.023
316	16.12	2.53	18.34	-8.59	-84.89	0.023
317	16.17	2.53	18.34	-7.66	-85.14	0.023
318	16.22	2.53	18.34	-6.72	-85.34	0.023
319	16.27	2.53	18.34	-5.78	-85.50	0.022
320	16.32	2.53	18.34	-4.84	-85.60	0.022
321	16.37	2.53	18.34	-3.90	-85.66	0.022

322	16.43	2.53	18.34	-2.96	-85.67	0.022
323	16.48	2.53	18.34	-2.03	-85.63	0.021
324	16.53	2.53	18.34	-1.09	-85.55	0.021
325	16.58	2.53	18.34	-0.15	-85.41	0.021
326	16.63	2.53	18.34	0.79	-85.22	0.021
327	16.68	2.53	18.34	1.73	-84.97	0.020
328	16.73	2.53	18.34	2.66	-84.68	0.020
329	16.78	2.53	18.34	3.60	-84.33	0.020
330	16.83	2.53	18.34	4.54	-83.94	0.019
331	16.89	2.53	18.34	5.48	-83.50	0.019
332	16.94	2.53	18.34	6.42	-83.02	0.019
333	16.99	2.53	18.34	7.36	-82.48	0.018
334	17.04	2.53	18.34	8.29	-81.90	0.018
335	17.09	2.53	18.34	9.23	-81.27	0.017
336	17.14	2.53	18.34	10.17	-80.59	0.017
337	17.19	2.53	18.34	11.11	-79.86	0.017
338	17.24	2.53	18.34	12.05	-79.09	0.016
339	17.30	2.53	18.34	12.98	-78.27	0.016
340	17.35	2.53	18.34	13.92	-77.39	0.016
341	17.40	2.53	18.34	14.86	-76.48	0.015
342	17.45	2.53	18.34	15.80	-75.51	0.015
343	17.50	2.53	18.34	16.74	-74.49	0.014
344	17.55	2.53	18.34	17.68	-73.43	0.014
345	17.60	2.53	18.34	18.61	-72.32	0.014
346	17.65	2.53	18.34	19.55	-71.16	0.013
347	17.70	2.53	18.34	20.49	-69.96	0.013
348	17.76	2.53	18.34	21.43	-68.70	0.012
349	17.81	2.53	18.34	22.37	-67.40	0.012
350	17.86	2.53	18.34	23.31	-66.05	0.012
351	17.91	2.53	18.34	24.24	-64.65	0.011
352	17.96	2.53	18.34	25.18	-63.20	0.011
353	18.01	2.53	18.34	26.12	-61.71	0.010
354	18.06	2.53	18.34	27.06	-60.16	0.010
355	18.11	2.53	18.34	28.00	-58.57	0.010
356	18.17	2.53	18.34	28.93	-56.93	0.009
357	18.22	2.53	18.34	29.87	-55.25	0.009

358	18.27	2.53	18.34	30.81	-53.51	0.008
359	18.32	2.53	18.34	31.75	-51.73	0.008
360	18.37	2.53	18.34	32.69	-49.90	0.008
361	18.42	2.53	18.34	33.63	-48.02	0.007
362	18.47	2.53	18.34	34.56	-46.09	0.007
363	18.52	2.53	18.34	35.50	-44.12	0.007
364	18.57	2.53	18.34	36.44	-42.09	0.006
365	18.63	2.53	18.34	37.38	-40.02	0.006
366	18.68	2.53	18.34	38.32	-37.90	0.005
367	18.73	2.53	18.34	39.25	-35.74	0.005
368	18.78	2.53	18.34	40.19	-33.52	0.005
369	18.83	2.53	18.34	41.13	-31.26	0.004
370	18.88	2.53	18.34	42.07	-28.95	0.004
371	18.93	2.53	18.34	43.01	-26.59	0.004
372	18.98	2.53	18.34	43.95	-24.18	0.003
373	19.04	2.53	18.34	44.88	-21.73	0.003
374	19.09	2.53	18.34	45.82	-19.22	0.003
375	19.14	2.53	18.34	46.76	-16.67	0.003
376	19.19	2.53	18.34	47.70	-14.07	0.002
377	19.24	2.53	18.34	48.64	-11.43	0.002
378	19.29	2.53	18.34	49.58	-8.73	0.002
379	19.34	2.53	18.34	50.51	-5.99	0.002
380	19.39	2.53	18.34	51.45	-3.20	0.001
381	19.44	2.53	18.34	52.39	-0.36	0.001
382	19.50	2.53	18.34	53.33	2.53	0.001
383	19.55	2.53	18.34	54.27	5.46	0.001
384	19.60	2.53	18.34	55.20	8.45	0.001
385	19.65	2.53	18.34	56.14	11.48	0.000
386	19.70	2.53	18.34	57.08	14.56	0.000
387	19.75	2.53	18.34	58.02	17.68	0.000
388	19.80	2.53	18.34	58.96	20.86	0.000
389	19.85	2.53	18.34	59.90	24.08	0.000
390	19.91	2.53	18.34	60.83	27.35	0.000
391	19.96	2.53	18.34	61.77	30.67	0.000
392	20.01	2.53	18.34	-91.48	32.88	0.000
393	20.06	2.53	18.34	-90.54	28.34	0.000



