MOTT MACDONALD

PennEast PIPELINE

HDD Design Report
Interstate 80 HDD Crossing

PennEast Pipeline Project

December 17, 2018

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1 Introduction

Mott MacDonald has prepared this HDD design report at the request of PennEast Pipeline Company, LLC (PennEast), for their proposed HDD crossing of Interstate 80 (I-80), part of the larger PennEast Pipeline Project. The proposed Project consists of 115 miles of 36-inch diameter (NPS 36) high pressure, natural gas pipeline from Luzerne County, Pennsylvania to Mercer County, New Jersey.

Specifically, this report summarizes Mott MacDonald's evaluation of the design elements and risk discussions (as determined in the information provided), and presents recommendations for enhancing the success of the I-80 HDD Crossing.

The drawings and design elements have been prepared and evaluated with the aid of a completed geotechnical subsurface investigation performed by Mott MacDonald, and laboratory assessment and testing analysis completed by Craig Test Boring Co., Inc (CTB). The soil and rock samples were obtained during the geotechnical investigation program, and sent to CTB laboratory for testing. Discussions on the geotechnical aspects in this design report have been extracted from the information presented in the site specific Geological Data Report (GDR).

1.1 Crossing Description

The proposed plan and profile is provided in Appendix A. The horizontal length of the proposed HDD is approximately 3,824 feet (with a true length of approximately 3,862 feet). The HDD entry point is located approximately 570 feet north of I-80, and the HDD exit point is located approximately 2,870 feet south of I-80. An elevation difference of approximately 30 feet exists between the HDD entry and exit locations, with the HDD entry location at the lower elevation.

The pipe staging area for the drag section is located on the south side of the crossing. It is envisioned that, due to limited workspace, this pipe string will be fabricated into two sections prior to pullback operations.

2 Anticipated Geotechnical Conditions

The following discussions on the anticipated geotechnical conditions are based on the information provided by the site-specific geotechnical investigation program. Borehole logs for borings completed to support the design of the crossings by HDD methods are provided in Appendix B.

The objective of these discussions is to provide an explanation of the various construction risks identified in subsequent sections related to the geotechnical conditions.

2.1 Subsurface Investigations

A total of four (4) borings, designated as B-I80-1, B-I80-2, B-I80-3, and B-I80-4, were completed as part of the geotechnical investigation program to support the evaluation and design of the I-80 HDD Crossing. More detailed discussions can be found in the site-specific GDR.

A summary of the subsurface materials encountered at the site is provided below.

2.2 Geotechnical Observations

2.2.1 Geotechnical Observations North of Interstate 80

The HDD installation on the north side of I-80 is anticipated to encounter soils overlying bedrock materials. Based on Boring B-I80-1, the site soils are anticipated to include the following:

- Very loose sandy silt with gravel from the ground surface to a depth of 3.5 feet (from Elev. 1762 to 1758.5 feet)
- Medium dense clayey gravel to a depth of 8.5 feet (to Elev. 1753.5 feet).
- Medium dense clayey sand with gravel to a depth of 13.5 feet (to Elev. 1748.5 feet).
- Medium dense clayey gravel to a depth of 18.5 feet (to Elev. 1743.5 feet).
- Medium dense to very dense clayey sand with gravel to a depth of 63.5 feet (to Elev. 1698.5 feet). Grain size distribution tests indicate gravel percentages up to 30 percent of the soil particles.
- Hard sandy clay with gravel to a depth of 80 feet (to Elev. 1682 feet). Grain size distribution tests indicate gravel percentages up to 12 percent of the soil particles.
- Completely weathered to highly weathered, very weak to weak mudstone to a depth of 100 feet (to Elev. 1662 feet). RQD values ranged between 0 and 7 percent (avg. 4 percent). Recovery values ranged between 47 to 100 percent (avg. 83 percent).
- Highly weathered, weak pebbly siltstone to a termination depth of 115 feet (to Elev. 1647 feet). RQD values ranged between 7 to 13 percent (avg. 9 percent). Recovery values ranged between 87 to 100 percent (avg. 95 percent).

Based on Boring B-I80-2, anticipated soils include:

- Very stiff silt with gravel from the ground surface to a depth of 8.5 feet (from Elev. 1764 to 1755.5 feet).
- Medium dense clayey sand with gravel to a depth of 13.5 feet (to Elev. 1750.5 feet).
- Very dense clayey gravel with boulders present to a depth of 18.5 feet (to Elev. 1745.5 feet).
- Medium dense clayey sand with gravel to a depth of 33.5 feet (to Elev. 1730.5 feet).
- Very dense clayey gravel to a depth of 38.5 feet (to Elev. 1725.5 feet).
- Medium dense to dense clayey sand with gravel to a depth of 53.5 feet (to Elev. 1710.5 feet).

- Hard sandy clay to a depth of 68.5 feet (to Elev. 1695.5 feet).
- Dense to very dense clayey sand with gravel to a depth of 88.5 feet (to Elev. 1675.5 feet).
- Very dense clayey gravel with sand to a depth of 93.5 feet (to Elev. 1670.5 feet).
- Hard clay with sand to a depth of 100 feet (to Elev. 1664 feet).
- Highly weathered, weak siltstone to a depth of 105 feet (to Elev. 1659 feet). Highly fractured zone at soil/rock interface. RQD value of 0 percent and recovery value of 100 percent.
- Moderately weathered to fresh, strong to very strong sandstone to a depth of 135 feet (to Elev. 1629 feet). RQD values ranged between 15 to 90 percent (avg. 62 percent). Recovery values ranged between 97 and 100 percent (avg. 100 percent).
- Slightly weathered to fresh, strong sandy siltstone to a depth of 145 feet (to Elev. 1619 feet). RQD values ranged between 70 and 88 percent (avg. 83 percent) and recovery values of 100 percent.
- Slightly weathered, strong sandstone to a depth of 160 feet (to Elev. 1604 feet). RQD values ranged between 33 to 72 percent (avg. 53 percent). Recovery ranged between 98 and 100 percent (avg. 99 percent).

Along the proposed HDD alignment, the bedrock on the north side of the I-80 appears to be of poor to good quality. RQD values range from 0 to 90 percent with an average value of 39 percent. The core recovery values on the north side ranged from 47 to 100 percent with an average value of 95 percent.

Laboratory testing of the sandstone from Boring B-I80-2 indicate a Uniaxial Compressive Strength (UCS) range from 7,803 to 6,603 psi with an average of 7,203 psi. The axial point load UCS ranged from 6,849 to 8,639 psi with an average of 7,744 psi. The diametral point load UCS ranged from 9,095 to 21,149 psi with an average of 15,122 psi. The splitting tensile strength was 1,431 psi.

2.2.2 Geotechnical Observations South of Interstate 80

The HDD installation on the south side of I-80 is anticipated to encounter soils overlying bedrock materials.

Based on Boring B-I80-3, the site soils are anticipated to include the following:

- Very soft sandy clay from the ground surface to a depth of 3.5 feet (from Elev. 1756 to 1752.5 feet).
- Very dense clayey gravel to a depth of 8.5 feet (to Elev. 1747.5 feet).
- Hard to very stiff gravelly clay to a depth of 95 feet (to Elev. 1661 feet).
- Highly weathered, weak sandstone with highly fractured zones to a depth of 105 feet (to Elev. 1651 feet). RQD values ranged between 0 and 7 percent (avg. 3.5 percent). Recovery values ranged between 62 and 75 percent (avg. 69 percent).
- Slightly weathered to moderately weathered, medium strong to fresh sandstone to a depth of 131.3 feet (to Elev. 1624.7 feet). RQD values ranged between 40 to 85 percent (avg. 72 percent) and recovery values of 100 percent.
- Fresh, medium strong conglomerate to a depth of 133.5 feet (to Elev. 1622.5 feet). RQD value of 73 percent and recovery value of 100 percent.
- Fresh, medium strong to strong to a depth of 220 feet (to Elev. 1536 feet). RQD values ranged between 67 to 100 percent (avg. 89 percent) and recovery values of 100 percent.

Based on Boring B-I80-4, the site soils are anticipated to include the following:

- Medium dense silty sand with gravel from the ground surface to a depth of 3.5 feet (from Elev. 1758.2 to 1754.7 feet).
- Medium dense to dense clayey sand with gravel to a depth of 78.5 feet (to Elev. 1679.7 feet). Grain size distribution tests indicate gravel percentages up to 23 percent of the soil particles.

- Hard sandy clay with gravel to a depth of 88.5 feet (to Elev. 1669.7 feet). Grain size distribution tests indicate gravel percentages up to 13 percent of the soil particles.
- Hard sandy silt to a depth of 93.5 feet (to Elev. 1664.7 feet).
- Very dense clayey gravel to a depth of 100 feet (to Elev. 1658.2 feet).
- Highly weathered to slightly weathered, weak to medium strong siltstone to a depth of 115 feet (to Elev. 1643.2 feet). RQD values ranged between 23 to 82 percent (avg. 57 percent). Recovery values ranged between 95 to 100 percent (avg. 98 percent).
- Slightly weathered to fresh, medium strong to very strong sandstone to a depth of 200 feet (to Elev. 1558.2 feet). RQD values ranged between 70 to 98 percent (avg. 81 percent). Recovery values ranged between 95 to 100 percent (avg. 100 percent).
- Moderately weathered, medium strong siltstone to a depth of 205 feet (to Elev. 1553.2 feet). RQD value of 35 percent and recovery value of 100 percent).
- Fresh, very strong quartzite with highly fractured zones to a termination depth of 220 feet (to Elev. 1538.2 feet). RQD values ranged between 62 to 90 percent (avg. 73 percent) and recovery values of 100 percent.

Overall, the bedrock south of I-80 appears to be of very poor to excellent quality, with RQD values ranging from 0 to 100 percent, and an average value of 78 percent. The core recovery values on the south side ranged from 62 to 100 percent, with an average value of 98.5 percent. Along the horizontal tangent the RQD values are anticipated to range from 78 to 97 percent with and average value of 89 percent.

Laboratory testing of the sandstone from Borings B-I80-3 and B-I80-4 indicate a Uniaxial Compressive Strength (UCS) range from 10,950 to 20,440 psi with an average of 16,021 psi. The axial point load UCS ranged from 7,435 to 17,804 psi with an average of 13,818 psi. The diametral point load UCS ranged from 6,474 to 25,886 psi with an average of 13,896 psi. The splitting tensile strength ranged from 1,377 psi to 3,027 psi with an average of 1,954 psi.

Laboratory testing of the siltstone from Boring B-I80-4 indicate a Uniaxial Compressive Strength (UCS) of 5,713 psi. The axial point load UCS was 9,002 psi and the diametral point load UCS was 5,086 psi. The splitting tensile strength was tested as 1,150 psi.

2.3 Karst Formations and Abandoned Mines

No karst features have been identified in the vicinity of the I-80 HDD Crossing. According to the Pennsylvania Mine Land Inventory, the closest mapped abandoned mine is located approximately eight (8) miles southwest of the crossing location.

3 Interstate 80 Crossing

3.1 HDD Bore Geometry and Alignment Considerations

3.1.1 Entry and Exit Angles

HDD operations are typically designed with entry angles between 8° and 16°, although steeper entry angles have been used where insufficient setback distance or steeply sloping ground exists for a given alignment. Exit angles are typically lower than the entry angle, as consideration must be given to the pipe diameter, the equipment necessary to transition the pipe into the bore, and the stresses induced as the pipe is forced over the break-over location as it enters the HDD bore.

For the I-80 Crossing, the entry and exit angles have both been set at 12°, relative to the horizontal.

3.1.2 Vertical and Horizontal Curvature

Vertical curvature is inherent to all HDD installations. The need for horizontal curvature is dependent on the restrictions specific to a single crossing. While horizontal curvature is feasible, it greatly increases the complexity of the scope of design and construction when required. It also increases the stress, and therefore the risk, to the pipe and the overall installation. Steering in both planes is not a standard industry practice, and can lead to complex radii and a reduction in the overall bending radius that the pipe will be subjected to. A straight alignment has been selected for this HDD crossing, thereby eliminating the risks associated with horizontal curvature.

The proposed vertical curve radius of 3,600 feet shown in Appendix A is consistent with the HDD industry standard of 1,200 times the 3 foot outer diameter of the pipe. This radius has been taken as the design radius for the crossing.

3.1.3 HDD Installation Depth

The depth of cover for a given HDD installation is dependent on several factors, including but not limited to:

- The anticipated geotechnical materials,
- The presence of preferential flow pathways,
- The design bending radius,
- The presence of existing utilities and/or structures, and
- Installation length.

Of these, the most important factors are the properties of the overlying geotechnical material, and the resistance these materials provide against the required installation-induced bore fluid pressures necessary to remove the cuttings.

Another important factor in establishing the proper installation depth is the ability to maintain bore stability over the course of the installation. This is accomplished by placing the HDD bore through geotechnical materials that are favorable to HDD operations.

As shown in Appendix A, the minimum depth of cover beneath I-80 and Wetland 102314_JC_001_PEM is approximately 150 feet and 127 feet, respectively.

3.1.4 Bore Diameter

The diameter of the HDD bore needs to be greater than the outer diameter of the pipe. This larger bore is required to facilitate the flow of drilling fluids around the pipe, reduce the frictional force acting on the pipe as it is installed, and to help the pipe negotiate curves in the alignment.

The acceptable industry standard for the final bore diameter is generally 1.5 times larger than the pipe outer diameter for small diameter pipe (less than 24 inches), and 12 inches larger than the outer diameter for large diameter installations. However, the actual diameter of the bore is typically dependent upon the geotechnical conditions and the required bore geometry. Hence, it may be necessary to increase the diameter beyond the typical industry standard to facilitate the installation process. To increase the likelihood of success, it is highly recommended that the final bore diameter be selected by the HDD Contractor, based on their experiences with similar geotechnical materials, pipe diameters, and installation lengths, and to suit their means and methods.

Based on typical HDD industry standards, the anticipated bore diameter for the NPS 36 pipe is 48 inches.

3.2 Line and Grade Accuracy

The horizontal and vertical position of the bottom hole assembly is tracked using a downhole survey tool, consisting of a probe that utilizes Earth's gravitational and magnetic fields. These tools have a nominal accuracy of approximately:

- Inclination: ± 0.1°
- Azimuth: ± 0.3° to 0.5°
- Tool-face: ± 0.1°

The accuracy of these tools can be enhanced by using a surface wire/coil loop established over the alignment. Inducing an electrical current through the wire creates a localized magnetic field that the probe can then use to determine its location relative to the surveyed coil and magnetic field.

These enhanced guidance systems include TruTracker and ParaTrack systems. The TruTracker guidance system relies on a closed loop surveyed wire layout that is at least as wide as the depth of the HDD installation. For highways and water body crossings, individual coils are often established on each side of the crossing feature. A ParaTrack system relies on a single wire placed directly over the HDD alignment centerline, with a return wire offset several hundred feet from the alignment to form a closed loop system. When augmented with a surface coil, the lateral and vertical position of the survey probe is plus or minus two (2) percent of the depth separating the location of the probe and the surface coil. Greater inaccuracies may occur if site constraints prevent the use of an energized wire grid on the ground surface.

Fiber-optic gyroscopic guidance systems have also been used to track downhole tooling. This type of system relies on an inertial measurement unit to calculate the position of the bottom hole assembly and is not affected by magnetic interference. This tool is very effective in accurately locating the surface tool position during pilot bore drilling.

With all of these methods, survey readings can be taken at the end of each drilled joint or every half of a joint. Stand-alone surveys can be completed where the surface coils are established. Here the inaccuracy is a function of the specific depth of cover at the location in question. Where the surface coils cannot be established, such as across a highway or beneath a river, the position of the bottom hole assembly is determined based on the calculated position of the previous measurement. In this manner, any inaccuracy built into the measured position is additive as the drill length increases. However, as the bottom hole assembly re-encounters the surface coil on the opposite side of the highway or river, the inaccuracy is once again a function of a stand-alone measurement based on the specific depth of cover at the location in question.

Mott MacDonald recommends the use of a gyroscopic guidance system for the I-80 Crossing to mitigate concerns associated with laying a surface coil along the proposed alignment and across the highway. If a ParaTrack system is proposed by the HDD Contractor, the HDD Contractor must assure adequate coverage of surveying with no gaps in coverage with a surface coil and/or beacon.

3.3 Required Workspace and Staging Areas

For the proposed HDD installation, the staging area for the north side of the crossing has been established at 253 feet by 263 feet, and the staging area for the south side of the crossing has been established at 250 feet by 264 feet. This area is required to stage equipment necessary for the installation, which includes the drill rig, stacks of drill pipe, operator control cabin, tooling trailers, crane or excavator, separation plant, mud tanks, mud pumps, Baker storage tanks, office trailer, and support trailers.

In addition to the entry and exit staging areas, a staging area of 75 feet wide by the length of the pipe string (greater width is required where multiple drag sections are required) is also required for welding sections of the pipe string, and preferably the entire pipe string when possible, prior to installation. The proposed staging area for the drag section is located on the west side of the crossing. The available length of the staging area is approximately 3,000 feet, resulting in the need for fabricating the pipe string into two (2) drag sections and the need for one (1) intermediate weld during pullback operations. The HDD Contractor will need to minimize delays during intermediate welding operations. The 100-foot width of the permanent easement and temporary workspace along the mainline to the south is sufficient to accommodate the two (2) pipe strings.

The temporary work space established for the I-80 Crossing is sufficient for HDD operations.

3.4 Requirement for Temporary Surface Casing

During the geotechnical investigation, layers of loose gravel were observed at relatively shallow depths on the north side of I-80. The gravels were observed to a depth of approximately 18.5 feet below ground surface on the north side of the crossing. These soils represent a significant risk to the overall bore stability, raveling of gravel into the bore, potential damage to the pipe string, and increased pullback loads/stresses. To support these soils and mitigate the risks associated with such deposits, a temporary conductor casing is recommended on the north side of the HDD installation. The approximate casing length required is 123 feet.

The minimum conductor casing diameter is recommended to be 56 inches to allow for the free passage of the 48-inch reamer assembly. Any required casing pipe shall be removed once pullback operations have been completed.

3.5 Drilling Fluid Make-Up Water and Source

HDD operations require a continuous source of water to support construction activities. It is typical for contractors to make use of an onsite source or have water delivered from a nearby source. In each case, the contractor should verify that the water source is suitable for HDD operations or treat it (filtration, pH, etc.) so that it is suitable for use.

For the proposed crossing, the no potential source of fresh water has been identified on site to support construction activities. Estimates of fresh water requirements is a function of maintaining drilling fluid flow within the bore during the HDD installation, and water requirements to adjust for hole volume, minor losses to processed spoil and surrounding geotechnical materials, wash water, etc. Daily fresh water usage typically ranges from 2,650 to 5,300 ft^3, depending on the process and storage capabilities of the Contractor.

Total fresh water requirements can be estimated as a function of the final reamed diameter. Factors of between two (2) and seven (7) times the final reamed diameter have been used to estimate the fresh water requirements necessary to support HDD operations. Based on a factor of five (5), the estimated total water usage (assuming no loss in circulation) is approximately 2,000,000 gallons (267,350 ft^3). This volume estimate assumes good HDD industry practices and procedures are followed, and that no significant fluid losses occur during the installation. This volume also includes fresh water required for buoyancy control during the HDD installation (estimated at approximately 202,000 gallons).

3.6 Disposal of Excess Drilling Fluid and Processed Spoils

Excess drilling fluids and processed spoils will need to be disposed of during the installation. The direct area around the HDD is not expected to be suitable for permanent disposal of drilling fluid or processed solids (based on local, state, and federal regulations). Local temporary storage will be required either in above ground tanks or a lined burrow pit. A suitable offsite disposal site should be located for disposal of drilling fluid and processed spoil per the local, state, and federal guidelines.

Disposal volumes of excess drilling fluid and spoil are estimated at approximately 727,100 gallons (3,600 yd^3) and 68,575 ft^3 (2,540 yd^3) respectively. During pullback operations, the estimated displaced fluid volume is approximately 200,000 gallons (990 yd^3).

3.7 Schedule

The duration of the HDD installation is conservatively estimated to take a total of 136 shifts (Table 1). This estimate is based on a 12-hour shift, regardless of whether 24-hour operations are conducted to complete the crossing. No provisions have been included for pad construction and erection and tear-down of a shelter (if used) in these durations. In addition, no contingency has been provided for weather or more difficult drilling conditions.

Table 1: Estimated schedule duration for the HDD crossing

Activity	Duration (Shifts)
Mobilization	3
Rig Up / Equipment Setup	6
Casing Installation	2
Pilot Bore Drilling	20
Reaming	95
Swab Pass	2
Product Pipe Pullback	2
Casing Removal	1
Rig Down and Demobilization	5
Total Number of Shifts	**136**

4 HDD Engineering Evaluation

4.1 Pipeline Properties

The pipeline properties used for the evaluation of the I-80 Crossing have been provided by PennEast, and are summarized in Table 2 below:

Table 2: Pipeline properties and input parameters for the HDD evaluation

Evaluation Parameter	Value
Pipe Size	NPS 36
Outer Diameter	36 in
Wall Thickness	0.762 in
Pipe Grade	X-70
Maximum Allowable Operating Pressure	1,480 psig
Minimum Operating Temperature	45°F
Maximum Operating Temperature	120°F
Poisson's Ratio	0.30
Elastic Modulus	29,200,000 psi
Coefficient of Thermal Expansion	6.5 x 10^{-6} in/in/°F
Design Factor	0.5

4.2 Design and Minimum Allowable Bend Radii

The minimum ultimate bend radius is a function of the maximum allowable operating pressure, pipe diameter, wall thickness, design factor, location factor, and specified minimum yield strength of the pipe material. Determination of the ultimate minimum bend radius is based on determining the hoop and longitudinal stresses under operating pressure and then determining the available magnitude of stress that the product pipe can accommodate in an alignment bend/curve.

The minimum ultimate bending radius evaluation is completed in accordance with:

- ASCE Manual of Practice No. 108 Pipeline Design for Installation by Horizontal Directional Drilling
- 49 CFR 192 Transportation of Natural and Other Gas by Pipeline- Minimum Federal Safety Standards
- ASME B31.8 Gas Transmission Distribution and Piping Systems
- ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids

Using the pipe properties presented in Table 2, the ultimate minimum bending radius is calculated for the pipe and pressure conditions. This radius represents the lowest radius that could be drilled without overstressing the pipe for the identified pipe properties and in-service loading. Based on the pipe properties provided in Table 2 and a design factor of 0.5, the ultimate minimum bending radius is approximately 2,500 feet.

The minimum allowable bending radius is the minimum radius that the HDD contractor is permitted to drill during their pilot bore to maintain the design alignment and profile. This radius is established above the calculated ultimate minimum bending radius to not overstress the pipe during the HDD installation process, and sufficiently below the design radius provided on the construction drawings. Based on an ultimate minimum bending radius of 2,500 feet, the minimum allowable bending radius has been established at 2,600 feet.

The design radius is the radius selected to develop the HDD plan and profile. This radius is greater than the minimum allowable bending radius given to the HDD contractor to complete the construction of the crossing. The design bending radius for developing the I-80 profile has been established at 3,600 feet, which is consistent with the HDD industry standard of 1,200 times the outer diameter of the NPS 36 pipe.

4.3 Operating Stress Evaluation

Evaluation of operating loads for pipelines installed by HDD methods is generally similar to the evaluation for pipelines installed by open-cut construction methods. The main difference between the two scenarios is that the condition of elastic bending (as a result of the curved HDD alignment profile) must be considered for the HDD installation. Elastic bending stresses occur as the pipe takes on the final shape of the HDD bore. As a rule, the bending stresses induced are not a critical stress condition on their own, but must be considered in a combined loading condition with other stress conditions such as hoop stress and longitudinal stress.

An operating stress evaluation has been completed in compliance with the American Society of Mechanical Engineers B31.4 and B31.8. The input parameters for this analysis are provided in Table 2. The results of the evaluation are provided in Table 3 below, and are based on the minimum allowable bending radius of 2,600 feet (the allowable bend radius provided to the HDD contractor). As observed in Table 3, the operating stresses are below the maximum allowable limits. Hence, the pipe properties (wall thickness and grade) are sufficient to meet the operating stresses within the HDD alignment.

Table 3: Summary of operating stress evaluation

Stress Condition	Estimated Stress (psi)	Percent of SMYS[1] (%)	Maximum Allowable Percent of SMYS[1] (%)
Longitudinal Bending Stress	16,846	24.1	--
Hoop Stress	34,961	49.9	50[2]
Longitudinal Tensile Stress from Hoop Stress	10,488	15.0	--
Longitudinal Stress from Thermal Expansion	-14,235	20.3	90[3]
Net Longitudinal Stress (Compression Side of the Curve)	-20,593	29.4	90[4]
Net Longitudinal Stress (Tension Side of the Curve)	13,099	18.7	90[4]
Maximum Shear Stress	27,777	39.7	45
Combined Biaxial Stress	55,553	79.4	90[4]

Notes: [1] Specified Minimum Yield Stress
[2] Limited by design factor
[3] Limited by ASME B31.4
[4] Limited by ASME B31.8

4.4 HDD Installation Load and Stress Evaluation

A total of six (6) pull load evaluations were completed for the HDD bore profile. These calculations are based on the installation load calculation method provided in American Society of Civil Engineer MREP 108 (2015), and the Pipeline Research Committee at the American Gas Association publication, entitled "Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide."

The pull load evaluation includes assumptions for final bore diameter, soil, and pipe roller friction coefficients, drilling fluid yield point, plastic viscosity, drilling fluid pumping rate, and other installation parameters such as buoyancy control measures (i.e. whether or not the pipe will be filled with water during pullback operations). In addition, the evaluation accounts for the capstan effect induced by curves in the alignment, fluidic drag, buoyancy of the pipe string within the bore, and the weight of the tail string at start-up and throughout the installation process.