394	20.11	2.53	18.34	-89.60	23.86	0.000
395	20.16	2.53	18.34	-88.67	19.42	0.000
396	20.21	2.53	18.34	-87.73	15.03	0.001
397	20.26	2.53	18.34	-86.79	10.69	0.001
398	20.31	2.53	18.34	-85.85	6.40	0.001
399	20.37	2.53	18.34	-84.91	2.16	0.002
400	20.42	2.53	18.34	-83.98	-2.04	0.003
401	20.47	2.53	18.34	-83.04	-6.19	0.003
402	20.52	2.53	18.34	-82.10	-10.29	0.004
403	20.57	2.53	18.34	-81.16	-14.34	0.005
404	20.62	2.53	18.34	-80.22	-18.35	0.006
405	20.67	2.53	18.34	-79.28	-22.30	0.006
406	20.72	2.53	18.34	-78.35	-26.21	0.007
407	20.78	2.53	18.34	-77.41	-30.07	0.008
408	20.83	2.53	18.34	-76.47	-33.88	0.009
409	20.88	2.53	18.34	-75.53	-37.65	0.011
410	20.93	2.53	18.34	-74.59	-41.36	0.012
411	20.98	2.53	18.34	-73.66	-45.03	0.013
412	21.03	2.53	18.34	-72.72	-48.65	0.014
413	21.08	2.53	18.34	-71.78	-52.22	0.015
414	21.13	2.53	18.34	-70.84	-55.75	0.017
415	21.18	2.53	18.34	-69.90	-59.23	0.018
416	21.24	2.53	18.34	-68.96	-62.65	0.019
417	21.29	2.53	18.34	-68.03	-66.03	0.021
418	21.34	2.53	18.34	-67.09	-69.37	0.022
419	21.39	2.53	18.34	-66.15	-72.65	0.024
420	21.44	2.53	18.34	-65.21	-75.89	0.025
421	21.49	2.53	18.34	-64.27	-79.07	0.027
422	21.54	2.53	18.34	-63.33	-82.21	0.028
423	21.59	2.53	18.34	-62.40	-85.31	0.030
424	21.64	2.53	18.34	-61.46	-88.35	0.031
425	21.70	2.53	18.34	-60.52	-91.35	0.033
426	21.75	2.53	18.34	-59.58	-94.30	0.035
427	21.80	2.53	18.34	-58.64	-97.20	0.036
428	21.85	2.53	18.34	-57.71	-100.05	0.038
429	21.90	2.53	18.34	-56.77	-102.85	0.039

430	21.95	2.53	18.34	-55.83	-105.61	0.041
431	22.00	2.53	18.34	-54.89	-108.32	0.043
432	22.05	2.53	18.34	-53.95	-110.98	0.044
433	22.11	2.53	18.34	-53.01	-113.59	0.046
434	22.16	2.53	18.34	-52.08	-116.15	0.048
435	22.21	2.53	18.34	-51.14	-118.67	0.049
436	22.26	2.53	18.34	-50.20	-121.14	0.051
437	22.31	2.53	18.34	-49.26	-123.56	0.053
438	22.36	2.53	18.34	-48.32	-125.93	0.054
439	22.41	2.53	18.34	-47.38	-128.25	0.056
440	22.46	2.53	18.34	-46.45	-130.53	0.057
441	22.51	2.53	18.34	-45.51	-132.76	0.059
442	22.57	2.53	18.34	-44.57	-134.94	0.061
443	22.62	2.53	18.34	-43.63	-137.07	0.062
444	22.67	2.53	18.34	-42.69	-139.15	0.064
445	22.72	2.53	18.34	-41.76	-141.19	0.065
446	22.77	2.53	18.34	-40.82	-143.18	0.067
447	22.82	2.53	18.34	-39.88	-145.12	0.068
448	22.87	2.53	18.34	-38.94	-147.01	0.070
449	22.92	2.53	18.34	-38.00	-148.85	0.071
450	22.98	2.53	18.34	-37.06	-150.65	0.073
451	23.03	2.53	18.34	-36.13	-152.40	0.074
452	23.08	2.53	18.34	-35.19	-154.10	0.076
453	23.13	2.53	18.34	-34.25	-155.75	0.077
454	23.18	2.53	18.34	-33.31	-157.35	0.078
455	23.23	2.53	18.34	-32.37	-158.91	0.080
456	23.28	2.53	18.34	-31.44	-160.42	0.081
457	23.33	2.53	18.34	-30.50	-161.88	0.082
458	23.38	2.53	18.34	-29.56	-163.29	0.084
459	23.44	2.53	18.34	-28.62	-164.65	0.085
460	23.49	2.53	18.34	-27.68	-165.97	0.086
461	23.54	2.53	18.34	-26.74	-167.24	0.087
462	23.59	2.53	18.34	-25.81	-168.46	0.088
463	23.64	2.53	18.34	-24.87	-169.63	0.089
464	23.69	2.53	18.34	-23.93	-170.75	0.091
465	23.74	2.53	18.34	-22.99	-171.83	0.092

466	23.79	2.53	18.34	-22.05	-172.86	0.093
467	23.85	2.53	18.34	-21.11	-173.84	0.094
468	23.90	2.53	18.34	-20.18	-174.77	0.094
469	23.95	2.53	18.34	-19.24	-175.65	0.095
470	24.00	2.53	18.34	-18.30	-176.49	0.096
471	24.05	2.53	18.34	-17.36	-177.28	0.097
472	24.10	2.53	18.34	-16.42	-178.01	0.098
473	24.15	2.53	18.34	-15.49	-178.71	0.098
474	24.20	2.53	18.34	-14.55	-179.35	0.099
475	24.25	2.53	18.34	-13.61	-179.95	0.100
476	24.31	2.53	18.34	-12.67	-180.49	0.100
477	24.36	2.53	18.34	-11.73	-180.99	0.101
478	24.41	2.53	18.34	-10.79	-181.45	0.101
479	24.46	2.53	18.34	-9.86	-181.85	0.102
480	24.51	2.53	18.34	-8.92	-182.20	0.102
481	24.56	2.53	18.34	-7.98	-182.51	0.103
482	24.61	2.53	18.34	-7.04	-182.77	0.103
483	24.66	2.53	18.34	-6.10	-182.98	0.103
484	24.72	2.53	18.34	-5.16	-183.15	0.104
485	24.77	2.53	18.34	-4.23	-183.26	0.104
486	24.82	2.53	18.34	-3.29	-183.33	0.104
487	24.87	2.53	18.34	-2.35	-183.35	0.104
488	24.92	2.53	18.34	-1.41	-183.32	0.104
489	24.97	2.53	18.34	-0.47	-183.25	0.104
490	25.02	2.53	18.34	0.46	-183.12	0.104
491	25.07	2.53	18.34	1.40	-183.04	0.104
492	25.12	2.53	18.34	2.34	-182.90	0.104
493	25.18	2.53	18.34	3.28	-182.72	0.104
494	25.23	2.53	18.34	4.22	-182.50	0.104
495	25.28	2.53	18.34	5.16	-182.22	0.104
496	25.33	2.53	18.34	6.09	-181.90	0.103
497	25.38	2.53	18.34	7.03	-181.52	0.103
498	25.43	2.53	18.34	7.97	-181.10	0.103
499	25.48	2.53	18.34	8.91	-180.63	0.102
500	25.53	2.53	18.34	9.85	-180.12	0.102
501	25.59	2.53	18.34	10.78	-179.55	0.101

502	25.64	2.53	18.34	11.72	-178.94	0.101
503	25.69	2.53	18.34	12.66	-178.28	0.100
504	25.74	2.53	18.34	13.60	-177.57	0.100
505	25.79	2.53	18.34	14.54	-176.82	0.099
506	25.84	2.53	18.34	15.48	-176.01	0.098
507	25.89	2.53	18.34	16.41	-175.16	0.098
508	25.94	2.53	18.34	17.35	-174.26	0.097
509	25.99	2.53	18.34	18.29	-173.31	0.096
510	26.05	2.53	18.34	19.23	-172.31	0.095
511	26.10	2.53	18.34	20.17	-171.27	0.094
512	26.15	2.53	18.34	21.11	-170.18	0.094
513	26.20	2.53	18.34	22.04	-169.04	0.093
514	26.25	2.53	18.34	22.98	-167.85	0.092
515	26.30	2.53	18.34	23.92	-166.61	0.091
516	26.35	2.53	18.34	24.86	-165.33	0.089
517	26.40	2.53	18.34	25.80	-163.99	0.088
518	26.46	2.53	18.34	26.73	-162.61	0.087
519	26.51	2.53	18.34	27.67	-161.19	0.086
520	26.56	2.53	18.34	28.61	-159.71	0.085
521	26.61	2.53	18.34	29.55	-158.18	0.084
522	26.66	2.53	18.34	30.49	-156.61	0.082
523	26.71	2.53	18.34	31.43	-154.99	0.081
524	26.76	2.53	18.34	32.36	-153.32	0.080
525	26.81	2.53	18.34	33.30	-151.61	0.078
526	26.86	2.53	18.34	34.24	-149.84	0.077
527	26.92	2.53	18.34	35.18	-148.03	0.076
528	26.97	2.53	18.34	36.12	-146.17	0.074
529	27.02	2.53	18.34	37.06	-144.26	0.073
530	27.07	2.53	18.34	37.99	-142.30	0.071
531	27.12	2.53	18.34	38.93	-140.30	0.070
532	27.17	2.53	18.34	39.87	-138.25	0.068
533	27.22	2.53	18.34	40.81	-136.14	0.067
534	27.27	2.53	18.34	41.75	-134.00	0.065
535	27.32	2.53	18.34	42.68	-131.80	0.064
536	27.38	2.53	18.34	43.62	-129.55	0.062
537	27.43	2.53	18.34	44.56	-127.26	0.061

538	27.48	2.53	18.34	45.50	-124.92	0.059
539	27.53	2.53	18.34	46.44	-122.53	0.057
540	27.58	2.53	18.34	47.38	-120.10	0.056
541	27.63	2.53	18.34	48.31	-117.61	0.054
542	27.68	2.53	18.34	49.25	-115.08	0.053
543	27.73	2.53	18.34	50.19	-112.50	0.051
544	27.79	2.53	18.34	51.13	-109.87	0.049
545	27.84	2.53	18.34	52.07	-107.19	0.048
546	27.89	2.53	18.34	53.00	-104.47	0.046
547	27.94	2.53	18.34	53.94	-101.69	0.044
548	27.99	2.53	18.34	54.88	-98.87	0.043
549	28.04	2.53	18.34	55.82	-96.00	0.041
550	28.09	2.53	18.34	56.76	-93.09	0.039
551	28.14	2.53	18.34	57.70	-90.12	0.038
552	28.19	2.53	18.34	58.63	-87.11	0.036
553	28.25	2.53	18.34	59.57	-84.05	0.035
554	28.30	2.53	18.34	60.51	-80.94	0.033
555	28.35	2.53	18.34	61.45	-77.78	0.031
556	28.40	2.53	18.34	62.39	-74.58	0.030
557	28.45	2.53	18.34	63.33	-71.33	0.028
558	28.50	2.53	18.34	64.26	-68.02	0.027
559	28.55	2.53	18.34	65.20	-64.68	0.025
560	28.60	2.53	18.34	66.14	-61.28	0.024
561	28.66	2.53	18.34	67.08	-57.83	0.022
562	28.71	2.53	18.34	68.02	-54.34	0.021
563	28.76	2.53	18.34	68.95	-50.80	0.019
564	28.81	2.53	18.34	69.89	-47.21	0.018
565	28.86	2.53	18.34	70.83	-43.57	0.017
566	28.91	2.53	18.34	71.77	-39.89	0.015
567	28.96	2.53	18.34	72.71	-36.16	0.014
568	29.01	2.53	18.34	73.65	-32.38	0.013
569	29.06	2.53	18.34	74.58	-28.55	0.012
570	29.12	2.53	18.34	75.52	-24.67	0.011
571	29.17	2.53	18.34	76.46	-20.74	0.009
572	29.22	2.53	18.34	77.40	-16.77	0.008
573	29.27	2.53	18.34	78.34	-12.75	0.007

574	29.32	2.53	18.34	79.28	-8.68	0.006
575	29.37	2.53	18.34	80.21	-4.56	0.006
576	29.42	2.53	18.34	81.15	-0.40	0.005
577	29.47	2.53	18.34	82.09	3.81	0.004
578	29.53	2.53	18.34	83.03	8.08	0.003
579	29.58	2.53	18.34	83.97	12.38	0.003
580	29.63	2.53	18.34	84.90	16.74	0.002
581	29.68	2.53	18.34	85.84	21.15	0.001
582	29.73	2.53	18.34	86.78	25.60	0.001
583	29.78	2.53	18.34	87.72	30.10	0.001
584	29.83	2.53	18.34	88.66	34.65	0.000
585	29.88	2.53	18.34	89.60	39.25	0.000
586	29.93	2.53	18.34	90.53	43.89	0.000
587	29.99	2.53	18.34	91.47	48.59	0.000
588	30.04	2.53	18.34	-94.01	46.43	0.003
589	30.09	2.53	18.34	-93.08	41.68	0.006
590	30.14	2.53	18.34	-92.14	36.97	0.010
591	30.19	2.53	18.34	-91.20	32.30	0.013
592	30.24	2.53	18.34	-90.26	27.69	0.016
593	30.29	2.53	18.34	-89.32	23.13	0.019
594	30.34	2.53	18.34	-88.38	18.61	0.022
595	30.40	2.53	18.34	-87.45	14.14	0.026
596	30.45	2.53	18.34	-86.51	9.72	0.029
597	30.50	2.53	18.34	-85.57	5.34	0.032
598	30.55	2.53	18.34	-84.63	1.02	0.035
599	30.60	2.53	18.34	-83.69	-3.26	0.038
600	30.65	2.53	18.34	-82.75	-7.49	0.042
601	30.70	2.53	18.34	-81.82	-11.67	0.045
602	30.75	2.53	18.34	-80.88	-15.80	0.048
603	30.80	2.53	18.34	-79.94	-19.89	0.051
604	30.86	2.53	18.34	-79.00	-23.93	0.055
605	30.91	2.53	18.34	-78.06	-27.92	0.058
606	30.96	2.53	18.34	-77.13	-31.86	0.061
607	31.01	2.53	18.34	-76.19	-35.75	0.064
608	31.06	2.53	18.34	-75.25	-39.60	0.067
609	31.11	2.53	18.34	-74.31	-43.39	0.071