Six (6) installation evaluations have been completed to investigate the effects of varying mud weights and buoyancy control measures during the installation of the pipe. The six (6) scenarios evaluated include:

- Case 1: Drilling Fluid Weight — 10 ppg (Specific Gravity of 1.20)
  Pipe — No buoyancy control (pipe empty of water)
- Case 2: Drilling Fluid Weight — 10 ppg (Specific Gravity of 1.20)
  Pipe — Full buoyancy control (pipe full of water)
- Case 3: Drilling Fluid Weight — 11 ppg (Specific Gravity of 1.32)
  Pipe — No buoyancy control (pipe empty of water)
- Case 4: Drilling Fluid Weight — 11 ppg (Specific Gravity of 1.32)
  Pipe — Full buoyancy control (pipe full of water)
- Case 5: Drilling Fluid Weight — 12 ppg (Specific Gravity of 1.44)
  Pipe — No buoyancy control (pipe empty of water)
- Case 6: Drilling Fluid Weight — 12 ppg (Specific Gravity of 1.44)
  Pipe — Full buoyancy control (pipe full of water)

A summary of the maximum anticipated pull load for each case scenario is provided in Table 4 below. Detailed calculations are provided in Appendix C. The anticipated installation loads shown in Table 4 are well below the ultimate allowable load of the pipe of approximately 3,542,953 lbs, based on a tensile stress equivalent to 60 percent of the yield stress for the given wall thickness and pipe grade provided in Table 2. It is important to note the difference in pull loads when buoyancy control measures are implemented and water is added to the pipe during pullback, as the estimated installation loads are typically lower when buoyancy control measures are used. Mott MacDonald recommends the use of buoyancy control measures to lower the overall installation loads and stresses for this installation.

A start-up factor of 1.5 has been applied to the estimated pullback forces to replicate the higher installation loads observed during stoppages and recommencing of pullback operations. This is referred to as the initial start-up pullback force in Table 4.

Table 4: Summary of anticipated pullback loads

Drilling Fluid Weight (ppg)	Product Pipe Buoyancy Condition	Estimated Pullback Force (lbs)	Initial Start-Up Force String 1 (lbs)	Initial Start-Up Force String 2 (lbs)
10 (Case 1)	Empty	741,907	55,227	509,677
10 (Case 2)	Full	392,779	55,227	313,929
11 (Case 3)	Empty	862,208	55,227	549,517
11 (Case 4)	Full	328,792	55,227	314,959
12 (Case 5)	Empty	982,072	55,227	589,345
12 (Case 6)	Full	277,983	55,227	320,941

Results of the corresponding installation stresses (based on the design bending radius of 3,600 feet) are summarized in Table 5.

Table 5: Summary of installation stress evaluation

Stress Condition	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Maximum Tensile Stress (Percent of Allowable)	8,795 psi (12.6%)	4,656 psi (6.7%)	10,221 psi (14.6%)	3,898 psi (5.6%)	11,642 psi (16.6%)	3,805 psi (5.4%)
Maximum Bending Stress (Percent of Allowable)	12,083 psi (17.3%)	12,083 psi (17.3%)	12,083 psi (17.3%)	12,083 psi (17.3%)	12,083 psi (17.3%)	12,083 psi (17.3%)
Maximum Hoop Stress (Percent of Allowable)	2,537 psi (3.6%)	421 psi (0.6%)	2,695 psi (3.9%)	651 psi (0.9%)	2,891 psi (4.1%)	881 psi (1.3%)
Maximum Unity Check – Tensile and Bending	0.42	0.35	0.45	0.34	0.47	0.34
Maximum Unity Check – Tensile, Bending, and Hoop	0.31	0.10	0.36	0.10	0.41	0.11

As observed in this Table, the results of the HDD installation stress evaluation are within the allowable limits for all cases.

4.5 Hydraulic Fracture Evaluation

The hydraulic fracture evaluation for this crossing has been completed in general accordance with the Delft Geotechnics Method outlined in Appendix B of the Army Corps of Engineers 1998 Report CPAR-GL-98 and 2002 Report ERDC/GSL TR-02-9 (Guidelines for Installation of Utilities Beneath Corp of Engineers Levees Using Horizontal Directional Drilling). This method is used to estimate the maximum effective pressure (i.e. drilling fluid pressure) that can be induced during an HDD operation within a particular soil horizon. This pressure is then compared with the fluid pressure required to induce slurry flow within the HDD bore to determine the potential for a hydraulic fracture for a given HDD alignment. The required fluid pressure for an HDD installation is governed by the drilling fluid weight (commonly referred to as the mud weight), installation length and depth, and drilling fluid flow properties (plastic viscosity, yield point, etc.).

The hydraulic fracture evaluation method described above and used in the HDD industry was developed for soil installations. Currently, no accepted method is available to model/predict the maximum allowable

drilling fluid pressure within bedrock materials. While bedrock tensile strength and unconfined compressive strength evaluations have been used to estimate the allowable drilling fluid pressure within bedrock materials, these methods tend to provide results that are not considered suitably conservative and greatly over-predict the true maximum allowable drilling fluid pressures. These over-predictions are a result of laboratory testing on sound or high quality bedrock samples that are not representative of the strengths of the weaker bedrock materials that contain natural fractures/joints that are washed out or impacted by the geotechnical coring process. Hence, for the bedrock hydraulic fracture evaluation, Mott MacDonald has elected to model the sandstone bedrock materials as strong soils. This conservative approach has been used by Mott MacDonald to successfully complete several HDD installations in similar bedrock materials.

The Delft Geotechnics Method assumes a uniform column of soil above any point of interest along the alignment. Where an increased risk of hydraulic fracture is identified, it does not necessarily mean that a hydraulic fracture will occur. A proper HDD execution plan, based on HDD industry standard construction practices, can reduce the risk of a hydraulic fracture from occurring.

In order to complete the hydraulic fracture evaluation, it is necessary to make several assumptions relative to the bore diameter, drilling fluid pumping rate, and drilling fluid properties. Parameters used in Mott MacDonald's evaluation are provided in Table 6 below. These parameters have been selected based on Mott MacDonald's experience in drilling within similar anticipated geotechnical materials.

Table 6: Assumptions used for hydraulic fracture evaluation

Evaluation Parameter	Value
Pilot Bore Diameter	12-¼ in
Drill Pipe Diameter	6-⅝ in
Drilling Fluid Pumping Rate	600 gal/min
Drilling Fluid Weight (Specific Gravity)	10.5 ppg (1.26)
Yield Point	24 lb./100 ft^2
Plastic Viscosity	16 cP

In addition to the assumptions provided in Table 6, assumptions are also required for the anticipated soil formation(s) and their properties including, but not limited to, geotechnical material strength, unit weight, cohesion, friction angle, and shear modulus. These assumptions are provided in Tables 7 and 8 for the varied subsurface materials that are anticipated for this crossing. For this evaluation, Mott MacDonald assumes that the encountered subsurface material will be similar to that described in Section 2.0, namely, a mixture of clayey sand and clayey gravel overlying predominately sandstone bedrock. For this evaluation, it has also been assumed that the drilling rig will be located on the north side of the crossing to complete the pilot bore.

Table 7: Material property assumptions for the clayey sand and gravel

Evaluation Parameter	Value
Soil Unit Weight Above / Below Water Table	125 lb./ft^3 / 135 lb./ft^3
Effective Cohesion	1,000 psf
Internal Friction Angle	30°
Young's Modulus	730,990 psf
Poisson's Ratio	0.33

Table 8: Material property assumptions for the sandstone bedrock

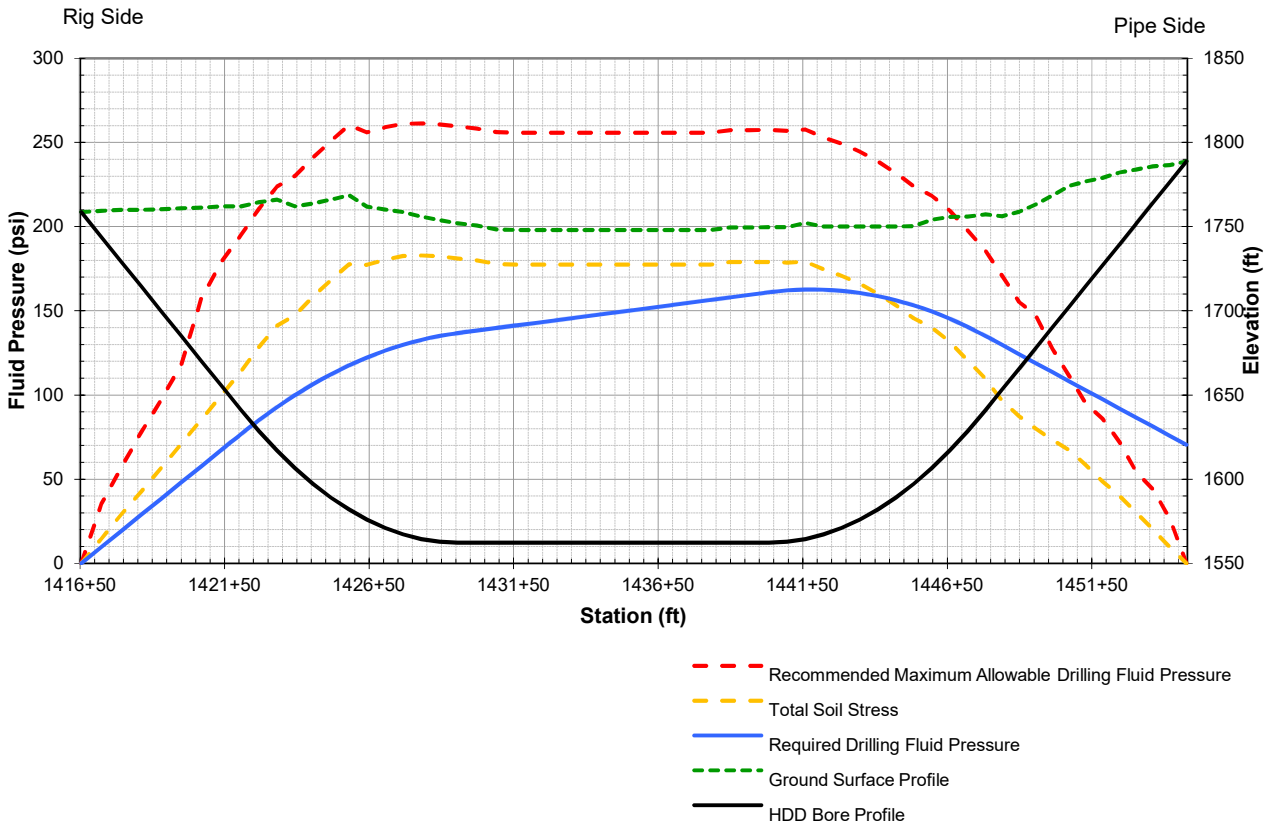
Evaluation Parameter	Value
Soil Unit Weight Above / Below Water Table	130 lb./ft^3 / 140 lb./ft^3
Effective Cohesion	0 psf
Internal Friction Angle	32°
Young's Modulus	835,417 psf
Poisson's Ratio	0.33

The results of the preliminary hydraulic fracture evaluation for the proposed crossing are provided in Figure 1 for the pilot bore phase of the installation process. More detailed results are provided in Appendix D. A safety factor has been incorporated into the hydraulic fracture evaluation for the allowable bore pressure within the bedrock, to account for assumptions incorporated into the design and heterogeneity of the geotechnical materials. The graph also displays the total soil/bedrock overburden stress representing the equivalent unit weight of the overlying soil without consideration of any soil strength. Mott MacDonald recommends holding discussions with the HDD contactor if the actual bore pressures trend higher than those values estimated in Appendix D during actual construction, especially if the observed bore pressures spike during the installation.

As shown in the graph, the required bore pressure to facilitate the installation process is well below the allowable bore pressure for the installation.

Once the pilot bore is completed, the hydraulic fracture risk associated with the reaming, swab, and pullback phase of the installation typically decreases, assuming the bore is reamed to its full extent and a subsequent swab pass is completed through the bore prior to installing the pipe. However, it is important to note that although the hydraulic fracture potential is significantly reduced, a hydraulic fracture event may still occur during the reaming pass if the bore becomes plugged or blocked such that the required drilling fluid pressure increases in magnitude to the point where it exceeds the estimated allowable mud pressure for the overlying soils. HDD industry standard construction practices, such as pumping sufficient drilling fluids, maintaining drilling fluid returns, monitoring and maintaining drilling fluid and returning slurry properties, etc., should reduce any potential loss of drilling fluids.

Figure 1: Calculated, Recommended, and Allowable Drilling Fluid Pressures



5 HDD Risk Discussions

5.1 HDD Risk Characterization

Risk identification and mitigation is paramount to successfully completing the I-80 Crossing. Discussions of the general risks associated with these crossings are presented below.

5.2 HDD Industry – State of Practice

Mott MacDonald maintains an up-to-date database of successfully completed HDD installations based on pipeline diameter and installation length, as shown in Table 9 below. This database is used to quickly and uniquely assess the achievable installation length for a given pipeline diameter. The green shaded cells indicate the common range of HDD industry experience/capability, and was established with the requirement that several contractors have successfully completed similar installation lengths at the specific diameter. The yellow shaded cells identify the installation lengths and diameters that are considered feasible with an experienced contractor in favorable ground conditions. The red shaded cells are considered to be at the limits of, or beyond, the current state-of-the-practice for the HDD industry.

Table 9: State of the HDD Industry

Product Pipe Diameter	Installation Length												
	1,000 m	1,200 m	1,400 m	1,600 m	1,800 m	2,000 m	2,200 m	2,400 m	2,600 m	2,800 m	3,000 m	3,500 m	3,750 m
	3,281 ft	3,937 ft	4,593 ft	5,249 ft	5,905 ft	6,562 ft	7,218 ft	7,874 ft	8,530 ft	9,186 ft	9,842 ft	11,483 ft	12,303 ft
200 mm (8 inch)	16	9	14	4	5	10	5	0	0	0	1	0	1
250 mm (10 inch)	9	9	4	11	1	0	3	1	0	0	0	0	0
300 mm (12 inch)	14	10	9	4	3	1	0	1	1	0	0	1	0
350 mm (14 inch)	3	5	3	0	1	0	0	0	0	0	0	0	0
400 mm (16 inch)	9	4	4	6	4	1	3	0	0	0	2	0	0
450 mm (18 inch)	0	0	0	2	0	0	0	0	0	0	0	0	1
500 mm (20 inch)	8	10	9	1	0	1	2	1	0	0	0	0	0
600 mm (24 inch)	29	30	9	12	9	4	1	2	0	0	1	0	0
750 mm (30 inch)	23	10	10	11	8	3	1	3	0	0	1	0	0
900 mm (36 inch)	23	21	21	6	2	1	2	0	1	0	0	0	0
1050 mm (42 inch)	29	21	11	5	1	1	0	0	0	0	0	0	0
1200 mm (48 inch)	1	2	1	0	0	0	0	0	0	0	0	0	0

Colour Coding:

- Within typical capabilities of industry. Multiple experienced contractors.
- Zone of limited industry application. Considered feasible with an experienced contractor and favourable ground conditions.
- Exceeds current capabilities of industry. Considered risky even with an experienced contractor and favourable ground conditions.

NOTE: Current State of the HDD Industry shown above is based solely on the reported installation lengths and diameters. Site-specific geotechnical and installation based risks have not been considered in developing this chart.

It is very important to note that the state of the HDD industry shown above includes crossings with similar elevations between HDD entry/exit locations and the crossing feature, good soils/bedrock materials, and adequate staging area for fabricating the pipe string. These completed projects mostly reflect those with low risk profiles (especially for larger and longer HDD installations). As such, when comparing a specific crossing to those completed projects within the HDD industry, the site-specific geotechnical and crossing risks need to be thoroughly considered and evaluated to verify the completed project listings are comparable and deemed to be adequate. If the current proposed crossing carries a low risk profile, then the comparison can serve as a guide to what has been successfully completed within the HDD industry. However, if the current proposed crossing carries a high risk profile, then the comparison to the completed projects may not be applicable.

As observed in Table 9, several HDD installations have been successfully completed at a diameter of NPS 36 for lengths considerably longer than the horizontal installation length of approximately 3,823 feet, with a

true pipe length of approximately 3,862 feet, required for the I-80 crossing. Therefore, from a constructability standpoint, the I-80 Crossing falls within the zone of typical experience of what has been accomplished to date within the HDD industry.

5.3 Geotechnical Risk Discussions

Sands, silts, and clays typically present no significant challenge to an HDD installation. These materials are often described as good to excellent materials in terms of feasibility. However, when these soils exist in a soft or loose state, they may not provide sufficient strength to resist the required fluid pressures necessary to complete an HDD installation. Within these materials, the required drilling fluid pressures can exceed their strength, resulting in the formation of a hydraulic fracture through the overlying soils and ponding of drilling fluids at the ground surface. This risk can only be mitigated by placing the HDD bore within more favorable geotechnical materials that provide greater resistance to induced drilling fluid pressures, or through the use of conductor casings to provide an open pathway for drilling fluid flow.

Soils containing gravels and larger size particles (cobbles) range from marginally acceptable to unacceptable in terms of feasibility, depending upon the percentage of gravels by weight and particle size. Only those particles that can be suspended within the drilling fluid can be removed from the bore. Generally speaking, gravel-sized particles less than approximately 0.5 to 0.75 inches can be removed from the bore, provided good HDD practices are followed. Particles greater in size typically cannot be suspended by the drilling fluid and tend to settle out and accumulate along the bottom of the bore. The risks associated with accumulation of larger particles within the bore increase with greater bore diameter, due to the greater exposed soil materials in the crown of a larger bore.

To mitigate risks associated with the anticipated soils, temporary conductor casing has been incorporated into the design of the profile on the north end of the installation.

Controlling and maintaining fluid flow within the bore is critical to the success of an HDD installation. Installation risks significantly increase when slurry circulation is not maintained within the HDD bore. The flow of drilling fluid follows the path of least resistance. As long as the bore is located within favorable geotechnical materials at a sufficient installation depth and properly drilled by the HDD contractor, a stable flow pathway can be created between the drill bit and the HDD entry or exit locations, and maintaining drilling fluid flow within the bore should not be an issue. As observed in the hydraulic fracture evaluation, loss of drilling fluids through the overlying soil is not anticipated for this crossing.

Bedrock can be highly variable and can be classified as being excellent to unacceptable with respect to HDD feasibility. Competent bedrock is well suited for HDD as the bore tends to remain open for extended periods of time. However, heavily weathered, jointed, fractured or fissured bedrock can present challenges with respect to bore stability. In fact, poor quality bedrock can present the same challenges as coarse granular (gravel) deposits where fracturing and jointing is extensive and present an unacceptable risk in terms of constructability to an HDD installation. The risk associated with these materials arises from the inability to support and maintain stability within the bore.

This risk increases with RQD ratings below 60 percent. For the I-80 Crossing, the bedrock exhibits a wide range of ratings, with an average of 66 percent overall, and several isolated areas below 60 percent. The areas of lower rock quality are not anticipated to significantly increase risks associated with this installation.

The strength of the bedrock can impact construction duration, with higher strength leading to more frequent trips out of the bore to replace worn tooling. The laboratory tests completed to date on the sandstone bedrock indicate unconfined compressive strengths ranging from 6,603 to 20,440 psi, with an average value of 12,494 psi. One sample of siltstone was tested and indicated an unconfined compressive strength of 5,713 psi.

High angle fractures were observed throughout the geotechnical borings. The presence of these fractures increases the risk to bore stability, as the vertical and intersecting fracture planes will be less likely to bridge the crown of the bore and maintain an open annular space for fluid flow. Bore collapse that occurs during the pilot bore and reaming phases of the installation can lead to spikes in drilling fluid pressure, lost circulation and hydraulic fracture, increased force on the downhole tooling, decreased steering control, and loss or damage of downhole tooling. A swab pass is recommended to determine the condition of each bore prior to pullback operations. If areas of higher drill rig effort (torque or thrust/pullback) are experienced, the HDD Contractor should complete additional passes with a hole opener to clear the bore of any debris within the bore.

Preferential flow pathways may occur where heavily weathered, jointed, fractured or fissured bedrock exists. If interconnected, preferential flow pathways may exist for drilling fluid losses into the rock mass or upwards towards the ground surface. Fortunately, the presence of the drilling fluid slurry within the bore often is capable of sealing fractures and/or joints as drilling fluids migrate into these features, resulting in low potential for inadvertent returns of drilling fluids at the ground surface.

Based on the anticipated geotechnical materials, the HDD installation has been designed within favorable geotechnical materials to the extent possible.

5.4 Crossing-Specific Risk Discussions

The length of the pipe staging area for the proposed crossing is insufficient to fabricate the pipe into a single string prior to pullback operations, and an intermediate weld will be required. Intermediate welds will require stoppage of pullback operations each time a new pipe segment is welded on. These stoppages represent a significant risk to the installation because the bore is required to remain open much longer than would be required for the installation of a single pipe string. Stoppages for the intermediate welds also provide downtime, while welding occurs, that allows the drilling fluids to “gel” and making it harder to resume pullback operations due to the increased friction between the gelled fluids and the pipe. Start-up loads will increase each time pullback operations are resumed. In some cases, the gel strength of the fluids is too great and the resulting loads lead to damage to the pipe, or the pipe may become stuck at its current position in the bore. This risk increases with each additional intermediate weld. Prior to pullback operations, a swab pass should be completed to gauge whether the bore has been conditioned to accept the pipe.

Areas of high torque and/or pull force should be re-reamed to lower the drill rig effort to pass tools through this portion of the bore. The pipe should be installed with the shortest sections of pipe first and the longest pipe section last to decrease the startup loads on the pipe required to resume drilling operations.

6 Summary

For the I-80 Crossing, geotechnical risks have been acknowledged, but no fatal deterrents have been identified within the alignment. Based on the required installation length and diameter, the HDD contracting community in North America has successfully completed a large number of HDD installations of similar lengths.

While not anticipated, if an attempted HDD installation is unsuccessful, the proposed HDD alignment could be modified using the same HDD entry/exit locations to accommodate an additional HDD attempt, depending on the condition that resulted in the HDD failure. Prior to attempting a second HDD crossing, a risk mitigation workshop should be held with all parties to determine the cause of the initial failure and any mitigation measures that could be adopted to reduce the risk(s) during the second HDD attempt.

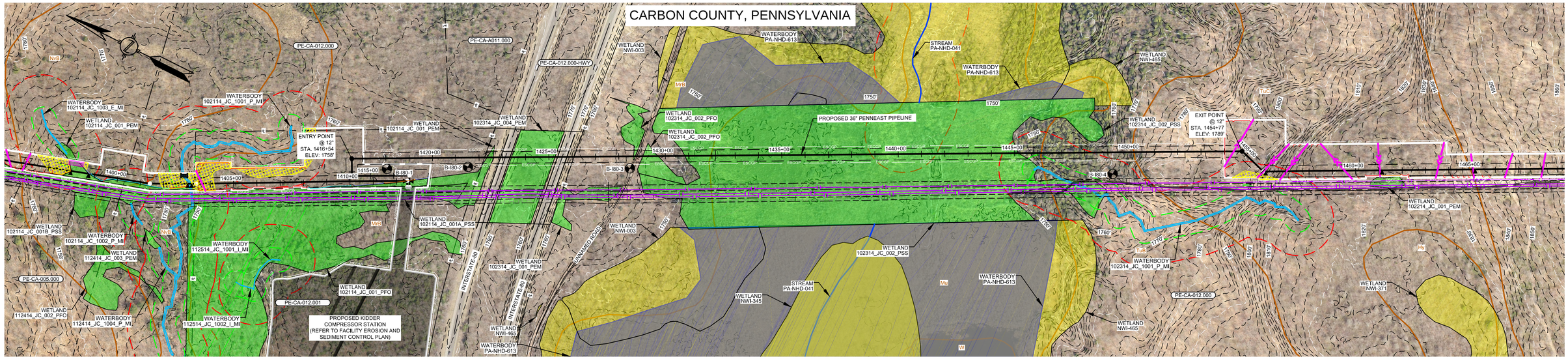
7 Limitations

This report is intended to be used in its entirety. The data, interpretations, conclusions, and recommendations contained within this report are provided for informational purposes for PennEast, and pertain specifically to the I-80 Crossing. The data and conclusions presented herein do not and should not be applied to any other project site or HDD installation. Interpretations of the subsurface conditions are based on the information obtained from the geotechnical borings. The subsurface conditions presented between the geotechnical borings are interpretations and may vary from the actual conditions encountered.

It is recommended that Mott MacDonald provide construction monitoring services to verify the subsurface conditions encountered during construction, provide field design services, and evaluate contractor performance in accordance with the contract and the approved contractor supplied work plan.

Appendix A

HDD Plan and Profile



CROSSING SPECIFIC HDD NOTES:

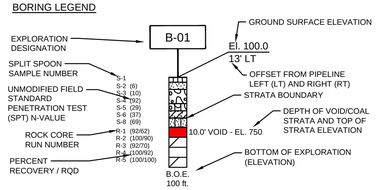
1. ALL DIMENSIONS AND ELEVATIONS ARE IN FEET, UNLESS OTHERWISE SPCIFIED.
2. ALL CHAINAGES ARE HORIZONTAL.
3. CONTRACTOR SHALL DETERMINE FINAL LOCATIONS AND DIMENSIONS OF ALL MUD PITS NECESSARY TO ACCOMMODATE THEIR MEANS AND METHODS.
4. CONTRACTOR TO STAGE ALL PERSONNEL AND EQUIPMENT WITHIN THE PERMITTED LIMIT OF DISTURBANCE AS DEPICTED ON THIS DRAWING, UNLESS OTHERWISE AUTHORIZED BY THE CLIENT.
5. CONTRACTOR SHALL DETERMINE DIAMETER, GRADE, WALL THICKNESS AND ADDITIONAL LENGTH OF TEMPORARY CONDUCTOR CASINGS IF DEEMED NECESSARY BY THE CONTRACTOR. ANY INSTALLED TEMPORARY CONDUCTOR CASING SHALL BE FULLY REMOVED UPON COMPLETION OF PULLBACK OPERATIONS.
6. THE MINIMUM ALLOWABLE DRILLING RADIUS SHALL BE 2,600 FEET BASED ON A 3-JOINT AVERAGE.
7. EXISTING UTILITY LOCATIONS AND DEPTHS, INCLUDING PRIVATE SERVICES, ARE APPROXIMATE AND SHALL BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO ANY CONSTRUCTION OPERATIONS. PENNSYLVANNIA LAW REQUIRES AT LEAST 48 HOURS AND NO MORE THAN TEN (10) WORKING DAYS NOTICE BEFORE EXCAVATION OR DEMOLITION.
8. HDD OPERATIONS SHALL BE CONDUCTED IN ACCORDANCE WITH ALL PERMIT REQUIREMENTS.
9. DOWNHOLE ANNULAR DRILLING FLUID PRESSURES SHALL BE MONITORED AT ALL TIMES DURING THE PILOT BORE DRILLING PROCESS. LOCATION OF MONITORING SHALL BE AS CLOSE TO THE DRILL BIT AS POSSIBLE.
10. HDD CONTRACTOR SHALL BE PREPARED TO PUMP A CEMENT GROUT DOWNHOLE TO HELP SEAL LARGE PREFERENTIAL FLOW PATHWAYS AND RESTORE DRILLING FLUID FLOW WITHIN THE HDD BORE IN THE EVENT HISTORIC MINE WORKINGS ARE ENCOUNTERED AND EXCESSIVE DRILLING FLUIID LOSSES OCCUR.
11. PILOT BORE SHALL BE CONTINUOUSLY TRACKED AT ALL TIMES. CONTRACTOR SHALL USE A GYROSCOPIC GUIDANCE SYSTEM TO COMPLETE THE PILOT BORE INSTALLATION. NO BLIND SECTIONS SHALL BE PERMITTED, EVEN WHEN THE DRILL BIT IS UNDER WATER.
12. IF THE CONTRACTOR ENCOUNTERS AN OBSTRUCTION THAT PREVENTS THE INSTALLATION ACCORDING TO THE PROJECT SPECIFICATIONS, THE CONTRACTOR SHALL PLACE A CEMENT BASED GROUT WITHIN THE BORE. WORK SHALL NOT RESUME UNTIL REVISED PLANS AND PROCEDURES HAVE BEEN SUBMITTED TO AND ACCEPTED BY THE OWNER.
13. PILOT BORE DRILLING TOLERANCES SHALL BE AS FOLLOWS:

Item	Tolerance
Pilot entry angle	Increase angle up to 1° (steeper), but no decrease in angle allowed.
Pilot entry location	As staked by Owner. No changes without Owner approval.
Pilot exit angle	Decrease angle up to 2° (flatter), but no increases in exit angle allowed.
Pilot exit location	Up to ten (10) feet shorter or longer.
Pilot depth	Up to three (3) feet shallower depth allowed. Up to ten (10) feet increase in pipe design depth (deeper) allowed.
Pilot alignment	Up to ten (10) feet left or right of the Owner survey centerline but not within five (5) feet of the right-of-way/easement boundary or any below grade utility or structure.

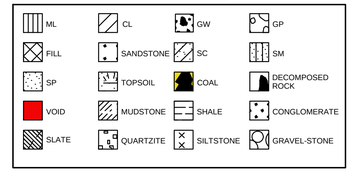
14. CROSS SECTIONS PRESENTS SUMMARY BOREHOLE LOG GRAPHICS, SEE FULL BOREHOLE LOG FOR DETAILS.

INTERSTATE 80 HDD PLAN VIEW
SCALE: 1" = 200'

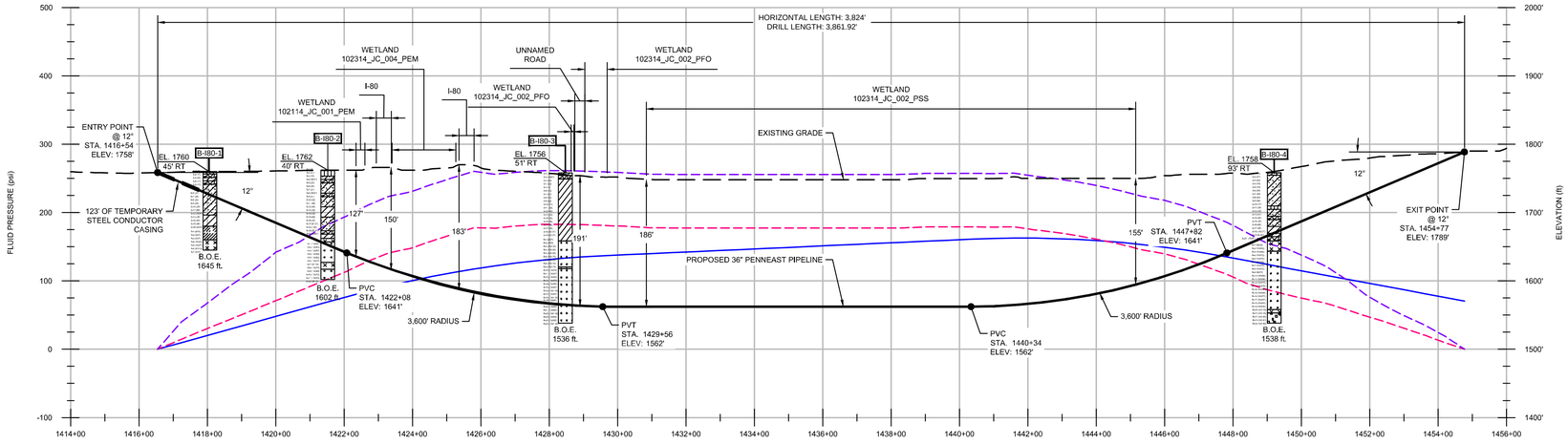
BORING LEGEND



SOIL AND ROCK STRATAGRAPHIC LEGEND:



GRAPHIC SCALE
200' 100' 0' 200'



REQUIRED DRILLING FLUID PRESSURE
RECOMMENDED MAXIMUM ALLOWABLE DRILLING FLUID PRESSURE
OVERBURDEN STRESS
HDD BORE PROFILE
GROUND SURFACE PROFILE

INTERSTATE 80 HDD PROFILE
HORIZONTAL SCALE: 1" = 200'
VERTICAL SCALE: 1" = 100'

GRAPHIC SCALE
HORIZ SCALE: 200' 100' 0' 200'
VERT SCALE: 100' 50' 0' 100'

NOTES:
1. THE CONTOURS AND IMAGERY SHOWN WERE PROVIDED BY PICTOMETRY, 2015. ADDITIONAL CONTOURS AND IMAGERY SUPPLEMENTED FROM PASDA.
2. EXISTING FEATURE SURVEYED PERFORMED BY MOTT MACDONALD 2015 THRU 2018. ADDITIONAL FEATURES DIGITIZED FROM IMAGERY. ALL LOCATIONS ARE APPROXIMATE AND SHALL BE VERIFIED BY CONTRACTOR.
3. PROPERTY LINES DEPICTED ON THIS PLAN ARE BASED ON GIS TAX MAP DATA AND RECTIFIED PROPERTY LINES AND ARE NOT THE RESULT OF A BOUNDARY SURVEY.
4. WATERBODY INFORMATION PROVIDED BY AECOM 2015 THRU 2018.

REFERENCE DRAWINGS

DWG. NO.	TITLE
000-03-01-054	ALIGNMENT SHEET
000-03-01-055	ALIGNMENT SHEET

REVISIONS

	REVISIONS	DATE	DRAWN	CK	APPR
A	ISSUED FOR PADEP	10/2018	JL (MM)	AJD (MM)	MJD (MM)

APPROVALS	
DRAWN BY	DATE
RJP (MM)	10/15/2018
CHECKED BY	DATE
CAF (MM)	10/15/2018
ENG. APPROVAL	DATE
MDN (MM)	10/15/2018
P.M. APPROVAL	DATE
MAW (MM)	10/15/2018

CLIENT APPROVAL
DATE

PREPARED FOR
PennEast PIPELINE

PENNEAST PIPELINE PROJECT
SOIL EROSION AND SEDIMENT CONTROL PLAN
PROPOSED 36" PIPELINE
HDD EXHIBIT PLAN AND PROFILE
INTERSTATE 80 HDD
CARBON COUNTY, PENNSYLVANIA

SCALE	DRAWING NO.	REVISION
AS SHOWN	000-03-07-013	A

COMMONWEALTH OF PENNSYLVANIA
MICHAEL A. WILCOX
ENGINEER
12/17/18

G:\PENNEAST\3553754_PENNEAST_PIPELINE_EPCM\DATA\PROD_STATE_PERMIT\WORK\PA\DRAFTING\EROSION_SEDIMENT_CONTROL_PLAN\HDD_DETAILS\000-03-07-013.DWG DUM64749

Appendix B

Geotechnical Boring Logs

MOTT MACDONALD

SOIL/ROCK BORING LOG LEGEND

USCS Group Symbol

UNIFIED SOIL CLASSIFICATION SYSTEM AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			FINE-GRAINED SOILS (more than 50% of material is smaller than No. 200 sieve size.)		
Gravels More than 50% of coarse fraction larger than N.4 sieve size	Clean Gravels (Less than 5% fines)		**SILTS AND CLAYS** Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey of clayey fine sands or clayey silts with slight plasticity
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines		OL	Organic silts and organic silty clays of low plasticity
	Gravels with fines (more than 12% fines)		**SILTS AND CLAYS** Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	GM	Silty gravels, gravel-sand-silt mixtures		CH	Inorganic clays of high plasticity, fats clays
	GC	Clayey gravels, gravel-sand-clay mixtures		OH	Organic clays of medium to high plasticity, organic silts
Sands More than 50% of coarse fraction larger than N.4 sieve size	Clean Sands (Less than 5% fines)		**HIGHLY ORGANIC SOILS**	PT	Peat and other highly organic soils
	SW	Well-graded sands, gravelly sands, little or no fines	Determine percentages of sand and Gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:		
	SP	Poorly-graded sands, gravelly sands, little or no fines			
	Sands with fines (More than 12% fines)				
	SM	Silty sands, sand-silt mixtures	Less than 5 percent ……GW, GP, SW, SP More than 12 percent ……GM, GC, SM, SC 5 to 12 percent ……Borderline cases requiring dual symbols		
	SC	Clayey sands, sand-clay mixtures			

Minor Components

Description	Criteria
20 – 30%	some
10 – 20%	little
1 – 10%	trace

Infilling

Description	Symbol
Clay	CL
Silt	ML
Sand	SD
Calcite	CA
Carbonate	C
Dolomite	DO
Gypsum/Tale	GY
Hematite	HE
Limonite	L
Quartz	QZ
Chlorite	CH
Pyrite	PY
Iron Oxide Staining	FE
Stylolite	ST
Not Determined	X
None	N
Healed	H

Weathering of Rock Mass

Description	Symbol	Criteria	Grade
Fresh (Unweathered)	FR	No visible sign of rock material weathering, except slight discoloration on major discontinuity surfaces.	I
Slightly Weathered	SL	Discoloration indicates weathering of rock material and discontinuity surfaces. All rock material may be discolored by weathering and may be somewhat weaker than externally than in its fresh condition.	II
Moderately Weathered	M	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a continuous framework or as corestones.	III
Highly Weathered	H	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones.	IV
Completely Weathered	C	All rock material is decomposed and/or disintegrated to soil. The original mass structure remains largely intact.	V
Residual Soil	RS	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

Discontinuity Spacing

Description	Symbol	Spacing (in.)
Extremely Close	EC	< 0.75
Very Close	VC	0.75 – 2.5
Close	C	2.5 – 8.0
Moderate	M	8 – 24
Wide	W	24 – 80
Very Wide	VW	80 – 240
Extremely Wide	EW	> 240

Spacing Type

Description	Symbol	Spacing (in.)
Joint	J	A natural fracture along which no displacement has occurred. May occur in parallel groups called sets.
Shear	S	A natural fracture along which differential movement has occurred. May be slickensided or striated.
Fault	F	A natural fracture along which displacement has occurred. Usually lined with gouge and slickensides.
Vein	V	A thin, sheet-like igneous intrusion into a fissure.
Bedding Joint	B	Joints that occur along bedding planes.
Foliation Joint	FJ	Joints that occur parallel to the foliation of a rock mass.
Shear Zone	SZ	Zone of fractured rock and gouge bordering the displacement plane.

Field Strength

Description	Criteria	Grade	Approx. Range of Uniaxial Compressive Strength (psi)
Extremely Weak	Indented by thumbnail.	R0	40 – 150
Very Weak	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife.	R1	150 – 700
Weak	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer.	R2	700 – 4,000
Medium Strong	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer.	R3	4,000 – 7,000
Strong	Specimen requires more than one blow of geological hammer to fracture it.	R4	7,000 – 15,000
Very Strong	Specimen requires many blows of geological hammer to fracture it.	R5	15,000 – 36,000
Extremely Strong	Specimen can only be chipped with geological hammer.	R6	>36,000

Roughness

Intermediate Scale	Symbol	Small Scale	Symbol
Stepped	S	Rough	R
Undulating	U	Smooth	Sm
Planar	P	Slickensided	K
Not Determined	X	Wavy	Wa
		Not Determined	X

Weathering/Alteration of Discontinuity Surfaces

Description	Symbol	Criteria
Fresh	FR	No visible sign of weathering on the rock discontinuity surfaces.
Discolored	DS	Discoloration of rock material discontinuity surfaces. Degree of discoloration and specific discolored mineral constituents (if applicable) indicated.
Disintegrated	DG	Discontinuity surface rock material is weathered to a soil with the rock material fabric intact. Rock material is friable, but the mineral grains are not decomposed.
Decomposed	DE	Discontinuity surface rock material is weathered to a soil with the rock material fabric intact and with some or all mineral grains decomposed.

Aperture

Description	Symbol	Aperture (in.)	
Very Tight	VT	< 0.004	"Closed" Features
Tight*	T	0.004 – 0.010	
Partly Open	PO	0.01 – 0.02	
Open**	O	0.02 – 0.10	"Gapped" Features
Moderately Wide	MW	0.1 – 0.4	
Wide	W	> 0.4	
Very Wide	VW	0.4 – 4.0	"Open" Features
Extremely Wide	EW	4.0 – 40.0	
Cavernous	CA	> 40	

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BOREHOLE LOG GRAPHIC LEGEND

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Delaware River Crossing, NJ/ PA	**Project Manager:**	Vatsal Shah
Client:	PennEast Pipeline	**Project Director:**	Michael Wilcox

Soil Log Graphic Legend


CH: USCS High Plasticity Clay


CL: USCS Low Plasticity Clay


CL-ML: USCS Low Plasticity Silty Clay


DECOMPOSED ROCK: Decomposed Rock


DOLOMITE: Dolomite


FILL: Miscellaneous and Manmade Fill


GM: USCS Silty Gravel


GP: USCS Poorly-graded Gravel


GP-GM: USCS Poorly-graded Gravel with Silt


GRAVEL-STONE: Gravel or Crushed Stone


ML: USCS Silt


QUARTZITE: Quartz and Quartzite


SC: USCS Sandy Clay to Clayey Sand


SM: USCS Silty Sand


SP: USCS Poorly-graded Sand


SP-SM: USCS Poorly-graded Sand with Silt


SW-SM: USCS Well-graded Sand with Silt


TOPSOIL: Topsoil


VOID: Underground Void

Rock Log Graphic Legend


DOLEMITE - OBSELETE: USE DOLOMITE


DOLOMITE - Dolomite


GNEISS - Gneiss


LIMESTONE - Limestone


SILTSTONE - Siltstone

▽ Ground Water Level
(Note that due to drilling process disturbance the ground water levels obtained during drilling are not as representative as those obtained from monitoring wells)

This legend reports all soil and rock graphics which have been used in the logs of this project only.

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SOIL BORING LOG

BORING NO.: **B-I80-1**
Page **1** of **4**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate 80, Carbon County, Pennsylvania	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jonathan Nelson
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	October 18, 2016 at 11:00 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	October 19, 2016 at 1:50 pm

Elevation: 1762 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 450 feet North of I-80 **Coord.:** **N:** 41.081977 **E:** -75.659638 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic ☐ _____

Drilling Fluid: ☐ Bentonite ☐ Polymer ☑ Water ☐ None

Drill Rod Size:

Casing Advance: Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	17	1 2 2 2		ML	0.4 Top (5") TOPSOIL with roots Bottom (19") Soft, Brownish yellow Sandy SILT with Gravel, moist (ML)	-	-	-	-	
1760						3.5					
5	S-2 5.0'- 7.0'	20	7 7 10 9		GC	Medium dense, Brownish yellow Clayey GRAVEL, moist (GC)	-	L	L	L	Gravel is Decomposed Sandstone.
	8.3'-'					8.5	-	-	-	-	
10	S-3 10.0'- 12.0'	12	24 9 11 9		SC	Medium dense, Brownish yellow Clayey SAND with Gravel, moist (SC)	-	L	L	L	
1750						13.5					
15	S-4 15.0'- 17.0'	2	7 5 6 7		GC	Medium dense, Brownish yellow Clayey GRAVEL, wet (GC)	-	-	-	-	Gravel is Decomposed Sandstone.
						18.5					

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
10/19/16	7:45	-	30.0	37.0	8.3
10/20/16	7:45	-	30.0	115.0	85.55

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-I80-1**

Field Test Legend: Dilatancy: N - None S - Slow R - Rapid; Toughness: L - Low M - Medium H - High; Plasticity: NP - Non-Plastic L - Low M - Medium H - High; Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

SOIL BORING LOG
(continued)

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	S-5 20.0'-22.0'	13	6 6 11 8		SC	Medium dense, Reddish brown Clayey SAND with Gravel, moist (SC)	-	L	L	-	
1740											
25	S-6 25.0'-27.0'	10	20 16 21 10		SC	Dense, Reddish brown Clayey SAND with Gravel, moist (SC)	-	L	L	-	
30	S-7 30.0'-32.0'	16	9 11 17 10		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	-	-	-	
1730											
35	S-8 35.0'-37.0'	9	10 8 14 13		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	-	
40	S-9 40.0'-42.0'	14	10 14 14 14		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SC) 41' - 41.2' medium to fine grained Sandstone fragments	-	-	-	-	
1720											
45	S-10 45.0'-47.0'	17	13 13 16 22		SC	Medium dense, Reddish brown Clayey SAND with Gravel, trace Cobble fragments, wet (SC)	-	L	L	L	

NOTES:

PROJECT NO.: 353754

BORING NO.: B-I80-1

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

SOIL BORING LOG
(continued)

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
50	S-11 50.0'-52.0'	18	9 21 47 61/6"		SC	Very dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	-	
1710											
55	S-12 55.0'-57.0'	11	11 50/5"		SC	Very dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	-	-	-	Refusal at 55.9 feet BGS. Gravel is angular to rounded Decomposed Sandstone and Siltstone.
60	S-13 60.0'-62.0'	17	10 13 26 21		SC	Dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	-	
1700											
						63.5					
65	S-14 65.0'-67.0'	22	17 20 25 24		CL	Hard, Reddish brown Sandy CLAY, wet (CL)	-	L	L	M	
70	S-15 70.0'-72.0'	21	12 18 28 28		CL	Hard, Reddish brown Sandy CLAY with Gravel, wet (CL)	-	L	L	M	
1690											
75	S-16	15	28		CL	Hard, Reddish brown Lean CLAY with Gravel and Sand, moist (CL)	-	M	M	M	

NOTES:

PROJECT NO.: 353754

BORING NO.: B-I80-1

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

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SOIL BORING LOG
(continued)

BORING NO.: **B-I80-1**
Page **4** of **4**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	**Visual - Manual Identification & Description** (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	75.0'-77.0'		40 50/3"								
80						80.0 Top of Rock at 80 feet BGS. See Rock Coring Log.					
1680											
85											
90											
1670											
95											
100											
1660											

NOTES:

PROJECT NO.: **353754**

BORING NO.: **B-I80-1**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

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CORE BORING LOG

BORING NO.: **B-I80-1**
Page **1** of **2**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate 80, Carbon County, Pennsylvania	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jonathan Nelson
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	October 18, 2016 at 11:00 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	October 19, 2016 at 1:50 pm

Elevation: 1762 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 450 feet North of I-80 **Coord.: N:** 41.081977 **E:** -75.659638

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983 **Rig Make & Model:** CME-750X **Drilling Method:** Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
	1.50	80.0							MUDSTONE, Reddish brown, medium to fine grained, completely weathered, very weak, extremely close to very close spaced discontinuities 80' - 85' Highly Fractured zone								Rig chatter from 80 to 100 feet BGS.
	1.30																
1680	1.70		R-1	28 47%	0 0%	R1	C			82.00	J	0	U,Sm	DE	VW	SI	
	2.10																
	2.20	85.0															
85	1.70	85.0							Pebbly MUDSTONE, Reddish brown to brownish yellow, medium to fine grained, highly weathered, weak, extremely close to close spaced discontinuities 85' - 90' Highly Fractured zone								Loss of water from 85.5 to 85.7 feet BGS.
	2.60									86.20	J	18	S,Sm	DG	MW	SI	
	2.20		R-2	55 92%	4 7%	R2	H			87.00	J	36	S,R	DG	MW	SI	
	2.50									88.50	J	18	U,Sm	DG	W	SI	
	3.00	90.0								89.40	B	36	U,Sm	DG	MW	SI	
90	3.50	90.0							Pebbly MUDSTONE, Reddish brown to brownish yellow, medium to fine grained, highly weathered, weak, extremely close to close spaced discontinuities	90.40	J	15	U,Sm	DS	MW	N	
	3.90								91.7' - 92.6' Vertical Fracture								
1670	4.10		R-3	56 93%	4 7%	R2	H			92.40	J	40	U,R	DS	MW	SI	
	4.50									93.50 93.70	J B	39 45	U,R U,Sm	DG DS	MW MW	SI N	
	4.00	95.0															
95	3.10	95.0							Pebbly MUDSTONE, Reddish brown to olive gray, medium to fine grained, highly weathered, weak, extremely close to close spaced discontinuities 95' - 100' Highly Fractured zone								
	4.70									95.90	B	28	U,R	DG	MW	SI	
	5.20		R-4	60 100%	0 0%	R2	H			97.00	J	83	P,R	DS	T	N	
	4.50									98.50	B	17	P,Sm	DS	O	N	
	4.70	100.0								99.20	J	27	U,Sm	DG	O	Fe	
									100.0								

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
10/19/16	7:45	-	30.0	37.0	8.3
10/20/16	7:45	-	30.0	115.0	85.6

Notes:

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CORE BORING LOG
(continued)

BORING NO.: **B-I80-1**
Page **2** of **2**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.30	100.0							Pebbly SILTSTONE, Olive gray to reddish brown, medium to fine grained, highly weathered, weak, extremely close to close spaced discontinuities 100' - 105' Highly Fractured zone	100.70	J	10	U,Sm	DG	MW	Fe	Loss of water from 100.5 - 100.6 feet BGS.
	4.50									101.30	B	25	U,Sm	DG	MW	Fe	
1660	5.20		R-5	60 100%	4 7%	R2	H			102.50	J	25	S,Sm	DS	MW	N	
	4.10									103.40	J	48	U,Sm	DS	MW	Fe	
	5.10	105.0								103.80	J	30	U,Sm	DS	T	SI	
105	4.10	105.0							Pebbly SILTSTONE, Olive gray to reddish brown, medium to fine grained, highly weathered, weak, extremely close to close spaced discontinuities 105' - 110' Highly Fractured zone	105.40	J	16	U,Sm	DS	O	Fe	
	5.50									106.20	J	7	U,Sm	DS	MW	Fe	
	4.70		R-6	58 97%	8 13%	R2	H			107.30	B	70	U,Sm	DG	MW	SD	
										107.90	F	89	U,R	DS	O	N	
	6.50									108.70	J	49	U,Sm	DS	O	Fe	
	4.30	110.0															
110	5.70	110.0							Pebbly SILTSTONE, Olive gray to reddish brown, medium to fine grained, highly weathered, weak, extremely close to close spaced discontinuities 110' - 115' Highly Fractured zone	110.30	J	54	U,Sm	DS	O	Fe	Partly Conglomerate.
	5.10																
1650	6.70		R-7	52 87%	4 7%	R2	H			112.20	J	69	U,Sm	DS	VW	Fe	
	5.10									113.10	J	44	U,Sm	DS	O	Fe	
										113.90	J	13	U,Sm	DS	MW	N	
	5.20	115.0								114.50	J	51	P,Sm	DE	VW	N	
115									115.0 End of Boring at 115 feet BGS. Borehole grouted with cement and bentonite hole plug.								
120																	
1640																	
125																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-I80-1**

Figure B-I80-1.1
B-I80-1 Box 1 Runs 1-4 Dry

Figure B-I80-1.2
B-I80-1 Box 1 Runs 1-4 Wet

MOTT MACDONALD	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I80-1

Figure B-I80-1.3
B-I80-1 Box 2 Runs 5-7 Dry

Figure B-I80-1.4
B-I80-1 Box 2 Runs 5-7 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I80-1

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SOIL BORING LOG

BORING NO.: **B-I80-2**
Page **1** of **4**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate 80, Carbon County, Pennsylvania	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jonathan Nelson
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	October 13, 2016 at 9:15 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	October 18, 2016 at 9:00 am

Elevation: 1764 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 90 feet North of I-80 **Coord.:** **N:** 41.081137 **E:** -75.659037 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type
☐ Safety
☐ Doughnut
☑ Automatic
☐ _____

Drilling Fluid
☐ Bentonite
☐ Polymer
☑ Water
☐ None

Drill Rod Size:
Casing Advance
Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	16	1 2 2 4			0.5 Top (6") TOPSOIL with roots	-	L	L	L	
					ML	Bottom (18") Soft, Yellowish red SILT, moist (ML)					
1760											
5	S-2 5.0'- 7.0'	19	7 9 15 16		ML	Very stiff, Yellowish red SILT with Gravel, moist (ML)	-	L	L	L	
						8.5					
10	S-3 10.0'- 12.0'	10	6 5 7 9		SC	Medium dense, Yellowish red Clayey SAND with Gravel, wet (SC)	-	L	L	L	
						13.5					
1750											
15	S-4 15.0'- 17.0' 15.5'-'	1	50/3"		GC	Very dense, Yellowish red Clayey GRAVEL, wet (GC) Boulders present	-	-	-	-	
							-	-	-	-	Rig chatter at 15.5 feet BGS.
						18.5					

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
10/17/16	8:00	-	95.0	115.0	37.2
10/18/16	8:30	-	95.0	160.0	111

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-I80-2**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

SOIL BORING LOG
(continued)

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	S-5 20.0'-22.0'	13	9 9 14 29		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SM)	-	L	L	L	
1740											
25	S-6 25.0'-27.0'	12	12 11 18 14		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SM)	-	L	L	L	
30	S-7 30.0'-32.0'	13	9 9 12 12		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SM)	-	L	L	L	
						33.5					
1730											
35	S-8 35.0'-37.0'	6	7 50/2"		GC	Very dense, Reddish brown Clayey GRAVEL, wet (GM)	-	L	L	L	
						38.5					
40	S-9 40.0'-42.0'	15	13 10 14 19		SC	Medium dense, Yellowish red Clayey SAND with Gravel, wet (SC)	-	-	-	-	
1720											
45	S-10 45.0'-47.0'	19	13 13 19 18		SC	Dense, Reddish brown Clayey SAND with Gravel, trace cobble fragments, wet (SC)	-	L	L	L	

NOTES:

PROJECT NO.: 353754

BORING NO.: B-I80-2

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

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SOIL BORING LOG
(continued)

BORING NO.: **B-I80-2**
Page **3** of **4**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
50	S-11 50.0'-52.0'	16	17 14 34 34		SC	Dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	L	
						53.5					
1710											
55	S-12 55.0'-57.0'	22	10 28 21 22		CL	Hard, Yellowish red Sandy CLAY, trace Gravel, wet (CL)	-	M	M	M	PP = 3.8 tsf TV = 0.48 tsf
60	S-13 60.0'-62.0'	24	9 14 21 23		CL	Hard, Yellowish red Sandy CLAY, trace Gravel, wet (CL)	-	M	M	M	PP = 4.0 tsf TV = 0.66 tsf
1700											
65	S-14 65.0'-67.0'	24	11 14 19 20		CL	Hard, Yellowish red Sandy CLAY, trace Gravel, wet (CL)	-	M	M	M	PP = 3.5 tsf TV = 0.85 tsf
						68.5					
70	S-15 70.0'-72.0'	20	58 21 42 42		SC	Very dense, Yellowish red Clayey SAND with Gravel, wet (SC)	-	L	L	L	
1690											
75	S-16	23	9		SC	Dense, Yellowish red Clayey SAND with Gravel, wet (SC)	-	L	L	L	PP = 4.0 tsf

NOTES:

PROJECT NO.: **353754** BORING NO.: **B-I80-2**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-I80-2**
Page **4** of **4**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	75.0'-77.0'		13 19 20								TV = 0.76 tsf
80	S-17 80.0'-82.0'	17	43 42 61/5"		SC	Very dense, Dark brown to yellowish red Clayey SAND with Gravel, wet (SC)	-	L	L	L	
1680											
85	S-18 85.0'-87.0'	20	18 46 59 50/3"		SC	Very dense, Yellowish red Clayey SAND with Gravel, wet (SC)	-	L	L	L	PP = 3.5 tsf
						88.5					
90	S-19 90.0'-92.0'	3	50/3"		GC	Very dense, Yellowish red Clayey GRAVEL with Sand, wet (GC)	-	L	L	-	Gravel is Decomposed Shale.
						93.5					
1670											
95	S-20 95.0'-97.0'	15	45 56/4"		CL	Hard, Yellowish red Lean CLAY with Sand, trace Gravel, wet (CL)	-	L	L	L	PP = 3.0 tsf
100						100.0 Top of Rock at 100 feet BGS. See Rock Coring Log.					