610	31.16	2.53	18.34	-73.37	-47.14	0.074
611	31.21	2.53	18.34	-72.43	-50.85	0.077
612	31.27	2.53	18.34	-71.50	-54.50	0.080
613	31.32	2.53	18.34	-70.56	-58.10	0.083
614	31.37	2.53	18.34	-69.62	-61.66	0.086
615	31.42	2.53	18.34	-68.68	-65.17	0.089
616	31.47	2.53	18.34	-67.74	-68.63	0.093
617	31.52	2.52	18.30	-66.81	-72.05	0.096
618	31.57	2.51	18.21	-65.87	-75.41	0.099
619	31.62	2.50	18.12	-64.94	-78.73	0.102
620	31.67	2.49	18.03	-64.02	-82.00	0.105
621	31.73	2.47	17.94	-63.10	-85.22	0.108
622	31.78	2.46	17.85	-62.18	-88.40	0.111
623	31.83	2.45	17.76	-61.27	-91.53	0.114
624	31.88	2.44	17.67	-60.36	-94.61	0.117
625	31.93	2.43	17.58	-59.46	-97.65	0.120
626	31.98	2.41	17.49	-58.56	-100.64	0.123
627	32.03	2.40	17.41	-57.67	-103.58	0.126
628	32.08	2.39	17.32	-56.78	-106.48	0.129
629	32.13	2.38	17.23	-55.90	-109.34	0.132
630	32.19	2.36	17.14	-55.02	-112.15	0.135
631	32.24	2.35	17.05	-54.14	-114.91	0.138
632	32.29	2.34	16.96	-53.27	-117.63	0.141
633	32.34	2.33	16.87	-52.41	-120.30	0.143
634	32.39	2.31	16.78	-51.55	-122.93	0.146
635	32.44	2.30	16.69	-50.69	-125.52	0.149
636	32.49	2.29	16.60	-49.84	-128.06	0.152
637	32.54	2.28	16.51	-48.99	-130.56	0.155
638	32.60	2.27	16.42	-48.15	-133.02	0.158
639	32.65	2.25	16.33	-47.31	-135.43	0.160
640	32.70	2.24	16.24	-46.48	-137.80	0.163
641	32.75	2.23	16.15	-45.65	-140.13	0.166
642	32.80	2.22	16.07	-44.82	-142.42	0.168
643	32.85	2.20	15.98	-44.01	-144.66	0.171
644	32.90	2.19	15.89	-43.19	-146.86	0.174
645	32.95	2.18	15.80	-42.38	-149.02	0.176

646	33.00	2.17	15.71	-41.57	-151.14	0.179
647	33.06	2.15	15.62	-40.77	-153.22	0.182
648	33.11	2.14	15.53	-39.97	-155.26	0.184
649	33.16	2.13	15.44	-39.18	-157.25	0.187
650	33.21	2.12	15.35	-38.39	-159.21	0.189
651	33.26	2.10	15.26	-37.61	-161.12	0.192
652	33.31	2.09	15.17	-36.83	-163.00	0.194
653	33.36	2.08	15.08	-36.06	-164.84	0.197
654	33.41	2.07	14.99	-35.29	-166.63	0.199
655	33.47	2.06	14.90	-34.52	-168.39	0.201
656	33.52	2.04	14.81	-33.76	-170.11	0.204
657	33.57	2.03	14.73	-33.01	-171.79	0.206
658	33.62	2.02	14.64	-32.26	-173.43	0.208
659	33.67	2.01	14.55	-31.51	-175.03	0.211
660	33.72	1.99	14.46	-30.77	-176.59	0.213
661	33.77	1.98	14.37	-30.03	-178.12	0.215
662	33.82	1.97	14.28	-29.30	-179.61	0.217
663	33.87	1.96	14.19	-28.57	-181.06	0.219
664	33.93	1.94	14.10	-27.85	-182.48	0.222
665	33.98	1.93	14.01	-27.13	-183.85	0.224
666	34.03	1.92	13.92	-26.41	-185.19	0.226
667	34.08	1.91	13.83	-25.70	-186.50	0.228
668	34.13	1.90	13.74	-25.00	-187.77	0.230
669	34.18	1.88	13.65	-24.30	-189.00	0.232
670	34.23	1.87	13.56	-23.60	-190.19	0.234
671	34.28	1.86	13.47	-22.91	-191.36	0.236
672	34.34	1.85	13.38	-22.22	-192.48	0.238
673	34.39	1.83	13.30	-21.54	-193.57	0.240
674	34.44	1.82	13.21	-20.86	-194.63	0.242
675	34.49	1.81	13.12	-20.19	-195.65	0.243
676	34.54	1.80	13.03	-19.52	-196.64	0.245
677	34.59	1.78	12.94	-18.85	-197.59	0.247
678	34.64	1.77	12.85	-18.19	-198.51	0.249
679	34.69	1.76	12.76	-17.54	-199.39	0.250
680	34.74	1.75	12.67	-16.89	-200.24	0.252
681	34.80	1.74	12.58	-16.24	-201.06	0.254