NOTES:

PROJECT NO.: **353754** BORING NO.: **B-I80-2**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

CORE BORING LOG

BORING NO.: **B-I80-2**
Page **1** of **3**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate 80, Carbon County, Pennsylvania	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jonathan Nelson
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	October 13, 2016 at 9:15 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	October 18, 2016 at 9:00 am

Elevation: 1764 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** 90 feet North of I-80 **Coord.: N:** 41.081137 **E:** -75.659037

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Horizontal Datum: NAD 1983 **Rig Make & Model:** CME-750X **Drilling Method:** Wireline

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
	2.00	100.0							SILTSTONE, Yellowish red to reddish brown, medium to fine grained, highly weathered, weak, extremely close to close spaced discontinuities 100' - 102.5' Highly Fractured zone								
	2.00																
	2.70		R-1	60 100%	0 0%	R2	H										
	3.00									103.00	J	19	U,Sm	DG	MW	ML	
										103.60	J	22	U,R	DS	MW	ML	
1660	5.70	105.0							105.0								
105	3.00	105.0							SANDSTONE, Olive gray to reddish brown, medium to fine grained, slightly weathered, strong, extremely close to moderately spaced discontinuities								Partly Conglomerate.
	2.70									106.10	J	0	P,Sm	DS	T	N	
	2.90		R-2	60 100%	50 83%	R4	SL										
	3.50									108.20	J	0	P,Sm	DS	MW	ML	
	3.50	110.0								109.20	J	22	U,Sm	FR	T	N	
110	3.00	110.0							SANDSTONE, Olive gray to reddish brown, medium to fine grained, slightly weathered, strong, extremely close to moderately spaced discontinuities								Partly Conglomerate.
	3.40									110.80	J	22	U,Sm	DS	O	ML	
										111.70	J	12	U,Sm	DS	O	ML	
	2.70		R-3	60 100%	40 67%	R4	SL			112.10	J	10	U,R	DS	PO	ML	
										112.60	J	10	U,Sm	DS	O	N	
	2.50									113.10 113.30	J J	9 10	U,Sm U,Sm	DS DS	O MW	N N	
1650	2.20	115.0								114.20	J	9	U,Sm	DS	O	N	
115	2.70	115.0							SANDSTONE, Olive gray to reddish brown, medium to fine grained, fresh, very strong, very close to moderately spaced discontinuities								Partly Conglomerate.
										115.60	J	4	P,Sm	DS	T	N	
										115.90	J	3	U,Sm	DS	T	SD	
	3.60									116.60	J	9	U,Sm	DS	T	SD	
										116.90	J	4	U,Sm	DS	T	SD	
	3.70		R-4	60 100%	54 90%	R4	FR			117.40	J	6	U,Sm	DS	T	N	
										118.00 118.20	B J	29 15	S,Sm U,Sm	DS FR	T T	L N	
	4.10																
	3.20	120.0								119.00	J	19	U,Sm	DS	T	SD	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
10/17/16	8:00	-	95.0	115.0	37.2
10/18/16	8:30	-	95.0	160.0	111.0

Notes:

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-I80-2**
Page **2** of **3**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath.	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
		120.0							SANDSTONE, Olive gray to reddish brown, medium to fine grained, slightly weathered, very strong, extremely close to moderately spaced discontinuities								Partly Conglomerate. Loss of water from 120 to 130 feet BGS.
	2.50									120.40	J	0	U,Sm	FR	T	N	
										120.80	J	3	U,Sm	DS	T	Fe	
	3.70																
										121.60	J	67	U,R	FR	MW	N	
	4.10		R-5	60 100%	49 82%	R4	SL			122.40	J	10	S,Sm	FR	O	L	
	4.20									123.40	J	0	U,Sm	DS	T	L	
1640										124.00	J	0	U,Sm	DS	O	L	
	3.80	125.0								124.60	J	6	U,Sm	FR	T	N	
125		125.0							SANDSTONE, Olive gray to reddish brown, medium to fine grained, moderately weathered, strong, extremely close to moderately spaced discontinuities 125' - 126.4' Highly Fractured zone								
	4.50									125.60	B	3	U,Sm	DS	O	N	
	2.40									126.40	B	10	U,Sm	DS	O	Fe	
	4.10		R-6	60 100%	22 37%	R4	M			127.70	J	7	U,Sm	FR	T	N	
	5.30									128.40	J	11	U,Sm	DS	T	Fe	
	7.10	130.0								129.40	J	14	U,Sm	DS	T	Fe	
130		130.0							SANDSTONE, Yellowish red to reddish brown, medium to fine grained, moderately weathered, strong, extremely close to close spaced discontinuities								Partly Conglomerate.
	4.20									130.40	J	8	U,Sm	DS	T	N	
										130.65	J	50	S,Sm	DS	MW	Fe	
	4.20									131.70	B	72	U,Sm	DS	MW	Fe	
	5.20		R-7	58 97%	9 15%	R4	M			132.50	B	3	U,Sm	DS	O	Fe	
										132.90	J	17	U,Sm	DS	W	N	
	3.40																
1630										134.00	J	3	U,Sm	FR	T	N	
	5.00	135.0							135.0	134.70	B	61	U,Sm	DS	O	Fe	
135		135.0							Sandy SILTSTONE, Olive gray to reddish brown, medium to fine grained, slightly weathered, strong, extremely close to moderately spaced discontinuities								
	3.10									135.70	J	36	U,Sm	DS	O	QZ	
										135.90	B	2	U,R	DS	O	Fe	
	5.20									136.50	J	26	U,Sm	FR	T	N	
	6.00		R-8	60 100%	42 70%	R4	SL			137.50	J	71	S,Sm	FR	O	N	
	3.70									138.30	B	11	U,R	FR	T	N	
	7.30	140.0								139.00	J	45	U,Sm	FR	T	N	
140		140.0							Sandy SILTSTONE, Olive gray to reddish brown, medium to fine grained, fresh, strong, close to moderately spaced discontinuities	140.00	J	3	U,Sm	FR	O	N	Partly Conglomerate.
	5.10									140.40	J	13	U,Sm	DS	O	N	
	4.15									141.10	J	25	U,Sm	FR	T	N	
	3.90		R-9	60 100%	53 88%	R4	FR			142.40	J	19	P,Sm	FR	T	N	
										142.90	J	20	U,Sm	FR	T	N	
	3.70																
1620										144.10	J	17	P,Sm	DS	T	N	
	3.20	145.0							145.0								
145		145.0															Partly Conglomerate.

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-I80-2**

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-I80-2**
Page **3** of **3**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00								SANDSTONE, Olive gray to reddish brown, medium to fine grained, slightly weathered, strong, extremely close to moderately spaced discontinuities	145.60	J	16	U,Sm	DS	T	N	
	5.70									146.40	J	7	U,Sm	FR	T	N	
	2.70		R-10	60 100%	43 72%	R4	SL			147.20	J	7	U,Sm	FR	T	N	
										147.90	J	0	U,Sm	FR	T	N	
	3.10									148.50	J	14	U,Sm	FR	T	N	
										148.90	J	8	U,Sm	FR	T	N	
	2.90	150.0								149.50	B	8	U,Sm	DS	T	Fe	
150		150.0							SANDSTONE with interbedded Siltstone, Olive gray, medium to fine grained, slightly weathered, strong, extremely close to moderately spaced discontinuities								
	5.15									150.30	J	27	U,Sm	FR	T	N	
										150.80	J	19	U,Sm	DS	O	N	
	5.40									151.40	B	49	U,Sm	DS	T	N	
										152.00	J	24	U,Sm	DS	MW	N	
	5.00		R-11	60 100%	32 53%	R4	SL			152.40	J	10	U,Sm	DS	O	Fe	
										153.00	B	29	S,Sm	FR	O	N	
	5.15																
1610										153.70	J	63	U,R	FR	T	N	
	5.20	155.0								154.30	J	26	U,Sm	FR	T	N	
155		155.0							Silty SANDSTONE, Olive gray to brown, medium to fine grained, slightly weathered, strong, extremely close to moderately spaced discontinuities								
	3.00									155.30	B	11	U,Sm	DS	T	N	
										155.60	J	29	U,Sm	DS	O	N	
	2.50									156.10	B	55	U,Sm	DS	T	L	
										156.40	J	43	U,Sm	FR	O	N	
	2.50		R-12	59 98%	20 33%	R4	SL			157.00	J	35	U,Sm	DS	MW	N	
										157.20	J	32	U,Sm	DS	MW	L	
	3.30									158.00	J	48	U,Sm	DS	O	L	
										158.90	B	25	U,R	DS	T	L	
	3.30	160.0								159.20	J	20	U,Sm	DS	T	L	
160									160.0 End of Boring at 160 feet BGS. Borehole grouted with cement and bentonite hole plug.								
1600																	
165																	
170																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-I80-2**

Figure B-I80-2.1
B-I80-2 Box 1 Runs 1-4 Dry

Figure B-I80-2.2
B-I80-2 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I80-2

Figure B-I80-2.3
B-I80-2 Box 2 Runs 5-8 Dry

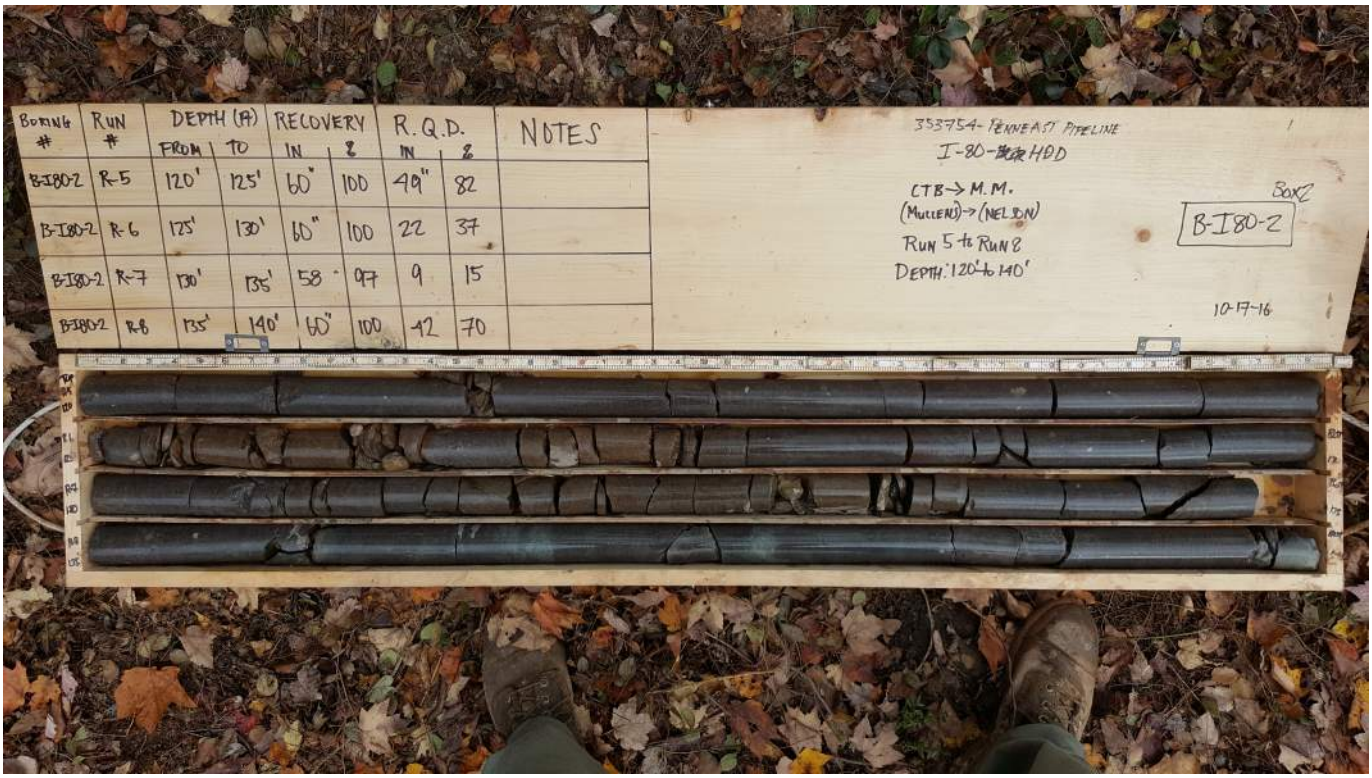

Figure B-I80-2.4
B-I80-2 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I80-2

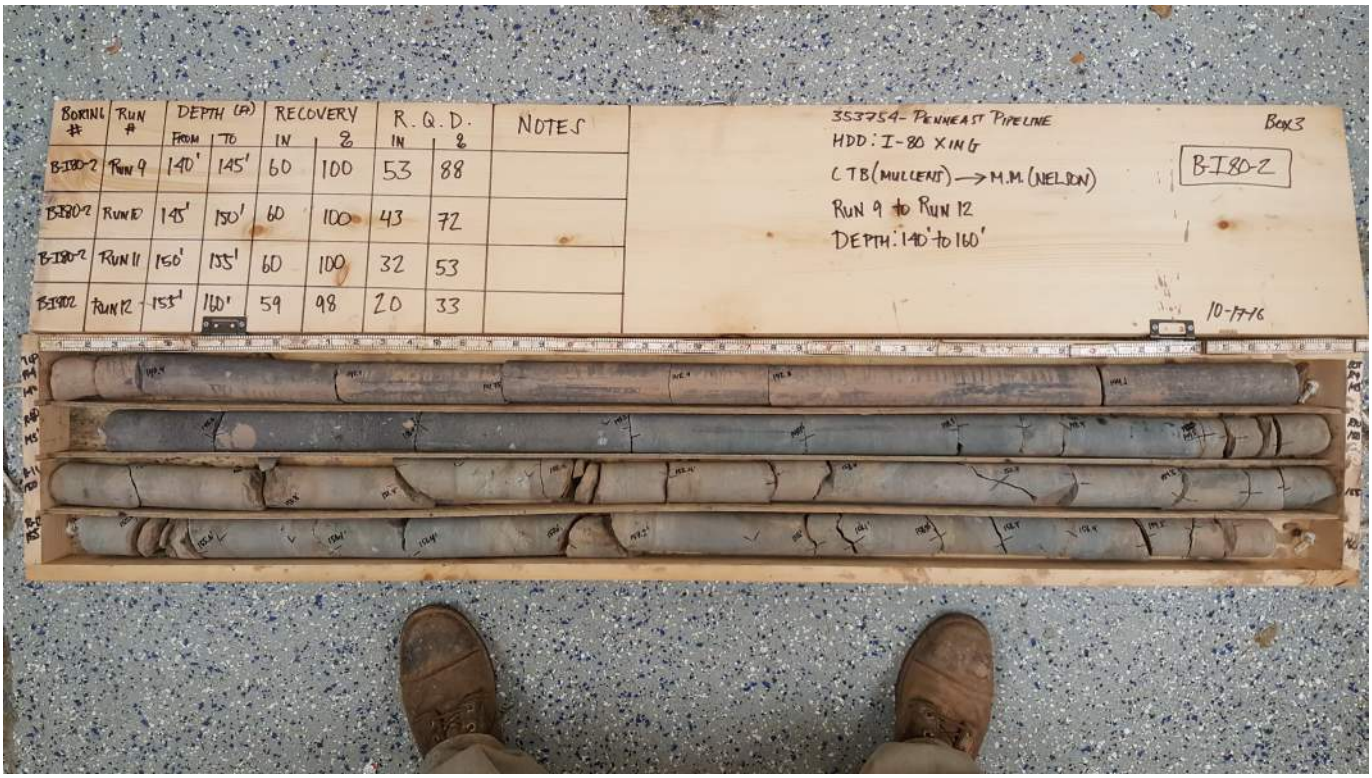

Figure B-I80-2.5
B-I80-2 Box 3 Runs 9-12 Dry

Figure B-I80-2.6
B-I80-2 Box 3 Runs 9-12 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I80-2

MOTT MACDONALD

SOIL BORING LOG

BORING NO.: **B-I80-3**
Page **1** of **4**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate 80, Carbon County, Pennsylvania	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	TJ Liveston
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	April 25, 2016 at 10:15 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	April 29, 2016 at 9:45 am

Elevation: 1756 ft. **Vertical Datum:** NAVD 1988

Boring Location: Off FFF Access Road and East of Buckeye Pipeline ROW.

Coord.: **N:** 41.079426 **E:** -75.65791

Horizontal Datum: NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type
☐ Safety
☐ Doughnut
☑ Automatic
☐ _____

Drilling Fluid
☐ Bentonite
☐ Polymer
☑ Water
☐ None

Drill Rod Size:

Casing Advance
Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	14	WOH 1 0 4		CL	Very soft, Brown Sandy CLAY, moist (CL)	-	-	-	-	PP=0.25 tsf. TV=N/A
						3.5					
5 1750	S-2 5.0'- 7.0'	4	8 28 50/4"		GC	Very dense, Reddish brown Clayey GRAVEL, wet (GC)	-	-	-	-	
						8.5					
10	S-3 10.0'- 12.0'	12	5 14 9 9		CL	Very stiff, Reddish brown Gravelly CLAY, wet (CL)	-	-	-	-	PP=2.0 tsf. TV=N/A
15 1740	S-4 15.0'- 17.0'	14	12 11 12 6		CL	Stiff, Reddish brown Gravelly CLAY, wet (CL)	-	-	-	-	PP=2.0 tsf. TV=N/A

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-I80-3**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-I80-3**
Page **2** of **4**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	S-5 20.0'-22.0'	16	1 1 3 4		CL	Soft, Reddish brown Gravelly CLAY, wet (CL)	-	-	-	-	PP=1.0 tsf. TV=N/A
25 1730	S-6 25.0'-27.0'	14	11 5 8 8		CL	Stiff, Reddish brown Gravelly CLAY, wet (CL)	-	-	-	-	PP=3.0 tsf. TV=N/A
30	S-7 30.0'-32.0'	8	4 12 15 12		CL	Very stiff, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=0.5 tsf. TV=N/A
35 1720	S-8 35.0'-37.0'	0	8 7 8 11		CL	No Recovery	-	-	-	-	
40	S-9 40.0'-42.0'	18	6 10 12 14		CL	Very stiff, Reddish brown Gravelly CLAY, wet (CL)	-	-	-	-	PP=2.5 tsf. TV=N/A
45 1710	S-10 45.0'-47.0'	8	16 34 37 18		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=2.5 tsf. TV=N/A

NOTES:

PROJECT NO.: **353754**

BORING NO.: **B-I80-3**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-I80-3**
Page **3** of **4**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
50	S-11 50.0'-52.0'	2	12 14 20 46		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=N/A TV=N/A
55 1700	S-12 55.0'-57.0'	18	9 16 24 22		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=4.0 tsf. TV=N/A
60	S-13 60.0'-62.0'	18	14 16 20 23		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=4.0 tsf. TV=N/A
65 1690	S-14 65.0'-67.0'	20	13 15 21 22		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=2.5 tsf. TV=N/A
70	S-15 70.0'-72.0'	20	13 19 27 42		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=4.0 tsf. TV=N/A
75	S-16	16	39		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=3.5 tsf.

NOTES:

PROJECT NO.: **353754**

BORING NO.: **B-I80-3**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-I80-3**
Page **4** of **4**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
1680	75.0'-77.0'		48 46 52								TV=N/A
80	S-17 80.0'-82.0'	6	25 28 40 58		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=3.5 tsf. TV=N/A
85 1670	S-18 85.0'-87.0'	6	32 48 50/5"		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=N/A TV=N/A
90	S-19 90.0'-92.0'	2	50/5"		CL	Hard, Reddish brown Gravelly CLAY with Sand, wet (CL)	-	-	-	-	PP=N/A TV=N/A
95 1660						95.0 Top of Rock at 95 feet BGS. See Rock Coring Log.					
100											

NOTES:

PROJECT NO.: **353754**

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NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD

CORE BORING LOG

BORING NO.: **B-I80-3**
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Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate 80, Carbon County, Pennsylvania	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	TJ Liveston
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	April 25, 2016 at 10:15 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	April 29, 2016 at 9:45 am

Elevation: 1756 ft. **Vertical Datum:** NAVD 1988

Boring Location: Off FFF Access Road and East of Buckeye Pipeline ROW.

Coord.: N: 41.079426 **E:** -75.65791

Horizontal Datum: NAD 1983

Rig Make & Model: CME-750X

Drilling Method: Wireline

Item	Casing	Core Barrel	Core Bit
Type	HW	NQ2	Imp. Diamond
Length (ft)	5	5	3.25
Inside Dia. (in.)	4	2.0	2.0

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS								
	3.10	95.0							SANDSTONE, Red, very fine to medium grained, highly weathered, weak, very close to close spaced discontinuities								
1660									95'-96.3' Highly Fractured zone								
	3.10																
									96.6'-100' Highly Fractured zone								
	3.10		R-1	37 62%	4 7%	R2	H										
	3.10																
	3.10	100.0															
100																	
	3.6	100.0							SANDSTONE, Red, very fine to medium grained, highly weathered, weak, very close to close spaced discontinuities								
									100'-100.4' Highly Fractured zone	100.60	J	15	U,R	DS	PO	Res	
									100.7'-101.1' Highly Fractured zone								
	3.6									101.25	J	0	U,R	DS	O	Res	
										101.40	J	0	S,R	DS	O	Res	
									101.8'-102' Highly Fractured zone	101.65	J	0	S,R	DS	O	Fgmts	
	3.6		R-2	45 75%	0 0%	R2	H			102.30	J	0	U,R	FR	PO	N	
									102.45'-102.7' Highly Fractured zone	102.60	J	0	U,R	DS	PO	Res	
										102.90	J	0	U,R	DS	O	Res	
										102.95	J	5	S,R	DS	O	Res	
	3.6									103.00	J	0	U,R	DS	O	Res	
									103.6'-103.8' Highly Fractured zone	103.50	J	0	P,R	FR	PO	N	
										103.75	J	0	P,R	FR	PO	N	
	3.6	105.0															
105																	
	9.00	105.0							SANDSTONE, Dark gray and red, very fine to medium grained, slightly weathered, medium strong, very close to close spaced discontinuities	105.30	J	0	S,R	FR	T	N	
									105'-105.1' Highly Fractured zone	105.40	J	0	U,R	FR	PO	N	
1650									105.6'-105.8' Highly Fractured zone	106.00	J	15	U,R	DS	PO	ST	
										106.20	J	0	P,R	DS	PO	ST	
	9.00								106.5'-106.7' Highly Fractured zone	106.30	J	0	U,R	DS	PO	ST	
										106.90	J	0	U,R	DS	PO	ST	
										107.20	J	5	S,R	DS	PO	ST	
	9.00		R-3	60 100%	24 40%	R3	SL			107.60	J	0	S,R	DS	O	Fgmts	
									108'-108.2' Highly Fractured zone								
	9.00																
										108.60	J	0	S,R	DS	PO	ST	
										108.65	J	0	S,R	DS	PO	ST	
										108.80	J	0	S,R	DG	O	Res	
	9.00	110.0								109.50	J	5	S,R	DS	PO	ST	
										109.70	J	5	U,R	DS	PO	ST	
110																	
	9.10	110.0							SANDSTONE, Gray to red, fine to medium grained, slightly weathered, medium strong, close spaced discontinuities	110.50	J	0	U,R	FR	T	N	
										110.65	J	0	U,R	FR	PO	N	
	9.10									111.30	J	0	U,R	FR	T	N	
										112.00	J	0	U,R	FR	T	N	
	9.10		R-4	60 100%	48 80%	R3	SL			112.50	J	0	U,R	FR	T	N	
										112.80	J	10	S,R	FR	T	N	
	9.10									113.25	J	10	S,R	DS	PO	Sa	
										113.80	J	10	S,R	FR	VT	N	
										114.10	J	5	U,R	FR	T	N	
	9.10	115.0								114.40	J	5	U,R	FR	T	N	
										114.60	J	5	S,R	FR	PO	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
		-			

Notes:

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
		115.0							SANDSTONE, Dark gray to red, fine to coarse grained, fresh, medium strong, very close to moderately spaced discontinuities	114.80	J	5	P,R	FR	T	N	
	9.00								Frequent conglomerates	115.70	J	5	S,R	FR	PO	Sa	
1640										116.10	J	0	P,R	FR	T	N	
	9.00																
										116.80	J	0	U,R	FR	T	Fgmts	
										116.90	J	5	U,R	FR	T	N	
	9.00		R-5	60 100%	48 80%	R3	FR			117.60	J	0	U,R	DG	PO	Res	
										117.90	J	0	U,R	FR	PO	Sa	
										118.10	J	10	U,R	DS	O	Sa	
	9.00																
										118.60	J	0	U,R	FR	T	N	
										119.00	J	0	U,R	FR	T	N	
										119.20	J	0	U,R	FR	T	N	
	9.00									119.40	J	30	U,R	FR	O	Sa	
		120.0															
120		120.0							SANDSTONE, Dark gray to red, fine to coarse grained, fresh, medium strong, very close to moderately spaced discontinuities	120.20	J	5	U,R	FR	PO	Sa	
	7.90								Conglomerates present	120.60	J	0	U,R	FR	T	N	
										120.90	J	5	U,R	FR	T	N	
	7.90																
										121.90	J	5	U,R	FR	T	N	
	7.90		R-6	60 100%	45 75%	R3	FR			122.40	J	0	U,R	DS	PO	ST	
										123.00	J	5	U,R	FR	VT	N	
										123.10	J	0	U,R	FR	VT	N	
	7.90																
										123.90	J	25	U,R	FR	PO	N	
										124.10	J	15	U,R	FR	PO	N	
	7.90									124.35	J	0	U,R	FR	T	N	
		125.0								124.43	J	5	U,R	FR	T	N	
125		125.0							SANDSTONE, Dark gray to red, fine to medium grained, fresh, medium strong, very close to medium spaced discontinuities	125.50	J	0	U,R	FR	PO	Sa	
	7.80																
1630																	
	7.80																
										127.10	J	0	S,R	FR	T	N	
										127.20	J	0	S,R	FR	T	N	
	7.80		R-7	60 100%	51 85%	R3	FR										
										128.20	J	0	U,R	FR	T	N	
										128.50	J	0	P,R	FR	T	N	
										128.80	J	0	U,R	FR	T	N	
	7.80									129.10	J	5	U,R	FR	T	N	
		130.0															
130		130.0							SANDSTONE, Dark gray to red, fine to medium grained, highly weathered, medium strong, very close to medium spaced discontinuities	130.25	J	0	U,R	DG	O	Sa	
	7.20								131.2'-131.3' Highly Fractured zone	130.70	J	20	U,R	FR	PO	Sa	
									131.3	131.00	J	0	U,R	FR	T	N	
	7.20								CONGLOMERATE, Grey, red and white, fine grained, fresh, medium strong, close to moderately spaced discontinuities	131.40	J	45	S,R	FR	T	N	
										131.90	J	0	S,R	FR	T	N	
										132.35	J	0	S,R	DG	O	N	
	7.20		R-8	60 100%	44 73%	R3	FR			132.80	J	0	U,R	FR	T	N	
									133.5	133.30	J	10	P,R	DS	T	ST	
	7.20									133.50	J	15	U,R	FR	O	Fgmts	
		135.0								134.50	J	10	U,R	FR	T	N	
135		135.0							SANDSTONE, Dark gray to red, fine to medium grained, fresh, medium strong, close to moderately spaced discontinuities	135.30	J	5	U,R	FR	PO	Fgmts	
	6.60									135.60	J	5	S,R	FR	O	Fgmts	
1620																	
	6.60																
										138.00	J	0	P,R	FR	T	N	
	6.60		R-9	60 100%	44 73%	R3	FR			138.30	J	0	S,R	FR	T	N	
										138.60	J	5	P,R	FR	T	N	
										139.00	J	0	S,R	FR	T	N	
	6.60									139.30	J	5	P,R	FR	VT	N	
		140.0								139.60	J	5	U,R	FR	T	N	
140		140.0							SANDSTONE, Dark gray to red, fine to medium grained, fresh, medium strong, very close to								

CORE BORING LOG
(continued)

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	6.50								moderately spaced discontinuities	140.30	J	0	U,R	FR	T	N	
										140.50	J	5	S,R	FR	PO	N	
	6.50									141.20	J	15	U,R	FR	T	N	
										141.25	J	15	U,R	FR	T	N	
	6.50		R-10	60 100%	43 72%	R3	FR			142.50	J	5	U,R	FR	PO	Fgmts	
	6.50									143.75	J	15	U,R	FR	O	Fgmts	
										144.00	J	30	S,R	FR	O	N	
	6.50									144.10	J	30	S,R	FR	O	N	
		145.0								144.50	J	20	U,R	FR	VT	N	
145										144.70	J	10	U,R	FR	T	N	
	7.00	145.0							SANDSTONE, Dark gray, fine to medium grained, fresh, medium strong, very close to moderately spaced discontinuities	145.50	J	0	P,R	DG	PO	Sa	
1610									145'-145.2' Highly Fractured zone	145.65	J	0	S,R	FR	PO	Sa	
									Pits presents	145.80	J	5	S,R	FR	PO	Sa	
	7.00									146.10	J	45	U,R	FR	PO	Sa	
										146.50	J	40	P,R	FR	T	N	
										146.80	J	10	U,R	FR	T	N	
	7.00		R-11	60 100%	40 67%	R3	FR			147.00	J	0	U,R	FR	T	N	
										147.60	J	5	U,R	FR	T	N	
	7.00									148.65	J	0	S,R	FR	VT	N	
										149.00	J	50	P,R	FR	T	Fgmts	
	7.00									149.10	J	5	S,R	FR	PO	Sa	
		150.0								149.50	J	40	S,R	FR	T	N	
150		150.0							SANDSTONE, Dark gray, fine to medium grained, fresh, medium strong, very close to moderately spaced discontinuities								
	6.90									151.20	J	5	S,R	FR	VT	N	
										151.40	J	5	U,R	FR	VT	N	
	6.90									151.90	J	40	S,R	FR	T	N	
			R-12	60 100%	54 90%	R3	FR			152.40	J	0	U,R	DG	O	Fgmts	
										152.80	J	0	S,R	FR	T	N	
	6.90									153.00	J	0	S,R	FR	O	Fgmts	
										153.75	J	5	S,R	FR	VT	N	
	6.90									154.60	J	0	S,R	FR	T	N	
		155.0															
155		155.0							SANDSTONE, Dark gray, fine to medium grained, fresh, medium strong, very close to moderately spaced discontinuities	155.20	J	40	P,R	DS	T	Fgmts	
	7.60									155.40	J	15	P,R	FR	T	N	
1600										155.60	J	15	P,R	FR	T	N	
	7.60									156.00	J	10	P,R	FR	T	N	
										156.80	J	55	P,R	FR	T	N	
	7.60		R-13	60 100%	45 75%	R3	FR			158.10	J	10	U,R	FR	T	N	
	7.60									159.00	J	0	U,R	FR	VT	N	
										159.30	J	10	U,R	FR	PO	N	
	7.60									159.60	J	5	S,R	FR	T	N	
		160.0															
160		160.0							SANDSTONE, Dark gray, fine to medium grained, fresh, medium strong, close to moderately spaced discontinuities	160.25	J	5	U,R	FR	T	N	
	8.00									160.60	J	185	S,R	FR	O	Fgmts	
										162.60	J	70	S,R	DS	PO	Sa	
	8.00		R-14	60 100%	51 85%	R3	FR			163.05	J	0	U,R	DG	O	Res	
	8.00																
		165.0															
165		165.0							SANDSTONE, Gray, fine to medium grained, fresh, medium strong, close to moderately spaced discontinuities	165.70	J	15	P,R	FR	T	N	
	8.00																

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	8.00									166.20	J	0	U,R	FR	T	N	
										166.80	J	15	U,R	FR	T	N	
	8.00		R-15	60 100%	58 97%	R3	FR										
	8.00									168.00	J	30	U,R	FR	T	N	
	8.00									169.30	J	5	S,R	FR	T	N	
		170.0								169.80	J	0	S,R	FR	PO	N	
170	7.60	170.0							SANDSTONE, Gray, fine to medium grained, fresh, medium strong, close to moderately spaced discontinuities								
	7.60									171.30	J	5	U,R	FR	T	N	
	7.60		R-16	60 100%	60 100%	R3	FR			172.50	J	5	U,R	FR	T	N	
	7.60																
	7.60									174.10	J	5	U,R	FR	T	N	
		175.0								174.50	J	5	U,R	FR	T	N	
175										174.85	J	5	U,R	FR	T	N	
	7.40	175.0							SANDSTONE, Gray, fine to medium grained, fresh, medium strong, close to wide spaced discontinuities								
1580										175.80	J	0	S,R	FR	T	N	
	7.40									176.20	J	15	U,R	FR	T	N	
	7.40		R-17	60 100%	58 97%	R3	FR										
	7.40																
	7.40									179.30	J	10	U,R	FR	T	N	
		180.0															
180	7.60	180.0							SANDSTONE, Gray, fine to medium grained, fresh, medium strong, close to wide spaced discontinuities								
	7.60									181.60	J	15	U,R	FR	VT	N	
	7.60		R-18	60 100%	60 100%	R3	FR			182.50	J	0	U,R	FR	T	N	
										182.90	J	0	U,R	FR	T	N	
	7.60																
	7.60									184.00	MB						
		185.0								184.60	MB						
185	7.30	185.0							SANDSTONE, Gray to red, fine to medium grained, fresh, medium strong, close to wide spaced discontinuities Pits and Vugs present								
1570										185.70	J	5	S,R	FR	T	N	
	7.30									186.40	J	5	U,R	FR	T	N	
										186.60	J	5	P,R	FR	T	N	
	7.30		R-19	60 100%	58 97%	R3	FR										
	7.30									188.40	J	5	U,R	FR	T	N	
	7.30																
		190.0								189.50	J	60	S,R	FR	T	N	
190	7.00	190.0							SANDSTONE, Gray to red, fine to medium grained, fresh, medium strong, close to moderately spaced discontinuities								
	7.00									191.30	J	5	U,R	FR	T	N	

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	7.00									192.10	J	10	S,R	FR	T	N	
	7.00		R-20	60 100%	57 95%	R3	FR			192.40	J	10	S,R	FR	T	N	
	7.00									193.50	J	5	U,R	FR	T	N	
										193.90	J	5	U,R	FR	T	N	
	7.00									194.30	J	5	U,R	FR	T	N	
		195.0															
195	8.30	195.0							SANDSTONE, Gray, fine to medium grained, fresh, strong, close to moderately spaced discontinuities	195.20	J	5	U,R	FR	T	N	
1560	8.30									196.10	J	10	U,R	FR	T	N	
	8.30		R-21	60 100%	56 93%	R4	FR			197.60	J	5	P,R	FR	T	N	
										197.80	J	40	P,R	FR	T	N	
	8.30																
	8.30	200.0								199.20	J	10	U,R	FR	T	N	
200	9.80	200.0							SANDSTONE, Gray, fine to medium grained, fresh, strong, close to moderately spaced discontinuities								
	9.80									201.50	J	10	U,R	FR	T	N	
	9.80		R-22	60 100%	60 100%	R4	FR			203.60	J	10	P,R	FR	T	N	
										203.70	J	0	S,R	FR	T	N	
	9.80									204.00	MB						
	9.80	205.0								204.70	MB						
205	9.80	205.0							SANDSTONE, Gray, fine to medium grained, fresh, strong, close to wide spaced discontinuities								
1550	9.80								206.3'-206.7' Vertical Infill	206.10	J	5	S,R	FR	VT	N	
										206.20	J	45	S,R	FR	VT	N	
	9.80		R-23	60 100%	50 83%	R4	FR										
	9.80									208.40	J	10	U,R	FR	T	N	
	9.80	210.0								209.20	J	15	P,R	FR	T	N	
										209.30	J	15	U,R	DG	PO	Res	
										209.60	J	5	P,R	FR	PO	Res	
210	10.80	210.0							SANDSTONE, Gray, fine to medium grained, slightly weathered, strong, very close to wide spaced discontinuities								
	10.80								211.7'-214.0' Vertical Fracture								
	10.80		R-24	60 100%	57 95%	R4	SL			212.10	J	0	U,R	DS	PO	Sa	
										212.40	J	5	U,R	DG	PO	Sa	
										212.90	J	55	U,R	DS	PO	ST	
	10.80									213.30	J	60	U,R	DS	PO	Sa	
										213.70	J	10	P,R	DG	O	Sa	
	10.80	215.0								214.60	J	5	U,R	FR	PO	N	
215	12.10	215.0							SANDSTONE, Gray, fine to medium grained, fresh, strong, very close to wide spaced discontinuities								
1540	12.10																

MOTT MACDONALD M M

CORE BORING LOG
(continued)

BORING NO.: **B-I80-3**
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Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	12.10		R-25	60 100%	60 100%	R4	FR										
	12.10																
	12.10	220.0							220.0								
220									End of Boring at 220 feet BGS. Borehole grouted with cement and bentonite hole plug.								
225																	
1530																	
230																	
235																	
1520																	
240																	

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-I80-3**

Figure B-I80-3.1
B-I80-3 Box 1 Runs 1-4 Dry

Figure B-I80-3.2
B-I80-3 Box 1 Runs 1-4 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I80-3

Figure B-I80-3.3
B-I80-3 Box 2 Runs 5-8 Dry

Figure B-I80-3.4
B-I80-3 Box 2 Runs 5-8 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I80-3

Figure B-I80-3.5
B-I80-3 Box 3 Runs 9-12 Dry

Figure B-I80-3.6
B-I80-3 Box 3 Runs 9-12 Wet

Figure B-I80-3.7
B-I80-3 Box 4 Runs 13-16 Dry

Figure B-I80-3.8
B-I80-3 Box 4 Runs 13-16 Wet

Figure B-I80-3.9
B-I80-3 Box 5 Runs 17-20 Dry

Figure B-I80-3.10
B-I80-3 Box 5 Runs 17-20 Wet

Figure B-I80-3.11
B-I80-3 Box 6 Runs 21-24 Dry

Figure B-I80-3.12
B-I80-3 Box 6 Runs 21-24 Wet

Figure B-I80-3.13
B-I80-3 Box 7 Run 25 Dry

Figure B-I80-3.14
B-I80-3 Box 7 Run 25 Wet

MOTT MACDONALD M M

SOIL BORING LOG

BORING NO.: **B-I80-4**
Page **1** of **4**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate 80, Carbon County, Pennsylvania	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jonathan Nelson/Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	December 28, 2016 at 10:30 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	December 29, 2016 at 9:20 am

Elevation: 1758.2 ft. **Vertical Datum:** NAVD 1988 **Boring Location:** Approximately 40 feet South of staked location **Coord.:** **N:** 41.074328 **E:** -75.654571 **Horizontal Datum:** NAD 1983

Item	Casing	Sampler	Core Barrel
Type	HW	SS	NQ2
Length (ft)	5	2	5
Inside Dia. (in.)	4	1.375	2.0
Hammer Wt. (lb.)	140	140	-
Hammer Fall (in.)	30	30	-

Rig Make & Model: CME-750X

☐ Truck ☐ Tripod ☐ Cat-Head
☑ ATV ☐ Geoprobe ☑ Winch
☐ Track ☐ Air Track ☑ Roller Bit
☐ Skid ☐ _____ ☐ Cutting Head

Hammer Type: ☐ Safety ☐ Doughnut ☑ Automatic ☐ _____

Drilling Fluid: ☐ Bentonite ☐ Polymer ☑ Water ☐ None

Drill Rod Size:

Casing Advance: Mud Rotary

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Group Symbol	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks
	S-1 0.0'- 2.0'	8	5 5 7 3		SM	0.3 3" - TOPSOIL Bottom (3") - Medium dense, Brownish yellow Silty SAND, with Gravel, moist (SM)	-	-	-	-	
						3.5					
5 1750	S-2 5.0'- 7.0'	9	7 8 19 10		SC	Medium dense, Reddish brown Clayey SAND, trace Gravel, wet (SC)	-	L	L	L	Gravel is Sandstone fragments.
10	S-3 10.0'- 12.0'	13	6 8 12 9		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	L	
15 1740	S-4 15.0'- 17.0'	12	6 6 9 13		SC	Medium dense, Reddish brown Clayey SAND, trace Gravel, wet (SC)	-	L	L	L	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water

Sample Type

O Open End Rod
T Thin-Wall Tube
U Undisturbed Sample
S Split Spoon Sample
G Geoprobe

Notes:

PP = Pocket Penetrometer
TV = Torvane

Boring No.: **B-I80-4**

Field Test Legend:
Dilatancy: N - None S - Slow R - Rapid
Toughness: L - Low M - Medium H - High
Plasticity: NP - Non-Plastic L - Low M - Medium H - High
Dry Strength: N - None L - Low M - Medium H - High VH - Very High

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-I80-4**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	S-5 20.0'-22.0'	9	5 7 8 8		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	L	
25	S-6 25.0'-27.0'	9	12 11 13 13		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	M	Gravel is Sandstone fragments.
1730											
30	S-7 30.0'-32.0'	8	23 22 23 12		SC	Dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	L	
35	S-8 35.0'-37.0'	13	6 7 13 10		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	M	M	M	
1720											
40	S-9 40.0'-42.0'	11	11 12 12 14		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	L	
45	S-10 45.0'-47.0'	15	12 8 9 11		SC	Medium dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	M	

NOTES:

PROJECT NO.: **353754**

BORING NO.: **B-I80-4**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-I80-4**
Page **3** of **4**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
1710											
50	S-11 50.0'-52.0'	15	12 18 21 18		SC	Dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	M	PP = N/A TV = N/A
55	S-12 55.0'-57.0'	14	22 15 18 17		SC	Dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	L	Gravel is Sandstone fragments.
1700											
60	S-13 60.0'-62.0'	12	56 18 23 17		SC	Dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	M	Boulder from 60 to 61 feet BGS.
65	S-14 65.0'-67.0'	16	14 12 28 42		SC	Dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	M	Cobbles from 66.5 to 66.8 fee BGS.
1690											
70	S-15 70.0'-72.0'	19	14 16 23 24		SC	Dense, Reddish brown Clayey SAND with Gravel, wet (SC)	-	L	L	M	
75	S-16	18	17		SC	Very dense, Reddish brown Clayey SAND, trace Gravel, wet (SC)	-	L	L	M	

NOTES:

PROJECT NO.: **353754**

BORING NO.: **B-I80-4**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

MOTT MACDONALD M M

SOIL BORING LOG
(continued)

BORING NO.: **B-I80-4**
Page **4** of **4**

Depth/ Elev. (ft)	Sample No. / Interval (ft)	Rec. (in)	Sample Blows per 6"	Stratum Graphic	USCS Symbol Group	Visual - Manual Identification & Description (Density/consistency, color, Group Name, constituents, particle size, structure, moisture, optional descriptions, geologic interpretation, Symbol)	Field Tests: Dilatancy	Toughness	Plasticity	Dry Strength	Remarks*
	75.0'-77.0'		28 34 32								
1680						78.5					
80	S-17 80.0'-82.0'	14	13 15 27 27		CL	Hard, Reddish brown Sandy CLAY with Gravel, wet (CL)	-	M	M	M	PP = N/A TV = N/A
85	S-18 85.0'-87.0'	4	31 75 >50/2"		CL	Hard, Reddish brown Sandy CLAY, wet (CL)	-	M	M	M	PP = N/A TV = N/A
1670						88.5					
90	S-19 90.0'-92.0'	14	26 71 64/4"		ML	Hard, Reddish brown Sandy SILT, wet (ML)	-	L	L	H	
						93.5					
95	S-20 95.0'-97.0'	5	70/5"		GC	Very dense, Reddish brown Clayey GRAVEL, wet (GC)	-	L	L	L	
1660											
100						100.0 Top of Rock at 100 feet BGS. See Rock Core Log.					

NOTES:

PROJECT NO.: **353754**

BORING NO.: **B-I80-4**

NOTES: 1.) "ppd" denotes soil sample average diametral pocket penetrometer reading. 2.) "ppa" denotes soil sample average axial pocket penetrometer reading.
3.) Maximum Particle Size is determined by direct observation within limitations of sampler size. 4.) Soil identifications and field tests based on visual-manual methods per ASTM D2488.

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CORE BORING LOG

BORING NO.: **B-I80-4**
Page **1** of **5**

Project:	PennEast Pipeline Project	**Project No.:**	353754
Location:	Interstate 80, Carbon County, Pennsylvania	**Project Mgr:**	Vatsal Shah
Client:	PennEast Pipeline	**Field Eng. Staff:**	Jonathan Nelson/Bernard Cortes
Drilling Co.:	Craig Test Boring Co., Inc.	**Date/Time Started:**	December 28, 2016 at 10:30 am
Driller/Helper:	Paul Mullins /Nick Beehler	**Date/Time Finished:**	December 29, 2016 at 9:20 am

Elevation: 1758.2 ft.		**Vertical Datum:** NAVD 1988		**Boring Location:** Approximately 40 feet South of staked location	**Coord.: N:** 41.074328 **E:** -75.654571
Item	**Casing**	**Core Barrel**	**Core Bit**		
Type	HW	NQ2	Imp. Diamond	**Horizontal Datum:** NAD 1983	**Drilling Method:** Wireline
Length (ft)	5	5	3.25	**Rig Make & Model:** CME-750X	
Inside Dia. (in.)	4	2.0	2.0		

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec (in. / %)	RQD (in / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
									SEE TEST BORING LOG FOR OVERBURDEN DETAILS		(See Legend for Rock Description System)						
	3.50	100.0							SILTSTONE, Reddish brown to greenish gray, fine grained, highly weathered, weak, extremely close to moderately spaced discontinuities								
	3.30																
	3.40		R-1	57 95%	14 23%	R2	H			102.10	J	0	U,Sm	DG	VW	ML	
	3.10									103.70	J	14	U,Sm	DG	O	ML	
	3.30	105.0								104.30	J	14	U,Sm	DS	T	N	
105	3.80	105.0							SILTSTONE, Reddish brown to greenish gray, fine to medium grained, slightly weathered, medium strong, close to moderately spaced discontinuities	105.90	J	11	U,Sm	DS	T	N	
	3.70									106.40	J	14	U,Sm	FR	T	N	
	3.50		R-2	60 100%	49 82%	R3	SL			107.40	J	17	U,Sm	DS	O	N	
1650	3.50									108.60	J	17	U,Sm	DS	O	N	
	3.10	110.0								109.70	J	22	U,Sm	DS	O	N	
110	3.30	110.0							SILTSTONE, Reddish brown fine to medium grained, slightly weathered, medium strong, close to moderately spaced discontinuities	111.00	J	35	U,Sm	FR	T	N	
	3.30									111.20	J	33	U,Sm	DS	PO	Fe	
	3.60		R-3	60 100%	39 65%	R3	SL			112.30	S	71	U,Sm	DS	PO	N	
	3.10									113.60	J	6	S,Sm	DS	MW	N	
	3.00	115.0								114.40	J	10	U,R	DS	O	ML	
115	3.10	115.0							115.0 SANDSTONE, Reddish brown to greenish gray, fine grained, slightly weathered, medium strong, close to moderately spaced discontinuities	115.80	J	7	U,Sm	DS	O	ML	
	3.20									116.60	J	21	U,Sm	FR	T	N	
	3.00		R-4	60 100%	43 72%	R3	SL			117.30	J	26	U,Sm	DS	PO	N	
1640	2.80									118.40	J	18	P,R	DS	PO	ML	
	3.10	120.0								119.00	J	7	U,Sm	DS	PO	N	

Water Level Data

Date	Time	Elapsed Time (hr)	Depth in feet to: Bot. of Casing	Bottom of Hole	Water
		-			

Notes:

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities Type	Dip	Rgh	Wea	Aper	Infill	Remarks
		120.0							SANDSTONE, Reddish brown, fine grained, slightly weathered, strong, close to moderately spaced discontinuities								
	2.70									120.60	J	10	U,Sm	FR	PO	N	
	2.90									121.30	J	10	U,Sm	FR	T	N	
	3.10		R-5	60 100%	42 70%	R4	SL			122.30	J	15	U,Sm	FR	T	N	
	2.90									123.30	J	10	U,Sm	FR	PO	N	
	3.00	125.0								124.10	J	7	U,Sm	FR	T	N	
125		125.0							SANDSTONE, Reddish brown, fine grained, slightly weathered, strong, close to moderately spaced discontinuities								
	3.20									125.70	J	85	S,Sm	FR	MW	N	
	3.00									126.30	J	0	U,Sm	FR	O	N	
	3.20		R-6	60 100%	47 78%	R4	SL			126.90	J	10	U,Sm	FR	T	N	
1630										127.70	J	15	U,Sm	FR	T	N	
	2.90									128.50	J	18	P,Sm	FR	O	N	
	3.30	130.0								129.30	J	5	P,R	FR	O	N	
130		130.0							SANDSTONE, Reddish brown to greenish gray, fine to medium grained, slightly weathered, strong, close to moderately spaced discontinuities								
	3.60																
	3.00									131.40	J	0	U,Sm	FR	T	N	
	3.00		R-7	60 100%	47 78%	R4	SL										
	3.10									133.00	J	11	U,Sm	FR	T	N	
										133.70	J	0	U,Sm	FR	T	N	
	2.90	135.0								134.40	J	10	U,Sm	FR	T	N	
135		135.0							SANDSTONE, Reddish brown to greenish gray, fine to medium grained, slightly weathered, strong, close to moderately spaced discontinuities								
	2.90									135.80	J	7	P,Sm	FR	O	N	
	3.10																
	3.10		R-8	60 100%	44 73%	R4	SL										
1620										138.10	J	10	U,Sm	FR	MW	N	
	3.00																
										138.90	J	10	S,Sm	FR	O	N	
	3.30	140.0								139.40	J	11	U,Sm	FR	O	N	
140		140.0							SANDSTONE, Reddish brown to greenish gray, slightly weathered, strong, close to moderately spaced discontinuities								
	2.90																
	3.10									141.00	J	9	U,Sm	FR	O	N	
										141.40	J	12	U,Sm	FR	PO	N	
	3.00		R-9	57 95%	42 70%	R4	SL			142.30	J	5	U,Sm	FR	T	N	
	3.00									143.20	J	22	U,Sm	FR	O	N	
	3.10	145.0								144.00	J	22	U,R	FR	T	N	
145		145.0															

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	**Visual Identification, Description and Remarks** (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.10								SANDSTONE, Greenish gray, fine to medium grained, slightly weathered, strong, close to moderately spaced discontinuities	145.80	J	25	U,R	FR	O	N	Increased drilling thrust.
	3.30									146.50	S	75	U,Sm	FR	MW	N	
	3.20		R-10	60 100%	53 88%	R4	SL										
1610	2.90																
	2.70	150.0								149.00	J	5	U,Sm	FR	PO	N	
150	2.90	150.0							SANDSTONE, Greenish gray to reddish brown, fine to medium grained, slightly weathered, strong, close to moderately spaced discontinuities								
	3.10									151.60	J	16	P,Sm	FR	MW	N	
	2.70		R-11	60 100%	59 98%	R4	SL										
	2.50									153.40	J	6	U,R	FR	PO	N	
	2.60	155.0								154.60	J	30	U,Sm	FR	T	N	
155	2.90	155.0							SANDSTONE, Greenish gray to reddish brown, fine to medium grained, slightly weathered, strong, extremely close to moderately spaced discontinuities								
	2.40									156.20	S	25	S,Sm	FR	O	N	
	2.50		R-12	60 100%	44 73%	R4	SL										
1600	2.50																
	2.70	160.0								159.00	J	30	U,Sm	FR	PO	N	
160	2.90	160.0							SANDSTONE, Reddish brown to greenish gray, fine to medium grained, slightly weathered, strong, close to moderately spaced discontinuities	160.30	J	24	U,R	FR	O	N	
	2.60									161.00	J	32	U,R	FR	O	N	
										161.70	J	22	U,Sm	FR	PO	N	
	2.50		R-13	60 100%	42 70%	R4	SL			162.70	J	0	U,R	FR	O	N	
										163.00	J	15	U,R	FR	T	N	
	2.70																
	2.80	165.0								164.20	J	16	U,R	FR	PO	N	
165	2.90	165.0							SANDSTONE, Reddish brown to greenish gray, fine to medium grained, slightly weathered, strong, close to moderately spaced discontinuities								
	2.70									166.20	J	14	P,Sm	FR	O	N	
	2.80		R-14	60 100%	59 98%	R4	SL			167.40	J	25	U,Sm	FR	T	N	
1590	2.60																
	2.60	170.0															
170	2.00	170.0							SANDSTONE, Reddish brown, fine to medium grained, fresh, medium strong, close spaced discontinuities	170.40	MB						

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
										170.70	J	10	P,Sm	FR	T	N	
										171.10	J	35	P,R	FR	T	N	
	2.00									171.60	J	30	P,Sm	FR	T	N	
	2.00		R-15	60 100%	57 95%	R3	FR			172.20	J	30	P,R	FR	PO	N	
	2.00									173.00	J	20	P,R	FR	PO	N	
										173.50	J	20	P,R	FR	PO	N	
	2.00	175.0								174.20	J	20	P,Sm	FR	T	N	
175										174.70	MB						
	4.00	175.0							SANDSTONE, Reddish brown, fine to medium grained, fresh, very strong, very close to close spaced discontinuities 175' - 175.5' Highly Fractured zone 176.5' - 176.6' Highly Fractured zone								Rig chatter from 175 to 180 feet BGS. Slower coring rates from 175 to 190 feet BGS.
	5.00									175.80	MB						
										176.00	MB						
	5.00		R-16	60 100%	46 77%	R5	FR			177.40	J	20	P,Sm	FR	T	N	
1580										178.00	J	20	P,R	FR	T	N	
	5.00									178.50	J	20	P,R	FR	T	N	
										179.20	J	30	P,R	FR	T	N	
	5.00	180.0								179.80	MB						
180		180.0							SANDSTONE, Reddish brown, fine to medium grained, fresh, very strong, very close to close spaced discontinuities								
	4.00									180.50	J	20	P,R	FR	PO	N	
	5.00									181.30	J	20	P,R	FR	PO	N	
										181.80	J	20	P,R	FR	T	N	
	5.00		R-17	60 100%	52 87%	R5	FR			182.60	J	20	P,R	FR	T	N	
	5.00									183.50	J	20	P,R	FR	T	N	
										183.90	J	20	P,R	FR	T	N	
	5.00	185.0								184.30	J	20	P,R	FR	T	N	
										184.70	J	20	P,R	FR	T	N	
185		185.0							SANDSTONE, Reddish brown, fine to medium grained, fresh, very strong, close spaced discontinuities								
	4.00									185.30	MB						
										185.50	J	20	P,R	FR	T	N	
	4.00									186.40	J	10	P,R	FR	T	N	
	4.00		R-18	60 100%	50 83%	R5	FR			187.30	J	10	P,R	FR	T	N	
1570										188.10	J	30	P,R	FR	T	N	
	4.00									188.90	J	50	P,R	FR	T	N	
	4.00	190.0								189.40	J	40	P,Sm	FR	O	N	
190		190.0							SANDSTONE, Reddish brown, fine to medium grained, fresh, very strong, close spaced discontinuities 191.9' - 192.4' Highly Fractured zone 194' - 194.3' Highly Fractured zone								
	3.00									190.70	J	50	P,Sm	FR	T	N	
	3.00									191.40	J	50	P,Sm	FR	T	N	
	3.00		R-19	60 100%	51 85%	R5	FR			192.90	J	40	P,Sm	FR	T	N	
	3.00									193.60	MB						
	3.00	195.0															
195		195.0							SANDSTONE, Reddish brown, fine to medium grained, fresh, very strong, extremely close to close spaced discontinuities 195.4' - 195.7' Highly Fractured zone								
	3.00																

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CORE BORING LOG
(continued)

BORING NO.: **B-I80-4**
Page **5** of **5**

Depth/ Elev. (ft)	Avg Core Rate (min /ft)	Depth (ft)	Run/ (Box) No.	Rec. (in. / %)	RQD (in. / %)	Rock Core Hard.	Rock Core Weath	Stratum Graphic	Visual Identification, Description and Remarks (Rock type, colour, texture, weathering, field strength, discontinuity spacing, optional additional geological observations)	Depth (ft.)	Discontinuities (See Legend for Rock Description System) Type	Dip	Rgh	Wea	Aper	Infill	Remarks
	3.00								196.7' - 196.8' Highly Fractured zone								
	3.00								199.3' - 200' Highly Fractured zone								
	3.00		R-20	60 100%	47 78%	R5	FR			197.40	J	10	P,Sm	FR	T	N	
1560	3.00									198.90	J	10	P,Sm	FR	T	N	
	3.00	200.0							200.0								
200	2.50	200.0							SILTSTONE, Gray, fine grained, moderately weathered, medium strong, extremely close to close discontinuities 200.8' - 201.3' Highly Fractured zone 202.3' - 205' Highly Weathered zone								No water return at 203 feet BGS. Very little water return from 203 to 205 feet BGS.
	2.50																
	2.50		R-21	60 100%	21 35%	R3	M										
	2.50																
	2.50	205.0							205.0								
205	2.50	205.0							QUARTZITE, Gray, fine grained, fresh, very strong, very close to close discontinuities 205.5' - 205.7' Highly Fractured zone 209.2' - 210' Highly Fractured zone								Losing water from 205 to 210 feet BGS. Water truck refilled 250 gallons.
	2.50									206.50	J	5	U,R	FR	T	N	
	2.50		R-22	60 100%	41 68%	R5	FR			207.80	J	80	P,Sm	FR	T	N	
1550	2.50									208.60	J	60	X,R	FR	T	N	
	2.50	210.0															
210	2.50	210.0							QUARTZITE, Gray, fine grained, fresh, very strong, extremely close to close discontinuities Gneissic bands throughout 210.6' - 210.9' Highly Fractured zone 212.6' - 213.2' Highly Fractured zone 213.9' - 214.4' Highly Fractured zone	210.40	J	10	P,R	FR	T	N	Losing water from 210 to 210.4 feet BGS. No to very little water return from 210.4 to 215 feet BGS. Water truck refilled 250 gallons.
	2.50																
	2.50		R-23	60 100%	37 62%	R5	FR										
	2.50																
	2.50	215.0															
215	3.50	215.0							QUARTZITE, Gray, fine grained, fresh, very strong, very close to close discontinuities Gneissic bands throughout 216.9' - 217.2' Highly Fractured zone	215.20	MB						No to very little water return from 215 to 220 feet BGS.
	4.50									215.90	J	5	P,R	FR	T	N	
	5.50		R-24	60 100%	54 90%	R5	FR			217.90	J	30	P,Sm	DS	T	-	
1540	5.50									218.40	J	30	P,R	FR	T	N	
	5.50	220.0								218.90	MB						
220									220.0	219.40 219.60	J MB	30	P,R	FR	T	N	
									End of Boring at 220 feet BGS. Borehole grouted with cement and bentonite holeplug.								

NOTES:

PROJECT NO.: **353754**

Boring No.: **B-I80-4**

Figure B-I80-4.1
B-I80-4 Box 1 Runs 1-4 Dry

Figure B-I80-4.2
B-I80-4 Box 1 Runs 1-4 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I80-4

Figure B-I80-4.3
B-I80-4 Box 2 Runs 5-8 Dry

Figure B-I80-4.4
B-I80-4 Box 2 Runs 5-8 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I80-4

Figure B-I80-4.5
B-I80-4 Box 3 Runs 9-12 Dry

Figure B-I80-4.6
B-I80-4 Box 3 Runs 9-12 Wet

MOTT MACDONALD	PennEast Pipeline Project Rock Core Photographs	BORING NO.: B-I80-4

Figure B-I80-4.7
B-I80-4 Box 4 Runs 13-16 Dry

Figure B-I80-4.8
B-I80-4 Box 4 Runs 13-16 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I80-4

Figure B-I80-4.9
B-I80-4 Box 5 Runs 17-20 Dry

Figure B-I80-4.10
B-I80-4 Box 5 Runs 17-20 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I80-4

Figure B-I80-4.11
B-I80-4 Box 6 Runs 21-24 Dry

Figure B-I80-4.12
B-I80-4 Box 6 Runs 21-24 Wet

MOTT MACDONALD M M	**PennEast Pipeline Project** **Rock Core Photographs**	**BORING NO.:** B-I80-4

Appendix C

Installation Load and Stress Evaluation

MOTT MACDONALD

Horizontal Directional Drilling
Minimum Radius Calculations - MAOP Based

Project Name: PennEast Pipeline
Project No: 353754
HDD Name: Interstate 80
Location: Carbon County, PA

By: S. Hammerschmidt
Checked: G. Duyvestyn
Owner: PennEast Pipeline
Date: 10/27/2015

References:

1. ASME/ANSI B31.4 section 402.3.2
2. ASME/ANSI B31.8 section 833.3
3. ASME/ANSI B31.8 section 833.4
4. ASME/ANSI B31.4 section 402.3.1

Design Parameters

Pipe Diameter	36	inches
Wall Thickness	0.762	inches
D/t Ratio	47	
MAOP	1,480	psi
SMYS	70,000	psi
Modulus of Elasticity	2.92E+07	psi
Design Factor	0.5	

Hoop Stress Calculation

Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness)
Calculated Hoop Stress 34,961 psi

Longitudinal Stress Calculation

Longitudinal Stress = Hoop Stress / 2
Calculated Longitudinal Stress 17,480 psi

Allowable Stress Calculation

Allowable Stress = Design Factor * SMYS
Calculated Allowable Stress 35,000 psi

Bending Stress Calculation

Bending Stress = Allowable Stress - Longitudinal Stress
Calculated Bending Stress 17,520 psi

Minimum Bend Radius Calculation

Minimum Radius = (Modulus of Elasticity * Pipe Diameter) / (2 * Bending Stress)
Calculated Minimum Radius 2,500 feet

MOTT MACDONALD

Horizontal Directional Drilling
Operating Stress Analysis - MAOP Based

Project Name: PennEast Pipeline
Project No: 353754
HDD Name: Interstate 80
Location: Carbon County, PA

By: S. Hammerschmidt
Checked: G. Duyvestyn
Owner: PennEast Pipeline
Date: 10/27/2015

References:

1. ASME/ANSI B31.4 section 402.3.2
2. ASME/ANSI B31.8 section 833.3
3. ASME/ANSI B31.8 section 833.4
4. ASME/ANSI B31.4 section 402.3.1

Design Parameters

Pipe Diameter	36	inches
Wall Thickness	0.762	inches
D/t Ratio	47	
MAOP	1,480	psi
SMYS	70,000	psi
Modulus of Elasticity	2.92E+07	psi
Combined Design Factor	0.5	
Poisson's Ratio	0.30	
Minimum Radius of Curvature	2,500	feet
Radius of Curvature Factor	104%	
Design Minimum Allowable Radius of Curvature	2,600	feet
Coefficient of Thermal Expansion	6.50E-06	in/in/°F
Assumed Installation Temperature	45	°F
Assumed Operating Temperature	120	°F

Longitudinal Stress from Bending

Longitudinal Stress from Bending		16,846	psi
	Percent SMYS	24.1%	

Hoop Stress

Calculated Hoop Stress		34,961	psi	Should be less than Design Factor x SMYS of	35,000 psi
	Percent SMYS	49.9%		Limited by Design Factor according to 49 CFR 192.11	

Longitudinal Tensile Stress from Hoop Stress

Longitudinal Tensile Stress from Hoop Stress		10,488	psi
	Percent SMYS	15.0%	

Longitudinal Stress from Thermal Expansion

Longitudinal Stress from Thermal Expansion		-14,235	psi	
	Percent SMYS	20.3%		Limited by 90% SMYS by ASME/ANSI B31.4 section 402.3.2

Net Longitudinal Stress (Compression Side of Curve)

Net Longitudinal Stress (Compression Side of Curve)		-20,593	psi	
	Percent SMYS	29.4%		Limited by 90% SMYS by ASME/ANSI B31.8 section 833.3

Net Longitudinal Stress Tension Side of Curve)

Net Longitudinal Stress (Tesion Side of Curve)		13,099	psi	
	Percent SMYS	18.7%		Limited by 90% SMYS by ASME/ANSI B31.8 section 833.3

Maximum Shear Stress

Maximum Shear Stress		27,777	psi	
	Percent SMYS	39.7%		Limited by 45% SMYS by ASME/ANSI B31.4 section 402.3.1

Combined Biaxial Stress Check

Combined Biaxial Stress Check		55,553	psi	
	Percent SMYS	79.4%		Limited to 90% SMYS by ASME/ANSI B31.8 section 833.4

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Hammerschmidt
Checked by: G. Duyvestyn
Date: 2/6/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Interstate 80

Reference:

1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		1454+77	44+342	0.0	0.0	1,788.7	545.2	--	--		55,227	lb	**27.6** tons
straight		1454+19	44+324	59.2	18.1	1,776.4	541.5	48.0	1219.2	0.3	61,013	lb	**30.5** tons
straight		1453+62	44+307	118.4	36.1	1,764.1	537.7	48.0	1219.2	0.3	66,798	lb	**33.4** tons
straight		1453+04	44+289	177.7	54.2	1,751.8	534.0	48.0	1219.2	0.3	72,583	lb	**36.3** tons
straight		1452+46	44+271	236.9	72.2	1,739.5	530.2	48.0	1219.2	0.3	78,368	lb	**39.2** tons
straight		1451+88	44+254	296.1	90.3	1,727.2	526.4	48.0	1219.2	0.3	84,153	lb	**42.1** tons
straight		1451+30	44+236	355.3	108.3	1,714.9	522.7	48.0	1219.2	0.3	89,938	lb	**45.0** tons
straight		1450+72	44+218	414.5	126.4	1,702.5	518.9	48.0	1219.2	0.3	95,723	lb	**47.9** tons
straight		1450+14	44+201	473.8	144.4	1,690.2	515.2	48.0	1219.2	0.3	101,509	lb	**50.8** tons
straight		1449+56	44+183	533.0	162.5	1,677.9	511.4	48.0	1219.2	0.3	107,300	lb	**53.6** tons
straight		1448+98	44+165	592.3	180.5	1,665.6	507.7	48.0	1219.2	0.3	113,091	lb	**56.5** tons
straight		1448+40	44+148	651.6	198.6	1,653.3	503.9	48.0	1219.2	0.3	118,883	lb	**59.4** tons
straight		1447+82	44+130	710.9	216.7	1,640.9	500.2	48.0	1219.2	0.3	124,674	lb	**62.3** tons
curve	vertical	1447+20	44+111	773.7	235.8	1,628.4	496.3	48.0	1219.2	0.3	174,635	lb	**87.3** tons
curve	vertical	1446+59	44+093	836.5	255.0	1,617.0	492.9	48.0	1219.2	0.3	161,310	lb	**80.7** tons
curve	vertical	1445+97	44+074	899.4	274.1	1,606.6	489.7	48.0	1219.2	0.3	161,754	lb	**80.9** tons
curve	vertical	1445+35	44+055	962.2	293.3	1,597.3	486.9	48.0	1219.2	0.3	509,677	lb	**254.8** tons
curve	vertical	1444+72	44+036	1,025.0	312.4	1,589.1	484.4	48.0	1219.2	0.3	345,110	lb	**172.6** tons
curve	vertical	1444+10	44+017	1,087.9	331.6	1,582.0	482.2	48.0	1219.2	0.3	350,840	lb	**175.4** tons
curve	vertical	1443+47	43+998	1,150.7	350.7	1,576.0	480.4	48.0	1219.2	0.3	398,892	lb	**199.4** tons
curve	vertical	1442+85	43+979	1,213.5	369.9	1,571.0	478.9	48.0	1219.2	0.3	409,528	lb	**204.8** tons
curve	vertical	1442+22	43+959	1,276.4	389.0	1,567.2	477.7	48.0	1219.2	0.3	420,129	lb	**210.1** tons
curve	vertical	1441+59	43+940	1,339.2	408.2	1,564.5	476.9	48.0	1219.2	0.3	430,608	lb	**215.3** tons
curve	vertical	1440+96	43+921	1,402.0	427.3	1,562.8	476.4	48.0	1219.2	0.3	440,912	lb	**220.5** tons
curve	vertical	1440+34	43+902	1,464.9	446.5	1,562.3	476.2	48.0	1219.2	0.3	451,013	lb	**225.5** tons
straight		1439+66	43+881	1,532.2	467.0	1,562.3	476.2	48.0	1219.2	0.3	457,974	lb	**229.0** tons
straight		1438+99	43+861	1,599.5	487.5	1,562.3	476.2	48.0	1219.2	0.3	464,936	lb	**232.5** tons
straight		1438+32	43+840	1,666.8	508.1	1,562.3	476.2	48.0	1219.2	0.3	471,898	lb	**235.9** tons
straight		1437+64	43+820	1,734.2	528.6	1,562.3	476.2	48.0	1219.2	0.3	478,860	lb	**239.4** tons
straight		1436+97	43+799	1,801.5	549.1	1,562.3	476.2	48.0	1219.2	0.3	485,821	lb	**242.9** tons
straight		1436+30	43+779	1,868.8	569.6	1,562.3	476.2	48.0	1219.2	0.3	492,783	lb	**246.4** tons
straight		1435+62	43+758	1,936.1	590.1	1,562.3	476.2	48.0	1219.2	0.3	499,745	lb	**249.9** tons
straight		1434+95	43+738	2,003.5	610.7	1,562.3	476.2	48.0	1219.2	0.3	506,707	lb	**253.4** tons
straight		1434+28	43+717	2,070.8	631.2	1,562.3	476.2	48.0	1219.2	0.3	513,668	lb	**256.8** tons
straight		1433+60	43+697	2,138.1	651.7	1,562.3	476.2	48.0	1219.2	0.3	520,630	lb	**260.3** tons
straight		1432+93	43+676	2,205.4	672.2	1,562.3	476.2	48.0	1219.2	0.3	527,592	lb	**263.8** tons
straight		1432+26	43+656	2,272.8	692.7	1,562.3	476.2	48.0	1219.2	0.3	534,554	lb	**267.3** tons
straight		1431+58	43+635	2,340.1	713.3	1,562.3	476.2	48.0	1219.2	0.3	541,516	lb	**270.8** tons
straight		1430+91	43+615	2,407.4	733.8	1,562.3	476.2	48.0	1219.2	0.3	548,478	lb	**274.2** tons
straight		1430+24	43+594	2,474.8	754.3	1,562.3	476.2	48.0	1219.2	0.3	555,440	lb	**277.7** tons
straight		1429+56	43+574	2,542.1	774.8	1,562.3	476.2	48.0	1219.2	0.3	562,402	lb	**281.2** tons
curve	vertical	1428+94	43+554	2,604.9	794.0	1,562.8	476.4	48.0	1219.2	0.3	650,374	lb	**325.2** tons
curve	vertical	1428+31	43+535	2,667.7	813.1	1,564.5	476.9	48.0	1219.2	0.3	627,553	lb	**313.8** tons
curve	vertical	1427+68	43+516	2,730.6	832.3	1,567.2	477.7	48.0	1219.2	0.3	628,883	lb	**314.4** tons
curve	vertical	1427+05	43+497	2,793.4	851.4	1,571.0	478.9	48.0	1219.2	0.3	635,926	lb	**318.0** tons
curve	vertical	1426+43	43+478	2,856.2	870.6	1,576.0	480.4	48.0	1219.2	0.3	644,964	lb	**322.5** tons
curve	vertical	1425+80	43+459	2,919.1	889.7	1,582.0	482.2	48.0	1219.2	0.3	654,760	lb	**327.4** tons
curve	vertical	1425+18	43+440	2,981.9	908.9	1,589.1	484.4	48.0	1219.2	0.3	664,798	lb	**332.4** tons
curve	vertical	1424+55	43+421	3,044.7	928.0	1,597.3	486.9	48.0	1219.2	0.3	674,839	lb	**337.4** tons
curve	vertical	1423+93	43+402	3,107.6	947.2	1,606.6	489.7	48.0	1219.2	0.3	684,765	lb	**342.4** tons
curve	vertical	1423+31	43+383	3,170.4	966.3	1,617.0	492.9	48.0	1219.2	0.3	694,518	lb	**347.3** tons
curve	vertical	1422+69	43+364	3,233.2	985.5	1,628.4	496.3	48.0	1219.2	0.3	704,067	lb	**352.0** tons
curve	vertical	1422+08	43+345	3,296.1	1,004.7	1,640.9	500.2	48.0	1219.2	0.3	713,397	lb	**356.7** tons
straight		1421+39	43+324	3,366.8	1,026.2	1,655.6	504.6	48.0	1219.2	0.3	716,960	lb	**358.5** tons
straight		1420+70	43+303	3,437.5	1,047.8	1,670.3	509.1	48.0	1219.2	0.3	720,523	lb	**360.3** tons
straight		1420+00	43+282	3,508.2	1,069.3	1,685.0	513.6	48.0	1219.2	0.3	724,087	lb	**362.0** tons
straight		1419+31	43+261	3,578.9	1,090.9	1,699.7	518.1	48.0	1219.2	0.3	727,650	lb	**363.8** tons
straight		1418+62	43+240	3,649.7	1,112.4	1,714.5	522.6	48.0	1219.2	0.3	731,214	lb	**365.6** tons
straight		1417+93	43+219	3,720.4	1,134.0	1,729.2	527.1	48.0	1219.2	0.3	734,778	lb	**367.4** tons
straight		1417+24	43+198	3,791.2	1,155.6	1,743.9	531.5	48.0	1219.2	0.3	738,342	lb	**369.2** tons
HDD Rig Location		1416+54	43+177	3,861.9	1,177.1	1,758.6	536.0	48.0	1219.2	0.3	741,907	lb	**371.0** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
655	4.51	0.94%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
723	4.99	1.03%	0	0.00	0.00%	151	1.04	0.22%	0.01	Yes	0.00	Yes
792	5.46	1.13%	0	0.00	0.00%	302	2.08	0.43%	0.01	Yes	0.00	Yes
860	5.93	1.23%	0	0.00	0.00%	453	3.12	0.65%	0.02	Yes	0.00	Yes
929	6.41	1.33%	0	0.00	0.00%	604	4.17	0.86%	0.02	Yes	0.01	Yes
998	6.88	1.43%	0	0.00	0.00%	755	5.21	1.08%	0.02	Yes	0.01	Yes
1,066	7.35	1.52%	0	0.00	0.00%	906	6.25	1.29%	0.02	Yes	0.02	Yes
1,135	7.82	1.62%	0	0.00	0.00%	1,058	7.29	1.51%	0.02	Yes	0.02	Yes
1,203	8.30	1.72%	0	0.00	0.00%	1,209	8.33	1.73%	0.02	Yes	0.03	Yes
1,272	8.77	1.82%	0	0.00	0.00%	1,360	9.38	1.94%	0.02	Yes	0.03	Yes
1,341	9.24	1.92%	0	0.00	0.00%	1,511	10.42	2.16%	0.02	Yes	0.04	Yes
1,409	9.72	2.01%	0	0.00	0.00%	1,662	11.46	2.37%	0.03	Yes	0.05	Yes
1,478	10.19	2.11%	0	0.00	0.00%	1,814	12.50	2.59%	0.03	Yes	0.06	Yes
2,070	14.27	2.96%	12,083	83.31	17.26%	1,967	13.56	2.81%	0.31	Yes	0.16	Yes
1,912	13.18	2.73%	12,083	83.31	17.26%	2,108	14.53	3.01%	0.30	Yes	0.17	Yes
1,918	13.22	2.74%	12,083	83.31	17.26%	2,235	15.41	3.19%	0.30	Yes	0.18	Yes
6,042	41.66	8.63%	12,083	83.31	17.26%	2,349	16.20	3.36%	0.38	Yes	0.24	Yes
4,091	28.21	5.84%	12,083	83.31	17.26%	2,450	16.89	3.50%	0.34	Yes	0.23	Yes
4,159	28.68	5.94%	12,083	83.31	17.26%	2,537	17.49	3.62%	0.34	Yes	0.24	Yes
4,729	32.60	6.76%	12,083	83.31	17.26%	2,241	15.45	3.20%	0.36	Yes	0.25	Yes
4,855	33.47	6.94%	12,083	83.31	17.26%	2,301	15.87	3.29%	0.36	Yes	0.26	Yes
4,980	34.34	7.11%	12,083	83.31	17.26%	2,348	16.19	3.35%	0.36	Yes	0.27	Yes
5,105	35.20	7.29%	12,083	83.31	17.26%	2,382	16.42	3.40%	0.36	Yes	0.27	Yes
5,227	36.04	7.47%	12,083	83.31	17.26%	2,402	16.56	3.43%	0.36	Yes	0.28	Yes
5,347	36.86	7.64%	12,083	83.31	17.26%	2,409	16.61	3.44%	0.37	Yes	0.28	Yes
5,429	37.43	7.76%	0	0.00	0.00%	2,409	16.61	3.44%	0.10	Yes	0.15	Yes
5,512	38.00	7.87%	0	0.00	0.00%	2,409	16.61	3.44%	0.10	Yes	0.15	Yes
5,594	38.57	7.99%	0	0.00	0.00%	2,409	16.61	3.44%	0.10	Yes	0.15	Yes
5,677	39.14	8.11%	0	0.00	0.00%	2,409	16.61	3.44%	0.10	Yes	0.16	Yes
5,759	39.71	8.23%	0	0.00	0.00%	2,409	16.61	3.44%	0.10	Yes	0.16	Yes
5,842	40.28	8.35%	0	0.00	0.00%	2,409	16.61	3.44%	0.10	Yes	0.16	Yes
5,924	40.85	8.46%	0	0.00	0.00%	2,409	16.61	3.44%	0.11	Yes	0.16	Yes
6,007	41.42	8.58%	0	0.00	0.00%	2,409	16.61	3.44%	0.11	Yes	0.16	Yes
6,089	41.98	8.70%	0	0.00	0.00%	2,409	16.61	3.44%	0.11	Yes	0.16	Yes
6,172	42.55	8.82%	0	0.00	0.00%	2,409	16.61	3.44%	0.11	Yes	0.16	Yes
6,254	43.12	8.93%	0	0.00	0.00%	2,409	16.61	3.44%	0.11	Yes	0.16	Yes
6,337	43.69	9.05%	0	0.00	0.00%	2,409	16.61	3.44%	0.11	Yes	0.16	Yes
6,419	44.26	9.17%	0	0.00	0.00%	2,409	16.61	3.44%	0.11	Yes	0.16	Yes
6,502	44.83	9.29%	0	0.00	0.00%	2,409	16.61	3.44%	0.12	Yes	0.16	Yes
6,584	45.40	9.41%	0	0.00	0.00%	2,409	16.61	3.44%	0.12	Yes	0.16	Yes
6,667	45.97	9.52%	0	0.00	0.00%	2,409	16.61	3.44%	0.12	Yes	0.16	Yes
7,710	53.16	11.01%	12,083	83.31	17.26%	2,402	16.56	3.43%	0.41	Yes	0.31	Yes
7,439	51.29	10.63%	12,083	83.31	17.26%	2,382	16.42	3.40%	0.40	Yes	0.31	Yes
7,455	51.40	10.65%	12,083	83.31	17.26%	2,348	16.19	3.35%	0.40	Yes	0.30	Yes
7,539	51.98	10.77%	12,083	83.31	17.26%	2,301	15.87	3.29%	0.41	Yes	0.30	Yes
7,646	52.72	10.92%	12,083	83.31	17.26%	2,241	15.45	3.20%	0.41	Yes	0.29	Yes
7,762	53.52	11.09%	12,083	83.31	17.26%	2,167	14.94	3.10%	0.41	Yes	0.29	Yes
7,881	54.34	11.26%	12,083	83.31	17.26%	2,080	14.34	2.97%	0.41	Yes	0.28	Yes
8,000	55.16	11.43%	12,083	83.31	17.26%	1,979	13.64	2.83%	0.41	Yes	0.27	Yes
8,118	55.97	11.60%	12,083	83.31	17.26%	1,865	12.86	2.66%	0.42	Yes	0.26	Yes
8,233	56.77	11.76%	12,083	83.31	17.26%	1,738	11.98	2.48%	0.42	Yes	0.25	Yes
8,346	57.55	11.92%	12,083	83.31	17.26%	1,597	11.01	2.28%	0.42	Yes	0.24	Yes
8,457	58.31	12.08%	12,083	83.31	17.26%	1,444	9.95	2.06%	0.42	Yes	0.23	Yes
8,499	58.60	12.14%	0	0.00	0.00%	1,263	8.71	1.80%	0.15	Yes	0.08	Yes
8,541	58.89	12.20%	0	0.00	0.00%	1,083	7.47	1.55%	0.15	Yes	0.07	Yes
8,584	59.18	12.26%	0	0.00	0.00%	902	6.22	1.29%	0.15	Yes	0.06	Yes
8,626	59.47	12.32%	0	0.00	0.00%	722	4.98	1.03%	0.15	Yes	0.05	Yes
8,668	59.77	12.38%	0	0.00	0.00%	541	3.73	0.77%	0.15	Yes	0.05	Yes
8,710	60.06	12.44%	0	0.00	0.00%	361	2.49	0.52%	0.16	Yes	0.04	Yes
8,753	60.35	12.50%	0	0.00	0.00%	180	1.24	0.26%	0.16	Yes	0.03	Yes
8,795	60.64	12.56%	0	0.00	0.00%	0	0.00	0.00%	0.16	Yes	0.03	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	1788.73	feet
	545.21	metres
Ground Elevation at Pipe Exit	1758.58	feet
	536.02	metres