682	34.85	1.72	12.49	-15.60	-201.85	0.255
683	34.90	1.71	12.40	-14.96	-202.60	0.257
684	34.95	1.70	12.31	-14.33	-203.32	0.259
685	35.00	1.69	12.22	-13.70	-204.01	0.260
686	35.05	1.67	12.13	-13.08	-204.67	0.262
687	35.10	1.66	12.04	-12.46	-205.29	0.263
688	35.15	1.65	11.96	-11.85	-205.88	0.265
689	35.21	1.64	11.87	-11.24	-206.44	0.266
690	35.26	1.62	11.78	-10.63	-206.97	0.267
691	35.31	1.61	11.69	-10.03	-207.47	0.269
692	35.36	1.60	11.60	-9.44	-207.94	0.270
693	35.41	1.59	11.51	-8.85	-208.38	0.271
694	35.46	1.58	11.42	-8.26	-208.79	0.273
695	35.51	1.56	11.33	-7.68	-209.17	0.274
696	35.56	1.55	11.24	-7.10	-209.52	0.275
697	35.61	1.54	11.15	-6.53	-209.84	0.276
698	35.67	1.53	11.06	-5.96	-210.13	0.277
699	35.72	1.51	10.97	-5.39	-210.39	0.278
700	35.77	1.50	10.88	-4.83	-210.62	0.279
701	35.82	1.49	10.79	-4.28	-210.83	0.280
702	35.87	1.48	10.70	-3.73	-211.00	0.281
703	35.92	1.46	10.62	-3.18	-211.15	0.282
704	35.97	1.45	10.53	-2.64	-211.27	0.283
705	36.02	1.44	10.44	-2.11	-211.36	0.284
706	36.08	1.43	10.35	-1.58	-211.43	0.285
707	36.13	1.41	10.26	-1.05	-211.47	0.286
708	36.18	1.40	10.17	-0.53	-211.48	0.287
709	36.23	1.39	10.08	-0.01	-211.46	0.288
710	36.28	1.38	9.99	0.51	-211.73	0.288
711	36.33	1.37	9.90	1.01	-211.96	0.289
712	36.38	1.35	9.81	1.52	-212.18	0.290
713	36.43	1.34	9.72	2.02	-212.36	0.290
714	36.48	1.33	9.63	2.51	-212.52	0.291
715	36.54	1.32	9.54	3.00	-212.66	0.292
716	36.59	1.30	9.45	3.49	-212.77	0.292
717	36.64	1.29	9.36	3.97	-212.85	0.293

718	36.69	1.28	9.28	4.45	-212.92	0.293
719	36.74	1.27	9.19	4.92	-212.95	0.294
720	36.79	1.25	9.10	5.39	-212.97	0.294
721	36.84	1.24	9.01	5.85	-212.95	0.294
722	36.89	1.23	8.92	6.31	-212.92	0.295
723	36.94	1.22	8.83	6.76	-212.86	0.295
724	37.00	1.21	8.74	7.21	-212.78	0.295
725	37.05	1.19	8.65	7.66	-212.68	0.296
726	37.10	1.18	8.56	8.10	-212.55	0.296
727	37.15	1.17	8.47	8.54	-212.40	0.296
728	37.20	1.16	8.38	8.97	-212.23	0.296
729	37.25	1.14	8.29	9.39	-212.04	0.297
730	37.30	1.13	8.20	9.82	-211.82	0.297
731	37.35	1.12	8.11	10.23	-211.59	0.297
732	37.41	1.11	8.02	10.65	-211.33	0.297
733	37.46	1.09	7.94	11.05	-211.05	0.297
734	37.51	1.08	7.85	11.46	-210.75	0.297
735	37.56	1.07	7.76	11.86	-210.43	0.297
736	37.61	1.06	7.67	12.25	-210.09	0.297
737	37.66	1.05	7.58	12.64	-209.73	0.297
738	37.71	1.03	7.49	13.03	-209.35	0.296
739	37.76	1.02	7.40	13.41	-208.95	0.296
740	37.81	1.01	7.31	13.78	-208.53	0.296
741	37.87	1.00	7.22	14.16	-208.10	0.296
742	37.92	0.98	7.13	14.52	-207.64	0.296
743	37.97	0.97	7.04	14.89	-207.16	0.295
744	38.02	0.96	6.95	15.24	-206.67	0.295
745	38.07	0.95	6.86	15.60	-206.16	0.295
746	38.12	0.93	6.77	15.95	-205.63	0.294
747	38.17	0.92	6.68	16.29	-205.08	0.294
748	38.22	0.91	6.59	16.63	-204.51	0.293
749	38.28	0.90	6.51	16.97	-203.93	0.293
750	38.33	0.89	6.42	17.30	-203.33	0.292
751	38.38	0.87	6.33	17.62	-202.71	0.292
752	38.43	0.86	6.24	17.94	-202.08	0.291
753	38.48	0.85	6.15	18.26	-201.43	0.291

754	38.53	0.84	6.06	18.57	-200.77	0.290
755	38.58	0.82	5.97	18.88	-200.09	0.289
756	38.63	0.81	5.88	19.18	-199.39	0.289
757	38.68	0.80	5.79	19.48	-198.68	0.288
758	38.74	0.79	5.70	19.78	-197.95	0.287
759	38.79	0.77	5.61	20.07	-197.20	0.286
760	38.84	0.76	5.52	20.35	-196.45	0.286
761	38.89	0.75	5.43	20.63	-195.68	0.285
762	38.94	0.74	5.34	20.91	-194.89	0.284
763	38.99	0.72	5.25	21.18	-194.09	0.283
764	39.04	0.71	5.17	21.44	-193.28	0.282
765	39.09	0.70	5.08	21.71	-192.45	0.281
766	39.15	0.69	4.99	21.96	-191.61	0.280
767	39.20	0.68	4.90	22.22	-190.76	0.279
768	39.25	0.66	4.81	22.47	-189.89	0.278
769	39.30	0.65	4.72	22.71	-189.01	0.277
770	39.35	0.64	4.63	22.95	-188.12	0.276
771	39.40	0.63	4.54	23.18	-187.21	0.275
772	39.45	0.61	4.45	23.41	-186.30	0.274
773	39.50	0.60	4.36	23.64	-185.37	0.272
774	39.55	0.59	4.27	23.86	-184.43	0.271
775	39.61	0.58	4.18	24.08	-183.48	0.270
776	39.66	0.56	4.09	24.29	-182.52	0.269
777	39.71	0.55	4.00	24.49	-181.55	0.267
778	39.76	0.54	3.91	24.70	-180.57	0.266
779	39.81	0.53	3.83	24.89	-179.58	0.265
780	39.86	0.52	3.74	25.09	-178.57	0.263
781	39.91	0.50	3.65	25.28	-177.56	0.262
782	39.96	0.49	3.56	25.46	-176.54	0.261
783	40.02	0.48	3.47	25.64	-175.51	0.259
784	40.07	0.47	3.38	25.82	-174.47	0.258
785	40.12	0.45	3.29	25.99	-173.42	0.256
786	40.17	0.44	3.20	26.15	-172.37	0.255
787	40.22	0.43	3.11	26.31	-171.30	0.253
788	40.27	0.42	3.02	26.47	-170.23	0.251
789	40.32	0.40	2.93	26.62	-169.15	0.250

790	40.37	0.39	2.84	26.77	-168.06	0.248
791	40.42	0.38	2.75	26.91	-166.96	0.247
792	40.48	0.37	2.66	27.05	-165.85	0.245
793	40.53	0.36	2.57	27.19	-164.74	0.243
794	40.58	0.34	2.49	27.32	-163.63	0.241
795	40.63	0.33	2.40	27.44	-162.50	0.240
796	40.68	0.32	2.31	27.56	-161.37	0.238
797	40.73	0.31	2.22	27.68	-160.23	0.236
798	40.78	0.29	2.13	27.79	-159.09	0.234
799	40.83	0.28	2.04	27.90	-157.94	0.232
800	40.89	0.27	1.95	28.00	-156.79	0.231
801	40.94	0.26	1.86	28.09	-155.63	0.229
802	40.99	0.24	1.77	28.19	-154.47	0.227
803	41.04	0.23	1.68	28.28	-153.30	0.225
804	41.09	0.22	1.59	28.36	-152.13	0.223
805	41.14	0.21	1.50	28.44	-150.95	0.221
806	41.19	0.19	1.41	28.51	-149.77	0.219
807	41.24	0.18	1.32	28.58	-148.59	0.217
808	41.29	0.17	1.23	28.65	-147.40	0.215
809	41.35	0.16	1.15	28.71	-146.21	0.213
810	41.40	0.15	1.06	28.77	-145.02	0.211
811	41.45	0.13	0.97	28.82	-143.82	0.208
812	41.50	0.12	0.88	28.87	-142.62	0.206
813	41.55	0.11	0.79	28.91	-141.42	0.204
814	41.60	0.10	0.70	28.95	-140.22	0.202
815	41.65	0.08	0.61	28.98	-139.01	0.200
816	41.70	0.07	0.52	29.01	-137.80	0.198
817	41.75	0.06	0.43	29.03	-136.60	0.195
818	41.81	0.05	0.34	29.05	-135.39	0.193
819	41.86	0.03	0.25	29.07	-134.18	0.191
820	41.91	0.02	0.16	29.08	-132.97	0.188
821	41.96	0.01	0.07	29.08	-131.75	0.186
822	42.01	2.73	6.82	29.16	-130.54	0.184
823	42.06	2.72	6.75	29.51	-129.32	0.181
824	42.11	2.71	6.69	29.85	-128.08	0.179
825	42.16	2.69	6.62	30.19	-126.82	0.177

826	42.22	2.68	6.55	30.53	-125.54	0.174
827	42.27	2.67	6.49	30.86	-124.25	0.172
828	42.32	2.65	6.42	31.19	-122.94	0.169
829	42.37	2.64	6.35	31.52	-121.61	0.167
830	42.42	2.63	6.29	31.84	-120.26	0.164
831	42.47	2.62	6.22	32.16	-118.90	0.162
832	42.52	2.60	6.15	32.48	-117.53	0.159
833	42.57	2.59	6.09	32.79	-116.13	0.157
834	42.62	2.58	6.02	33.10	-114.72	0.154
835	42.68	2.57	5.95	33.41	-113.30	0.152
836	42.73	2.55	5.89	33.71	-111.86	0.149
837	42.78	2.54	5.82	34.01	-110.40	0.146
838	42.83	2.53	5.75	34.31	-108.93	0.144
839	42.88	2.52	5.69	34.60	-107.45	0.141
840	42.93	2.50	5.62	34.89	-105.95	0.138
841	42.98	2.49	5.55	35.17	-104.43	0.136
842	43.03	2.48	5.49	35.46	-102.90	0.133
843	43.09	2.47	5.42	35.73	-101.35	0.130
844	43.14	2.45	5.35	36.01	-99.80	0.128
845	43.19	2.44	5.29	36.28	-98.22	0.125
846	43.24	2.43	5.22	36.55	-96.64	0.122
847	43.29	2.41	5.15	36.82	-95.03	0.119
848	43.34	2.40	5.09	37.08	-93.42	0.117
849	43.39	2.39	5.02	37.34	-91.79	0.114
850	43.44	2.38	4.95	37.59	-90.15	0.111
851	43.49	2.36	4.89	37.84	-88.50	0.108
852	43.55	2.35	4.82	38.09	-86.84	0.105
853	43.60	2.34	4.75	38.34	-85.16	0.103
854	43.65	2.33	4.69	38.58	-83.46	0.100
855	43.70	2.31	4.62	38.82	-81.76	0.097
856	43.75	2.30	4.55	39.05	-80.05	0.094
857	43.80	2.29	4.49	39.28	-78.32	0.091
858	43.85	2.28	4.42	39.51	-76.58	0.088
859	43.90	2.26	4.35	39.74	-74.83	0.085
860	43.96	2.25	4.29	39.96	-73.07	0.082
861	44.01	2.24	4.22	40.17	-71.29	0.079

862	44.06	2.23	4.15	40.39	-69.51	0.076
863	44.11	2.21	4.09	40.60	-67.71	0.073
864	44.16	2.20	4.02	40.81	-65.91	0.070
865	44.21	2.19	3.95	41.01	-64.09	0.067
866	44.26	2.17	3.89	41.21	-62.26	0.064
867	44.31	2.16	3.82	41.41	-60.43	0.061
868	44.36	2.15	3.75	41.60	-58.58	0.058
869	44.42	2.14	3.69	41.79	-56.72	0.055
870	44.47	2.12	3.62	41.98	-54.86	0.052
871	44.52	2.11	3.56	42.16	-52.98	0.049
872	44.57	2.10	3.49	42.34	-51.09	0.046
873	44.62	2.09	3.42	42.52	-49.20	0.043
874	44.67	2.07	3.36	42.69	-47.30	0.040
875	44.72	2.06	3.29	42.86	-45.38	0.037
876	44.77	2.05	3.22	43.03	-43.46	0.034
877	44.83	2.04	3.16	43.19	-41.53	0.031
878	44.88	2.02	3.09	43.35	-39.59	0.028
879	44.93	2.01	3.02	43.51	-37.65	0.025
880	44.98	2.00	2.96	43.66	-35.70	0.022
881	45.03	1.98	2.89	43.81	-33.74	0.019
882	45.08	1.97	2.82	43.96	-31.77	0.016
883	45.13	1.96	2.76	44.10	-29.79	0.012
884	45.18	1.95	2.69	44.24	-27.81	0.009
885	45.23	1.93	2.62	44.38	-25.82	0.006
886	45.29	1.92	2.56	44.51	-23.82	0.003
887	45.34	1.91	2.49	44.64	-21.82	0.000
888	45.39	1.90	2.42	44.76	-19.80	-0.003
889	45.44	1.88	2.36	44.89	-17.79	-0.006
890	45.49	1.87	2.29	45.01	-15.76	-0.009
891	45.54	1.86	2.22	45.12	-13.74	-0.013
892	45.59	1.85	2.16	45.23	-11.70	-0.016
893	45.64	1.83	2.09	45.34	-9.66	-0.019
894	45.70	1.82	2.02	45.45	-7.61	-0.022
895	45.75	1.81	1.96	45.55	-5.56	-0.025
896	45.80	1.80	1.89	45.65	-3.50	-0.028
897	45.85	-45.76	-231.91	34.39	-1.72	-0.031

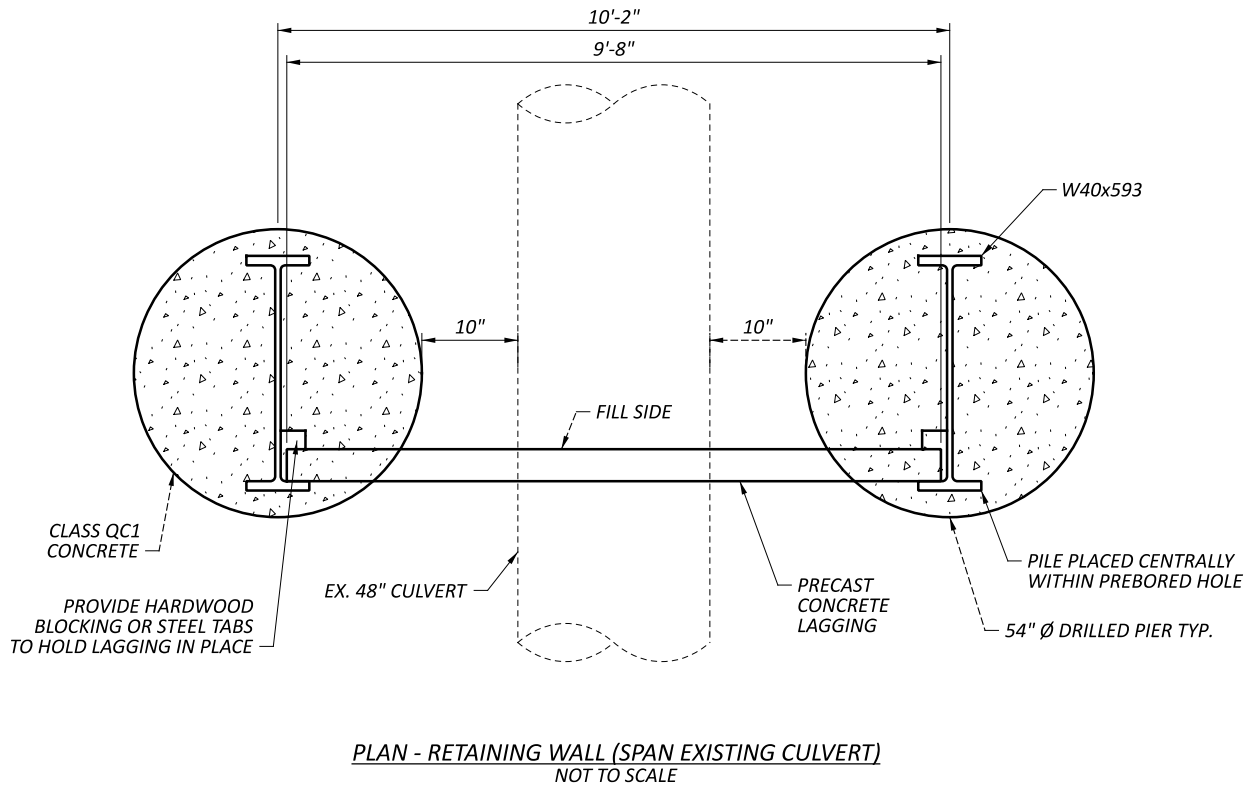
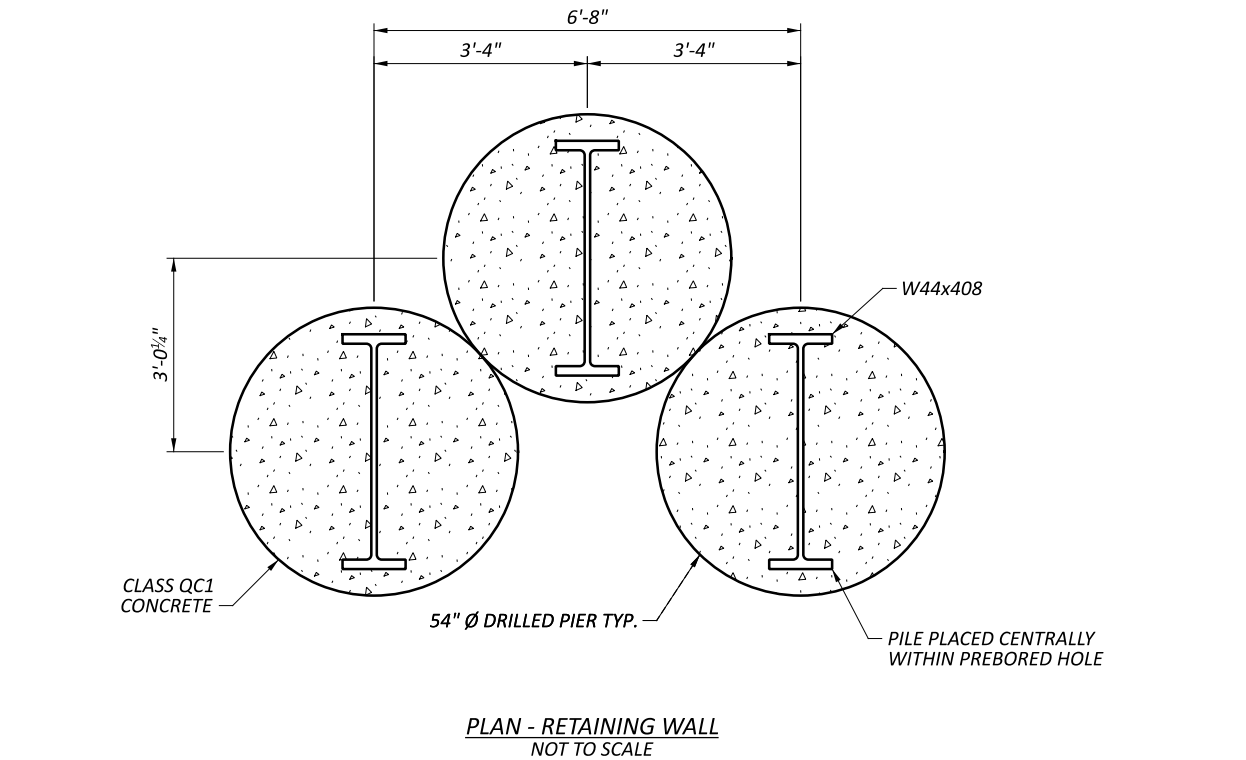
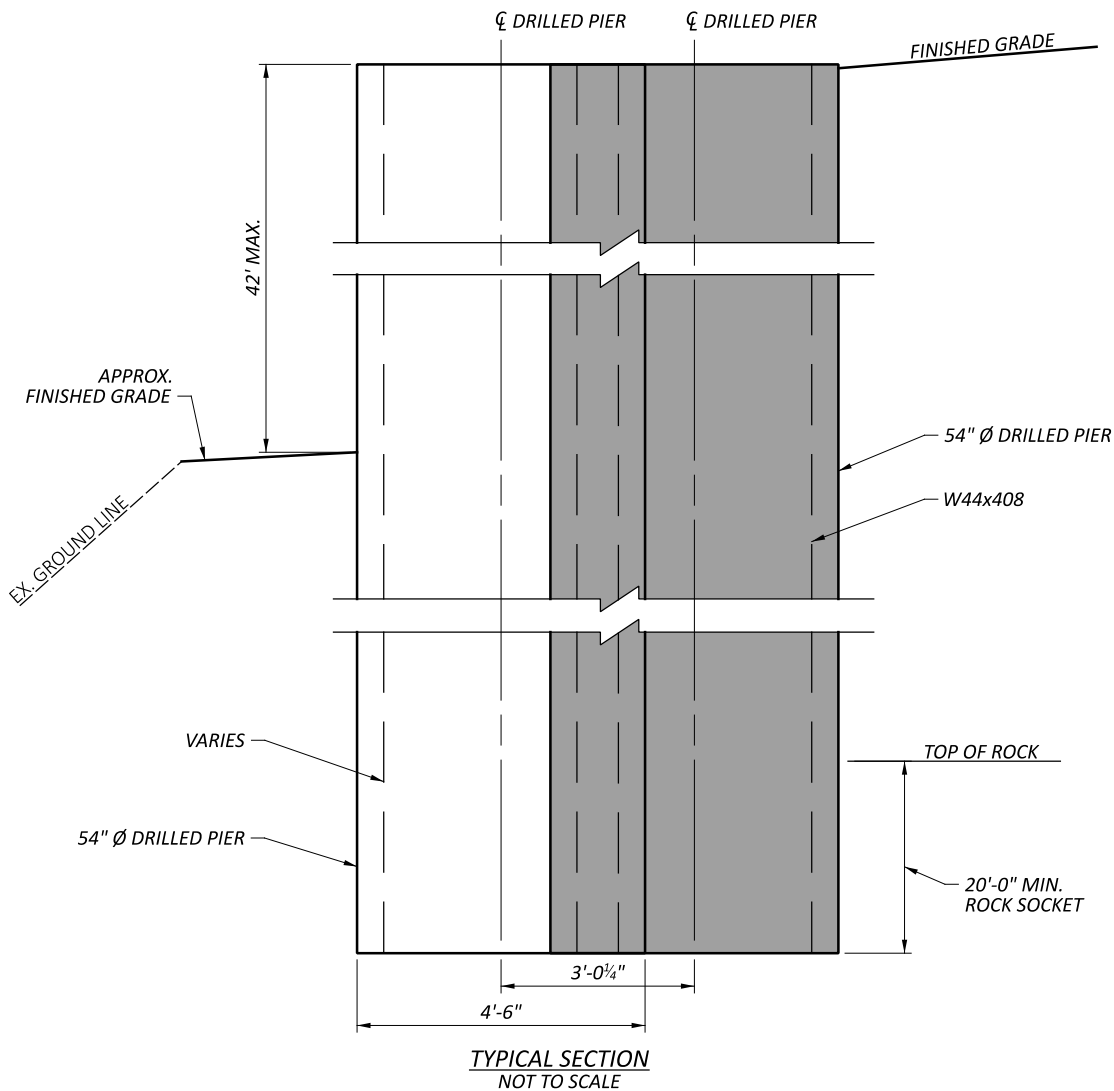
898	45.90	-45.76	-231.91	22.52	-0.54	-0.034
899	45.95	-45.76	-231.90	0.00	0.28	-0.038

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The above data can be selected using mouse, then copy and paste into Excel to create graphics



## **Cantilever Wall Detail**





BORING	STATION	OFFSET	APPROX. SURFACE ELEVATION	APPROX. ROCK SURFACE ELEVATION
B-005-0-23	504+48	243' LT	858.7	810.2
B-006-0-23	504+40	322' LT	839.8	804.8
B-007-0-23	505+17	280' LT	849.7	814.7



DRILLED SHAFT WALL DETAILS  
CRITICAL SECTION STA. 504+50

DESIGN AGENCY



DESIGNER

AKB

REVIEWER

DMV 09/08/23

PROJECT ID

115420

SHEET

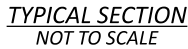
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TOTAL

1



## **Tieback Wall Detail**



BORING	STATION	OFFSET	APPROX. SURFACE ELEVATION	APPROX. ROCK SURFACE ELEVATION
B-005-0-23	504+48	243' LT	858.7	810.2
B-006-0-23	504+40	322' LT	839.8	804.8
B-007-0-23	505+17	280' LT	849.7	814.7

PLAN - RETAINING WALL (MAIN WALL)  
NOT TO SCALE

PLAN - RETAINING WALL (CULVERT SPAN)  
NOT TO SCALE