	TOTAL PULL LOADS		
Maximum Values	741,907	lb	371.0 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
8,795	60.6	12.56%	12,083	83.3	17.26%	2,537	17.5	3.62%	0.42	0.31

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	0.0	lbs/ft
	0.00	kg/m
Net Buoyant Weight of pipe	-241.7	lbs/ft
	-360.42	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m
Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	741,907	lb
	3,300	kN
Factor of Safety	4.8	
Start-up Load Factor	1.5	
Required Pipe Pull Load	509,677	lb
	2,267	kN
Factor of Safety	7.0	

Soil and Mud Properties

Mud Weight	10	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.199	Specific Gravity
Friction Coeff. (GS or rollers)	0.2	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Hammerschmidt
Checked by: G. Duyvestyn
Date: 2/6/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Interstate 80

Reference:
1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		1454+77	44+342	0.0	0.0	1,788.7	545.2	--	--		55,227	lb	**27.6** tons
straight		1454+19	44+324	59.2	18.1	1,776.4	541.5	48.0	1219.2	0.3	54,662	lb	**27.3** tons
straight		1453+62	44+307	118.4	36.1	1,764.1	537.7	48.0	1219.2	0.3	54,096	lb	**27.0** tons
straight		1453+04	44+289	177.7	54.2	1,751.8	534.0	48.0	1219.2	0.3	53,531	lb	**26.8** tons
straight		1452+46	44+271	236.9	72.2	1,739.5	530.2	48.0	1219.2	0.3	52,965	lb	**26.5** tons
straight		1451+88	44+254	296.1	90.3	1,727.2	526.4	48.0	1219.2	0.3	52,399	lb	**26.2** tons
straight		1451+30	44+236	355.3	108.3	1,714.9	522.7	48.0	1219.2	0.3	51,834	lb	**25.9** tons
straight		1450+72	44+218	414.5	126.4	1,702.5	518.9	48.0	1219.2	0.3	51,268	lb	**25.6** tons
straight		1450+14	44+201	473.8	144.4	1,690.2	515.2	48.0	1219.2	0.3	50,702	lb	**25.4** tons
straight		1449+56	44+183	533.0	162.5	1,677.9	511.4	48.0	1219.2	0.3	50,136	lb	**25.1** tons
straight		1448+98	44+165	592.3	180.5	1,665.6	507.7	48.0	1219.2	0.3	49,570	lb	**24.8** tons
straight		1448+40	44+148	651.6	198.6	1,653.3	503.9	48.0	1219.2	0.3	49,004	lb	**24.5** tons
straight		1447+82	44+130	710.9	216.7	1,640.9	500.2	48.0	1219.2	0.3	48,437	lb	**24.2** tons
curve	vertical	1447+20	44+111	773.7	235.8	1,628.4	496.3	48.0	1219.2	0.3	83,468	lb	**41.7** tons
curve	vertical	1446+59	44+093	836.5	255.0	1,617.0	492.9	48.0	1219.2	0.3	55,537	lb	**27.8** tons
curve	vertical	1445+97	44+074	899.4	274.1	1,606.6	489.7	48.0	1219.2	0.3	41,719	lb	**20.9** tons
curve	vertical	1445+35	44+055	962.2	293.3	1,597.3	486.9	48.0	1219.2	0.3	313,929	lb	**157.0** tons
curve	vertical	1444+72	44+036	1,025.0	312.4	1,589.1	484.4	48.0	1219.2	0.3	211,555	lb	**105.8** tons
curve	vertical	1444+10	44+017	1,087.9	331.6	1,582.0	482.2	48.0	1219.2	0.3	213,282	lb	**106.6** tons
curve	vertical	1443+47	43+998	1,150.7	350.7	1,576.0	480.4	48.0	1219.2	0.3	225,586	lb	**112.8** tons
curve	vertical	1442+85	43+979	1,213.5	369.9	1,571.0	478.9	48.0	1219.2	0.3	229,523	lb	**114.8** tons
curve	vertical	1442+22	43+959	1,276.4	389.0	1,567.2	477.7	48.0	1219.2	0.3	233,264	lb	**116.6** tons
curve	vertical	1441+59	43+940	1,339.2	408.2	1,564.5	476.9	48.0	1219.2	0.3	236,894	lb	**118.4** tons
curve	vertical	1440+96	43+921	1,402.0	427.3	1,562.8	476.4	48.0	1219.2	0.3	240,465	lb	**120.2** tons
curve	vertical	1440+34	43+902	1,464.9	446.5	1,562.3	476.2	48.0	1219.2	0.3	244,012	lb	**122.0** tons
straight		1439+66	43+881	1,532.2	467.0	1,562.3	476.2	48.0	1219.2	0.3	248,187	lb	**124.1** tons
straight		1438+99	43+861	1,599.5	487.5	1,562.3	476.2	48.0	1219.2	0.3	252,362	lb	**126.2** tons
straight		1438+32	43+840	1,666.8	508.1	1,562.3	476.2	48.0	1219.2	0.3	256,537	lb	**128.3** tons
straight		1437+64	43+820	1,734.2	528.6	1,562.3	476.2	48.0	1219.2	0.3	260,712	lb	**130.4** tons
straight		1436+97	43+799	1,801.5	549.1	1,562.3	476.2	48.0	1219.2	0.3	264,887	lb	**132.4** tons
straight		1436+30	43+779	1,868.8	569.6	1,562.3	476.2	48.0	1219.2	0.3	269,062	lb	**134.5** tons
straight		1435+62	43+758	1,936.1	590.1	1,562.3	476.2	48.0	1219.2	0.3	273,237	lb	**136.6** tons
straight		1434+95	43+738	2,003.5	610.7	1,562.3	476.2	48.0	1219.2	0.3	277,412	lb	**138.7** tons
straight		1434+28	43+717	2,070.8	631.2	1,562.3	476.2	48.0	1219.2	0.3	281,586	lb	**140.8** tons
straight		1433+60	43+697	2,138.1	651.7	1,562.3	476.2	48.0	1219.2	0.3	285,761	lb	**142.9** tons
straight		1432+93	43+676	2,205.4	672.2	1,562.3	476.2	48.0	1219.2	0.3	289,936	lb	**145.0** tons
straight		1432+26	43+656	2,272.8	692.7	1,562.3	476.2	48.0	1219.2	0.3	294,111	lb	**147.1** tons
straight		1431+58	43+635	2,340.1	713.3	1,562.3	476.2	48.0	1219.2	0.3	298,286	lb	**149.1** tons
straight		1430+91	43+615	2,407.4	733.8	1,562.3	476.2	48.0	1219.2	0.3	302,462	lb	**151.2** tons
straight		1430+24	43+594	2,474.8	754.3	1,562.3	476.2	48.0	1219.2	0.3	306,637	lb	**153.3** tons
straight		1429+56	43+574	2,542.1	774.8	1,562.3	476.2	48.0	1219.2	0.3	310,812	lb	**155.4** tons
curve	vertical	1428+94	43+554	2,604.9	794.0	1,562.8	476.4	48.0	1219.2	0.3	379,477	lb	**189.7** tons
curve	vertical	1428+31	43+535	2,667.7	813.1	1,564.5	476.9	48.0	1219.2	0.3	337,719	lb	**168.9** tons
curve	vertical	1427+68	43+516	2,730.6	832.3	1,567.2	477.7	48.0	1219.2	0.3	320,604	lb	**160.3** tons
curve	vertical	1427+05	43+497	2,793.4	851.4	1,571.0	478.9	48.0	1219.2	0.3	309,789	lb	**154.9** tons
curve	vertical	1426+43	43+478	2,856.2	870.6	1,576.0	480.4	48.0	1219.2	0.3	309,499	lb	**154.7** tons
curve	vertical	1425+80	43+459	2,919.1	889.7	1,582.0	482.2	48.0	1219.2	0.3	314,810	lb	**157.4** tons
curve	vertical	1425+18	43+440	2,981.9	908.9	1,589.1	484.4	48.0	1219.2	0.3	319,490	lb	**159.7** tons
curve	vertical	1424+55	43+421	3,044.7	928.0	1,597.3	486.9	48.0	1219.2	0.3	323,802	lb	**161.9** tons
curve	vertical	1423+93	43+402	3,107.6	947.2	1,606.6	489.7	48.0	1219.2	0.3	327,891	lb	**163.9** tons
curve	vertical	1423+31	43+383	3,170.4	966.3	1,617.0	492.9	48.0	1219.2	0.3	331,849	lb	**165.9** tons
curve	vertical	1422+69	43+364	3,233.2	985.5	1,628.4	496.3	48.0	1219.2	0.3	335,735	lb	**167.9** tons
curve	vertical	1422+08	43+345	3,296.1	1,004.7	1,640.9	500.2	48.0	1219.2	0.3	339,590	lb	**169.8** tons
straight		1421+39	43+324	3,366.8	1,026.2	1,655.6	504.6	48.0	1219.2	0.3	346,237	lb	**173.1** tons
straight		1420+70	43+303	3,437.5	1,047.8	1,670.3	509.1	48.0	1219.2	0.3	352,885	lb	**176.4** tons
straight		1420+00	43+282	3,508.2	1,069.3	1,685.0	513.6	48.0	1219.2	0.3	359,533	lb	**179.8** tons
straight		1419+31	43+261	3,578.9	1,090.9	1,699.7	518.1	48.0	1219.2	0.3	366,180	lb	**183.1** tons
straight		1418+62	43+240	3,649.7	1,112.4	1,714.5	522.6	48.0	1219.2	0.3	372,830	lb	**186.4** tons
straight		1417+93	43+219	3,720.4	1,134.0	1,729.2	527.1	48.0	1219.2	0.3	379,480	lb	**189.7** tons
straight		1417+24	43+198	3,791.2	1,155.6	1,743.9	531.5	48.0	1219.2	0.3	386,130	lb	**193.1** tons
HDD Rig Location		1416+54	43+177	3,861.9	1,177.1	1,758.6	536.0	48.0	1219.2	0.3	392,779	lb	**196.4** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
655	4.51	0.94%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
648	4.47	0.93%	0	0.00	0.00%	25	0.17	0.04%	0.01	Yes	0.00	Yes
641	4.42	0.92%	0	0.00	0.00%	50	0.35	0.07%	0.01	Yes	0.00	Yes
635	4.38	0.91%	0	0.00	0.00%	75	0.52	0.11%	0.01	Yes	0.00	Yes
628	4.33	0.90%	0	0.00	0.00%	100	0.69	0.14%	0.01	Yes	0.00	Yes
621	4.28	0.89%	0	0.00	0.00%	125	0.86	0.18%	0.01	Yes	0.00	Yes
614	4.24	0.88%	0	0.00	0.00%	150	1.04	0.21%	0.01	Yes	0.00	Yes
608	4.19	0.87%	0	0.00	0.00%	175	1.21	0.25%	0.01	Yes	0.00	Yes
601	4.14	0.86%	0	0.00	0.00%	200	1.38	0.29%	0.01	Yes	0.00	Yes
594	4.10	0.85%	0	0.00	0.00%	225	1.55	0.32%	0.01	Yes	0.00	Yes
588	4.05	0.84%	0	0.00	0.00%	251	1.73	0.36%	0.01	Yes	0.00	Yes
581	4.01	0.83%	0	0.00	0.00%	276	1.90	0.39%	0.01	Yes	0.00	Yes
574	3.96	0.82%	0	0.00	0.00%	301	2.07	0.43%	0.01	Yes	0.00	Yes
989	6.82	1.41%	12,083	83.31	17.26%	326	2.25	0.47%	0.29	Yes	0.06	Yes
658	4.54	0.94%	12,083	83.31	17.26%	349	2.41	0.50%	0.28	Yes	0.06	Yes
495	3.41	0.71%	12,083	83.31	17.26%	371	2.55	0.53%	0.28	Yes	0.06	Yes
3,721	25.66	5.32%	12,083	83.31	17.26%	389	2.68	0.56%	0.34	Yes	0.09	Yes
2,508	17.29	3.58%	12,083	83.31	17.26%	406	2.80	0.58%	0.32	Yes	0.08	Yes
2,528	17.43	3.61%	12,083	83.31	17.26%	421	2.90	0.60%	0.32	Yes	0.08	Yes
2,674	18.44	3.82%	12,083	83.31	17.26%	371	2.56	0.53%	0.32	Yes	0.08	Yes
2,721	18.76	3.89%	12,083	83.31	17.26%	381	2.63	0.54%	0.32	Yes	0.08	Yes
2,765	19.07	3.95%	12,083	83.31	17.26%	389	2.68	0.56%	0.32	Yes	0.08	Yes
2,808	19.36	4.01%	12,083	83.31	17.26%	395	2.72	0.56%	0.32	Yes	0.08	Yes
2,851	19.65	4.07%	12,083	83.31	17.26%	398	2.75	0.57%	0.32	Yes	0.08	Yes
2,893	19.94	4.13%	12,083	83.31	17.26%	399	2.75	0.57%	0.32	Yes	0.08	Yes
2,942	20.29	4.20%	0	0.00	0.00%	399	2.75	0.57%	0.05	Yes	0.01	Yes
2,992	20.63	4.27%	0	0.00	0.00%	399	2.75	0.57%	0.05	Yes	0.01	Yes
3,041	20.97	4.34%	0	0.00	0.00%	399	2.75	0.57%	0.05	Yes	0.01	Yes
3,091	21.31	4.42%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,140	21.65	4.49%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,190	21.99	4.56%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,239	22.33	4.63%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,289	22.67	4.70%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,338	23.02	4.77%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,388	23.36	4.84%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,437	23.70	4.91%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,487	24.04	4.98%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,536	24.38	5.05%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,586	24.72	5.12%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,635	25.06	5.19%	0	0.00	0.00%	399	2.75	0.57%	0.06	Yes	0.01	Yes
3,685	25.40	5.26%	0	0.00	0.00%	399	2.75	0.57%	0.07	Yes	0.01	Yes
4,499	31.02	6.43%	12,083	83.31	17.26%	398	2.75	0.57%	0.35	Yes	0.10	Yes
4,003	27.60	5.72%	12,083	83.31	17.26%	395	2.72	0.56%	0.34	Yes	0.09	Yes
3,801	26.20	5.43%	12,083	83.31	17.26%	389	2.68	0.56%	0.34	Yes	0.09	Yes
3,672	25.32	5.25%	12,083	83.31	17.26%	381	2.63	0.54%	0.34	Yes	0.09	Yes
3,669	25.30	5.24%	12,083	83.31	17.26%	371	2.56	0.53%	0.34	Yes	0.09	Yes
3,732	25.73	5.33%	12,083	83.31	17.26%	359	2.48	0.51%	0.34	Yes	0.09	Yes
3,787	26.11	5.41%	12,083	83.31	17.26%	345	2.38	0.49%	0.34	Yes	0.09	Yes
3,839	26.47	5.48%	12,083	83.31	17.26%	328	2.26	0.47%	0.34	Yes	0.09	Yes
3,887	26.80	5.55%	12,083	83.31	17.26%	309	2.13	0.44%	0.34	Yes	0.09	Yes
3,934	27.12	5.62%	12,083	83.31	17.26%	288	1.99	0.41%	0.34	Yes	0.09	Yes
3,980	27.44	5.69%	12,083	83.31	17.26%	265	1.83	0.38%	0.34	Yes	0.09	Yes
4,026	27.76	5.75%	12,083	83.31	17.26%	239	1.65	0.34%	0.34	Yes	0.09	Yes
4,104	28.30	5.86%	0	0.00	0.00%	209	1.44	0.30%	0.07	Yes	0.01	Yes
4,183	28.84	5.98%	0	0.00	0.00%	179	1.24	0.26%	0.07	Yes	0.01	Yes
4,262	29.39	6.09%	0	0.00	0.00%	150	1.03	0.21%	0.08	Yes	0.01	Yes
4,341	29.93	6.20%	0	0.00	0.00%	120	0.83	0.17%	0.08	Yes	0.01	Yes
4,420	30.47	6.31%	0	0.00	0.00%	90	0.62	0.13%	0.08	Yes	0.01	Yes
4,499	31.02	6.43%	0	0.00	0.00%	60	0.41	0.09%	0.08	Yes	0.01	Yes
4,577	31.56	6.54%	0	0.00	0.00%	30	0.21	0.04%	0.08	Yes	0.01	Yes
4,656	32.10	6.65%	0	0.00	0.00%	0	0.00	0.00%	0.08	Yes	0.01	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	1788.73	feet
	545.21	metres
Ground Elevation at Pipe Exit	1758.58	feet
	536.02	metres

	TOTAL PULL LOADS		
Maximum Values	392,779	lb	196.4 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
4,656	32.1	6.65%	12,083	83.3	17.26%	421	2.9	0.60%	0.35	0.10

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	404.5	lbs/ft
	603.26	kg/m
Net Buoyant Weight of pipe	162.8	lbs/ft
	242.84	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m
Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	392,779	lb
	1,747	kN
Factor of Safety	9.0	
Start-up Load Factor	1.5	
Required Pipe Pull Load	313,929	lb
	1,396	kN
Factor of Safety	11.3	

Soil and Mud Properties

Mud Weight	10	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.199	Specific Gravity
Friction Coeff. (GS or rollers)	0.2	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Hammerschmidt
Checked by: G. Duyvestyn
Date: 2/6/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Interstate 80

Reference:

1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		1454+77	44+342	0.0	0.0	1,788.7	545.2	--	--		55,227	lb	**27.6** tons
straight		1454+19	44+324	59.2	18.1	1,776.4	541.5	48.0	1219.2	0.3	62,582	lb	**31.3** tons
straight		1453+62	44+307	118.4	36.1	1,764.1	537.7	48.0	1219.2	0.3	69,937	lb	**35.0** tons
straight		1453+04	44+289	177.7	54.2	1,751.8	534.0	48.0	1219.2	0.3	77,292	lb	**38.6** tons
straight		1452+46	44+271	236.9	72.2	1,739.5	530.2	48.0	1219.2	0.3	84,647	lb	**42.3** tons
straight		1451+88	44+254	296.1	90.3	1,727.2	526.4	48.0	1219.2	0.3	92,002	lb	**46.0** tons
straight		1451+30	44+236	355.3	108.3	1,714.9	522.7	48.0	1219.2	0.3	99,357	lb	**49.7** tons
straight		1450+72	44+218	414.5	126.4	1,702.5	518.9	48.0	1219.2	0.3	106,712	lb	**53.4** tons
straight		1450+14	44+201	473.8	144.4	1,690.2	515.2	48.0	1219.2	0.3	114,067	lb	**57.0** tons
straight		1449+56	44+183	533.0	162.5	1,677.9	511.4	48.0	1219.2	0.3	121,430	lb	**60.7** tons
straight		1448+98	44+165	592.3	180.5	1,665.6	507.7	48.0	1219.2	0.3	128,792	lb	**64.4** tons
straight		1448+40	44+148	651.6	198.6	1,653.3	503.9	48.0	1219.2	0.3	136,155	lb	**68.1** tons
straight		1447+82	44+130	710.9	216.7	1,640.9	500.2	48.0	1219.2	0.3	143,518	lb	**71.8** tons
curve	vertical	1447+20	44+111	773.7	235.8	1,628.4	496.3	48.0	1219.2	0.3	195,486	lb	**97.7** tons
curve	vertical	1446+59	44+093	836.5	255.0	1,617.0	492.9	48.0	1219.2	0.3	184,123	lb	**92.1** tons
curve	vertical	1445+97	44+074	899.4	274.1	1,606.6	489.7	48.0	1219.2	0.3	186,478	lb	**93.2** tons
curve	vertical	1445+35	44+055	962.2	293.3	1,597.3	486.9	48.0	1219.2	0.3	549,517	lb	**274.8** tons
curve	vertical	1444+72	44+036	1,025.0	312.4	1,589.1	484.4	48.0	1219.2	0.3	373,447	lb	**186.7** tons
curve	vertical	1444+10	44+017	1,087.9	331.6	1,582.0	482.2	48.0	1219.2	0.3	424,646	lb	**212.3** tons
curve	vertical	1443+47	43+998	1,150.7	350.7	1,576.0	480.4	48.0	1219.2	0.3	437,832	lb	**218.9** tons
curve	vertical	1442+85	43+979	1,213.5	369.9	1,571.0	478.9	48.0	1219.2	0.3	451,056	lb	**225.5** tons
curve	vertical	1442+22	43+959	1,276.4	389.0	1,567.2	477.7	48.0	1219.2	0.3	464,166	lb	**232.1** tons
curve	vertical	1441+59	43+940	1,339.2	408.2	1,564.5	476.9	48.0	1219.2	0.3	477,077	lb	**238.5** tons
curve	vertical	1440+96	43+921	1,402.0	427.3	1,562.8	476.4	48.0	1219.2	0.3	489,745	lb	**244.9** tons
curve	vertical	1440+34	43+902	1,464.9	446.5	1,562.3	476.2	48.0	1219.2	0.3	502,143	lb	**251.1** tons
straight		1439+66	43+881	1,532.2	467.0	1,562.3	476.2	48.0	1219.2	0.3	510,973	lb	**255.5** tons
straight		1438+99	43+861	1,599.5	487.5	1,562.3	476.2	48.0	1219.2	0.3	519,804	lb	**259.9** tons
straight		1438+32	43+840	1,666.8	508.1	1,562.3	476.2	48.0	1219.2	0.3	528,635	lb	**264.3** tons
straight		1437+64	43+820	1,734.2	528.6	1,562.3	476.2	48.0	1219.2	0.3	537,465	lb	**268.7** tons
straight		1436+97	43+799	1,801.5	549.1	1,562.3	476.2	48.0	1219.2	0.3	546,296	lb	**273.1** tons
straight		1436+30	43+779	1,868.8	569.6	1,562.3	476.2	48.0	1219.2	0.3	555,126	lb	**277.6** tons
straight		1435+62	43+758	1,936.1	590.1	1,562.3	476.2	48.0	1219.2	0.3	563,957	lb	**282.0** tons
straight		1434+95	43+738	2,003.5	610.7	1,562.3	476.2	48.0	1219.2	0.3	572,787	lb	**286.4** tons
straight		1434+28	43+717	2,070.8	631.2	1,562.3	476.2	48.0	1219.2	0.3	581,618	lb	**290.8** tons
straight		1433+60	43+697	2,138.1	651.7	1,562.3	476.2	48.0	1219.2	0.3	590,449	lb	**295.2** tons
straight		1432+93	43+676	2,205.4	672.2	1,562.3	476.2	48.0	1219.2	0.3	599,279	lb	**299.6** tons
straight		1432+26	43+656	2,272.8	692.7	1,562.3	476.2	48.0	1219.2	0.3	608,110	lb	**304.1** tons
straight		1431+58	43+635	2,340.1	713.3	1,562.3	476.2	48.0	1219.2	0.3	616,941	lb	**308.5** tons
straight		1430+91	43+615	2,407.4	733.8	1,562.3	476.2	48.0	1219.2	0.3	625,772	lb	**312.9** tons
straight		1430+24	43+594	2,474.8	754.3	1,562.3	476.2	48.0	1219.2	0.3	634,603	lb	**317.3** tons
straight		1429+56	43+574	2,542.1	774.8	1,562.3	476.2	48.0	1219.2	0.3	643,434	lb	**321.7** tons
curve	vertical	1428+94	43+554	2,604.9	794.0	1,562.8	476.4	48.0	1219.2	0.3	734,458	lb	**367.2** tons
curve	vertical	1428+31	43+535	2,667.7	813.1	1,564.5	476.9	48.0	1219.2	0.3	714,621	lb	**357.3** tons
curve	vertical	1427+68	43+516	2,730.6	832.3	1,567.2	477.7	48.0	1219.2	0.3	718,832	lb	**359.4** tons
curve	vertical	1427+05	43+497	2,793.4	851.4	1,571.0	478.9	48.0	1219.2	0.3	728,633	lb	**364.3** tons
curve	vertical	1426+43	43+478	2,856.2	870.6	1,576.0	480.4	48.0	1219.2	0.3	740,302	lb	**370.2** tons
curve	vertical	1425+80	43+459	2,919.1	889.7	1,582.0	482.2	48.0	1219.2	0.3	752,611	lb	**376.3** tons
curve	vertical	1425+18	43+440	2,981.9	908.9	1,589.1	484.4	48.0	1219.2	0.3	765,057	lb	**382.5** tons
curve	vertical	1424+55	43+421	3,044.7	928.0	1,597.3	486.9	48.0	1219.2	0.3	777,416	lb	**388.7** tons
curve	vertical	1423+93	43+402	3,107.6	947.2	1,606.6	489.7	48.0	1219.2	0.3	789,583	lb	**394.8** tons
curve	vertical	1423+31	43+383	3,170.4	966.3	1,617.0	492.9	48.0	1219.2	0.3	801,508	lb	**400.8** tons
curve	vertical	1422+69	43+364	3,233.2	985.5	1,628.4	496.3	48.0	1219.2	0.3	813,170	lb	**406.6** tons
curve	vertical	1422+08	43+345	3,296.1	1,004.7	1,640.9	500.2	48.0	1219.2	0.3	824,555	lb	**412.3** tons
straight		1421+39	43+324	3,366.8	1,026.2	1,655.6	504.6	48.0	1219.2	0.3	829,261	lb	**414.6** tons
straight		1420+70	43+303	3,437.5	1,047.8	1,670.3	509.1	48.0	1219.2	0.3	833,967	lb	**417.0** tons
straight		1420+00	43+282	3,508.2	1,069.3	1,685.0	513.6	48.0	1219.2	0.3	838,673	lb	**419.3** tons
straight		1419+31	43+261	3,578.9	1,090.9	1,699.7	518.1	48.0	1219.2	0.3	843,379	lb	**421.7** tons
straight		1418+62	43+240	3,649.7	1,112.4	1,714.5	522.6	48.0	1219.2	0.3	848,086	lb	**424.0** tons
straight		1417+93	43+219	3,720.4	1,134.0	1,729.2	527.1	48.0	1219.2	0.3	852,793	lb	**426.4** tons
straight		1417+24	43+198	3,791.2	1,155.6	1,743.9	531.5	48.0	1219.2	0.3	857,501	lb	**428.8** tons
HDD Rig Location		1416+54	43+177	3,861.9	1,177.1	1,758.6	536.0	48.0	1219.2	0.3	862,208	lb	**431.1** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
655	4.51	0.94%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
742	5.12	1.06%	0	0.00	0.00%	166	1.15	0.24%	0.01	Yes	0.00	Yes
829	5.72	1.18%	0	0.00	0.00%	332	2.29	0.47%	0.01	Yes	0.00	Yes
916	6.32	1.31%	0	0.00	0.00%	499	3.44	0.71%	0.02	Yes	0.00	Yes
1,003	6.92	1.43%	0	0.00	0.00%	665	4.58	0.95%	0.02	Yes	0.01	Yes
1,091	7.52	1.56%	0	0.00	0.00%	831	5.73	1.19%	0.02	Yes	0.01	Yes
1,178	8.12	1.68%	0	0.00	0.00%	997	6.87	1.42%	0.02	Yes	0.02	Yes
1,265	8.72	1.81%	0	0.00	0.00%	1,163	8.02	1.66%	0.02	Yes	0.02	Yes
1,352	9.32	1.93%	0	0.00	0.00%	1,329	9.17	1.90%	0.02	Yes	0.03	Yes
1,439	9.92	2.06%	0	0.00	0.00%	1,496	10.31	2.14%	0.03	Yes	0.04	Yes
1,527	10.53	2.18%	0	0.00	0.00%	1,662	11.46	2.37%	0.03	Yes	0.05	Yes
1,614	11.13	2.31%	0	0.00	0.00%	1,829	12.61	2.61%	0.03	Yes	0.06	Yes
1,701	11.73	2.43%	0	0.00	0.00%	1,995	13.75	2.85%	0.03	Yes	0.07	Yes
2,317	15.98	3.31%	12,083	83.31	17.26%	2,164	14.92	3.09%	0.31	Yes	0.18	Yes
2,183	15.05	3.12%	12,083	83.31	17.26%	2,319	15.99	3.31%	0.31	Yes	0.19	Yes
2,211	15.24	3.16%	12,083	83.31	17.26%	2,459	16.95	3.51%	0.31	Yes	0.20	Yes
6,514	44.91	9.31%	12,083	83.31	17.26%	2,584	17.82	3.69%	0.39	Yes	0.27	Yes
4,427	30.52	6.32%	12,083	83.31	17.26%	2,695	18.58	3.85%	0.35	Yes	0.26	Yes
5,034	34.71	7.19%	12,083	83.31	17.26%	2,384	16.43	3.41%	0.36	Yes	0.27	Yes
5,190	35.79	7.41%	12,083	83.31	17.26%	2,465	16.99	3.52%	0.36	Yes	0.29	Yes
5,347	36.87	7.64%	12,083	83.31	17.26%	2,531	17.45	3.62%	0.37	Yes	0.30	Yes
5,502	37.94	7.86%	12,083	83.31	17.26%	2,583	17.81	3.69%	0.37	Yes	0.30	Yes
5,656	38.99	8.08%	12,083	83.31	17.26%	2,620	18.07	3.74%	0.37	Yes	0.31	Yes
5,806	40.03	8.29%	12,083	83.31	17.26%	2,642	18.22	3.77%	0.37	Yes	0.32	Yes
5,953	41.04	8.50%	12,083	83.31	17.26%	2,650	18.27	3.79%	0.38	Yes	0.32	Yes
6,057	41.76	8.65%	0	0.00	0.00%	2,650	18.27	3.79%	0.11	Yes	0.19	Yes
6,162	42.49	8.80%	0	0.00	0.00%	2,650	18.27	3.79%	0.11	Yes	0.19	Yes
6,267	43.21	8.95%	0	0.00	0.00%	2,650	18.27	3.79%	0.11	Yes	0.19	Yes
6,371	43.93	9.10%	0	0.00	0.00%	2,650	18.27	3.79%	0.11	Yes	0.19	Yes
6,476	44.65	9.25%	0	0.00	0.00%	2,650	18.27	3.79%	0.12	Yes	0.19	Yes
6,581	45.37	9.40%	0	0.00	0.00%	2,650	18.27	3.79%	0.12	Yes	0.19	Yes
6,685	46.09	9.55%	0	0.00	0.00%	2,650	18.27	3.79%	0.12	Yes	0.19	Yes
6,790	46.82	9.70%	0	0.00	0.00%	2,650	18.27	3.79%	0.12	Yes	0.19	Yes
6,895	47.54	9.85%	0	0.00	0.00%	2,650	18.27	3.79%	0.12	Yes	0.19	Yes
6,999	48.26	10.00%	0	0.00	0.00%	2,650	18.27	3.79%	0.12	Yes	0.19	Yes
7,104	48.98	10.15%	0	0.00	0.00%	2,650	18.27	3.79%	0.13	Yes	0.19	Yes
7,209	49.70	10.30%	0	0.00	0.00%	2,650	18.27	3.79%	0.13	Yes	0.20	Yes
7,314	50.43	10.45%	0	0.00	0.00%	2,650	18.27	3.79%	0.13	Yes	0.20	Yes
7,418	51.15	10.60%	0	0.00	0.00%	2,650	18.27	3.79%	0.13	Yes	0.20	Yes
7,523	51.87	10.75%	0	0.00	0.00%	2,650	18.27	3.79%	0.13	Yes	0.20	Yes
7,628	52.59	10.90%	0	0.00	0.00%	2,650	18.27	3.79%	0.14	Yes	0.20	Yes
8,707	60.03	12.44%	12,083	83.31	17.26%	2,642	18.22	3.77%	0.43	Yes	0.36	Yes
8,471	58.41	12.10%	12,083	83.31	17.26%	2,620	18.07	3.74%	0.42	Yes	0.35	Yes
8,521	58.75	12.17%	12,083	83.31	17.26%	2,583	17.81	3.69%	0.42	Yes	0.35	Yes
8,638	59.55	12.34%	12,083	83.31	17.26%	2,531	17.45	3.62%	0.42	Yes	0.35	Yes
8,776	60.51	12.54%	12,083	83.31	17.26%	2,465	16.99	3.52%	0.43	Yes	0.34	Yes
8,922	61.51	12.75%	12,083	83.31	17.26%	2,384	16.43	3.41%	0.43	Yes	0.33	Yes
9,069	62.53	12.96%	12,083	83.31	17.26%	2,288	15.77	3.27%	0.43	Yes	0.33	Yes
9,216	63.54	13.17%	12,083	83.31	17.26%	2,177	15.01	3.11%	0.44	Yes	0.32	Yes
9,360	64.54	13.37%	12,083	83.31	17.26%	2,052	14.14	2.93%	0.44	Yes	0.30	Yes
9,501	65.51	13.57%	12,083	83.31	17.26%	1,912	13.18	2.73%	0.44	Yes	0.29	Yes
9,640	66.46	13.77%	12,083	83.31	17.26%	1,757	12.11	2.51%	0.44	Yes	0.28	Yes
9,775	67.39	13.96%	12,083	83.31	17.26%	1,588	10.95	2.27%	0.45	Yes	0.27	Yes
9,830	67.78	14.04%	0	0.00	0.00%	1,389	9.58	1.98%	0.18	Yes	0.10	Yes
9,886	68.16	14.12%	0	0.00	0.00%	1,191	8.21	1.70%	0.18	Yes	0.09	Yes
9,942	68.55	14.20%	0	0.00	0.00%	993	6.84	1.42%	0.18	Yes	0.08	Yes
9,998	68.93	14.28%	0	0.00	0.00%	794	5.48	1.13%	0.18	Yes	0.07	Yes
10,054	69.32	14.36%	0	0.00	0.00%	596	4.11	0.85%	0.18	Yes	0.06	Yes
10,109	69.70	14.44%	0	0.00	0.00%	397	2.74	0.57%	0.18	Yes	0.05	Yes
10,165	70.09	14.52%	0	0.00	0.00%	199	1.37	0.28%	0.18	Yes	0.05	Yes
10,221	70.47	14.60%	0	0.00	0.00%	0	0.00	0.00%	0.18	Yes	0.04	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	1788.73	feet
	545.21	metres
Ground Elevation at Pipe Exit	1758.58	feet
	536.02	metres

	TOTAL PULL LOADS		
Maximum Values	862,208	lb	431.1 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
10,221	70.5	14.60%	12,083	83.3	17.26%	2,695	18.6	3.85%	0.45	0.36

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	0.0	lbs/ft
	0.00	kg/m
Net Buoyant Weight of pipe	-294.6	lbs/ft
	-439.27	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m

Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	862,208	lb
	3,835	kN
Factor of Safety	4.1	

Start-up Load Factor	1.5	
Required Pipe Pull Load	549,517	lb
	2,444	kN
Factor of Safety	6.4	

Soil and Mud Properties

Mud Weight	11	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.319	Specific Gravity
Friction Coeff. (GS or rollers)	0.2	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Hammerschmidt
Checked by: G. Duyvestyn
Date: 2/6/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Interstate 80

Reference:
1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		1454+77	44+342	0.0	0.0	1,788.7	545.2	--	--		55,227	lb	**27.6** tons
straight		1454+19	44+324	59.2	18.1	1,776.4	541.5	48.0	1219.2	0.3	54,394	lb	**27.2** tons
straight		1453+62	44+307	118.4	36.1	1,764.1	537.7	48.0	1219.2	0.3	53,561	lb	**26.8** tons
straight		1453+04	44+289	177.7	54.2	1,751.8	534.0	48.0	1219.2	0.3	52,727	lb	**26.4** tons
straight		1452+46	44+271	236.9	72.2	1,739.5	530.2	48.0	1219.2	0.3	51,894	lb	**25.9** tons
straight		1451+88	44+254	296.1	90.3	1,727.2	526.4	48.0	1219.2	0.3	51,060	lb	**25.5** tons
straight		1451+30	44+236	355.3	108.3	1,714.9	522.7	48.0	1219.2	0.3	50,227	lb	**25.1** tons
straight		1450+72	44+218	414.5	126.4	1,702.5	518.9	48.0	1219.2	0.3	49,393	lb	**24.7** tons
straight		1450+14	44+201	473.8	144.4	1,690.2	515.2	48.0	1219.2	0.3	48,560	lb	**24.3** tons
straight		1449+56	44+183	533.0	162.5	1,677.9	511.4	48.0	1219.2	0.3	47,725	lb	**23.9** tons
straight		1448+98	44+165	592.3	180.5	1,665.6	507.7	48.0	1219.2	0.3	46,891	lb	**23.4** tons
straight		1448+40	44+148	651.6	198.6	1,653.3	503.9	48.0	1219.2	0.3	46,057	lb	**23.0** tons
straight		1447+82	44+130	710.9	216.7	1,640.9	500.2	48.0	1219.2	0.3	45,222	lb	**22.6** tons
curve	vertical	1447+20	44+111	773.7	235.8	1,628.4	496.3	48.0	1219.2	0.3	82,122	lb	**41.1** tons
curve	vertical	1446+59	44+093	836.5	255.0	1,617.0	492.9	48.0	1219.2	0.3	56,017	lb	**28.0** tons
curve	vertical	1445+97	44+074	899.4	274.1	1,606.6	489.7	48.0	1219.2	0.3	43,983	lb	**22.0** tons
curve	vertical	1445+35	44+055	962.2	293.3	1,597.3	486.9	48.0	1219.2	0.3	314,959	lb	**157.5** tons
curve	vertical	1444+72	44+036	1,025.0	312.4	1,589.1	484.4	48.0	1219.2	0.3	205,135	lb	**102.6** tons
curve	vertical	1444+10	44+017	1,087.9	331.6	1,582.0	482.2	48.0	1219.2	0.3	208,952	lb	**104.5** tons
curve	vertical	1443+47	43+998	1,150.7	350.7	1,576.0	480.4	48.0	1219.2	0.3	211,600	lb	**105.8** tons
curve	vertical	1442+85	43+979	1,213.5	369.9	1,571.0	478.9	48.0	1219.2	0.3	213,894	lb	**106.9** tons
curve	vertical	1442+22	43+959	1,276.4	389.0	1,567.2	477.7	48.0	1219.2	0.3	215,974	lb	**108.0** tons
curve	vertical	1441+59	43+940	1,339.2	408.2	1,564.5	476.9	48.0	1219.2	0.3	217,927	lb	**109.0** tons
curve	vertical	1440+96	43+921	1,402.0	427.3	1,562.8	476.4	48.0	1219.2	0.3	219,806	lb	**109.9** tons
curve	vertical	1440+34	43+902	1,464.9	446.5	1,562.3	476.2	48.0	1219.2	0.3	221,645	lb	**110.8** tons
straight		1439+66	43+881	1,532.2	467.0	1,562.3	476.2	48.0	1219.2	0.3	223,951	lb	**112.0** tons
straight		1438+99	43+861	1,599.5	487.5	1,562.3	476.2	48.0	1219.2	0.3	226,257	lb	**113.1** tons
straight		1438+32	43+840	1,666.8	508.1	1,562.3	476.2	48.0	1219.2	0.3	228,563	lb	**114.3** tons
straight		1437+64	43+820	1,734.2	528.6	1,562.3	476.2	48.0	1219.2	0.3	230,869	lb	**115.4** tons
straight		1436+97	43+799	1,801.5	549.1	1,562.3	476.2	48.0	1219.2	0.3	233,176	lb	**116.6** tons
straight		1436+30	43+779	1,868.8	569.6	1,562.3	476.2	48.0	1219.2	0.3	235,482	lb	**117.7** tons
straight		1435+62	43+758	1,936.1	590.1	1,562.3	476.2	48.0	1219.2	0.3	237,788	lb	**118.9** tons
straight		1434+95	43+738	2,003.5	610.7	1,562.3	476.2	48.0	1219.2	0.3	240,094	lb	**120.0** tons
straight		1434+28	43+717	2,070.8	631.2	1,562.3	476.2	48.0	1219.2	0.3	242,400	lb	**121.2** tons
straight		1433+60	43+697	2,138.1	651.7	1,562.3	476.2	48.0	1219.2	0.3	244,706	lb	**122.4** tons
straight		1432+93	43+676	2,205.4	672.2	1,562.3	476.2	48.0	1219.2	0.3	247,012	lb	**123.5** tons
straight		1432+26	43+656	2,272.8	692.7	1,562.3	476.2	48.0	1219.2	0.3	249,318	lb	**124.7** tons
straight		1431+58	43+635	2,340.1	713.3	1,562.3	476.2	48.0	1219.2	0.3	251,624	lb	**125.8** tons
straight		1430+91	43+615	2,407.4	733.8	1,562.3	476.2	48.0	1219.2	0.3	253,931	lb	**127.0** tons
straight		1430+24	43+594	2,474.8	754.3	1,562.3	476.2	48.0	1219.2	0.3	256,237	lb	**128.1** tons
straight		1429+56	43+574	2,542.1	774.8	1,562.3	476.2	48.0	1219.2	0.3	258,543	lb	**129.3** tons
curve	vertical	1428+94	43+554	2,604.9	794.0	1,562.8	476.4	48.0	1219.2	0.3	328,792	lb	**164.4** tons
curve	vertical	1428+31	43+535	2,667.7	813.1	1,564.5	476.9	48.0	1219.2	0.3	288,566	lb	**144.3** tons
curve	vertical	1427+68	43+516	2,730.6	832.3	1,567.2	477.7	48.0	1219.2	0.3	272,924	lb	**136.5** tons
curve	vertical	1427+05	43+497	2,793.4	851.4	1,571.0	478.9	48.0	1219.2	0.3	263,514	lb	**131.8** tons
curve	vertical	1426+43	43+478	2,856.2	870.6	1,576.0	480.4	48.0	1219.2	0.3	256,673	lb	**128.3** tons
curve	vertical	1425+80	43+459	2,919.1	889.7	1,582.0	482.2	48.0	1219.2	0.3	252,495	lb	**126.2** tons
curve	vertical	1425+18	43+440	2,981.9	908.9	1,589.1	484.4	48.0	1219.2	0.3	255,465	lb	**127.7** tons
curve	vertical	1424+55	43+421	3,044.7	928.0	1,597.3	486.9	48.0	1219.2	0.3	258,059	lb	**129.0** tons
curve	vertical	1423+93	43+402	3,107.6	947.2	1,606.6	489.7	48.0	1219.2	0.3	260,423	lb	**130.2** tons
curve	vertical	1423+31	43+383	3,170.4	966.3	1,617.0	492.9	48.0	1219.2	0.3	262,644	lb	**131.3** tons
curve	vertical	1422+69	43+364	3,233.2	985.5	1,628.4	496.3	48.0	1219.2	0.3	264,777	lb	**132.4** tons
curve	vertical	1422+08	43+345	3,296.1	1,004.7	1,640.9	500.2	48.0	1219.2	0.3	266,862	lb	**133.4** tons
straight		1421+39	43+324	3,366.8	1,026.2	1,655.6	504.6	48.0	1219.2	0.3	270,812	lb	**135.4** tons
straight		1420+70	43+303	3,437.5	1,047.8	1,670.3	509.1	48.0	1219.2	0.3	274,762	lb	**137.4** tons
straight		1420+00	43+282	3,508.2	1,069.3	1,685.0	513.6	48.0	1219.2	0.3	278,712	lb	**139.4** tons
straight		1419+31	43+261	3,578.9	1,090.9	1,699.7	518.1	48.0	1219.2	0.3	282,662	lb	**141.3** tons
straight		1418+62	43+240	3,649.7	1,112.4	1,714.5	522.6	48.0	1219.2	0.3	286,613	lb	**143.3** tons
straight		1417+93	43+219	3,720.4	1,134.0	1,729.2	527.1	48.0	1219.2	0.3	290,565	lb	**145.3** tons
straight		1417+24	43+198	3,791.2	1,155.6	1,743.9	531.5	48.0	1219.2	0.3	294,516	lb	**147.3** tons
HDD Rig Location		1416+54	43+177	3,861.9	1,177.1	1,758.6	536.0	48.0	1219.2	0.3	298,467	lb	**149.2** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
655	4.51	0.94%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
645	4.45	0.92%	0	0.00	0.00%	40	0.28	0.06%	0.01	Yes	0.00	Yes
635	4.38	0.91%	0	0.00	0.00%	80	0.55	0.11%	0.01	Yes	0.00	Yes
625	4.31	0.89%	0	0.00	0.00%	120	0.83	0.17%	0.01	Yes	0.00	Yes
615	4.24	0.88%	0	0.00	0.00%	161	1.11	0.23%	0.01	Yes	0.00	Yes
605	4.17	0.86%	0	0.00	0.00%	201	1.38	0.29%	0.01	Yes	0.00	Yes
595	4.11	0.85%	0	0.00	0.00%	241	1.66	0.34%	0.01	Yes	0.00	Yes
586	4.04	0.84%	0	0.00	0.00%	281	1.94	0.40%	0.01	Yes	0.00	Yes
576	3.97	0.82%	0	0.00	0.00%	321	2.21	0.46%	0.01	Yes	0.00	Yes
566	3.90	0.81%	0	0.00	0.00%	361	2.49	0.52%	0.01	Yes	0.00	Yes
556	3.83	0.79%	0	0.00	0.00%	402	2.77	0.57%	0.01	Yes	0.00	Yes
546	3.76	0.78%	0	0.00	0.00%	442	3.05	0.63%	0.01	Yes	0.00	Yes
536	3.70	0.77%	0	0.00	0.00%	482	3.32	0.69%	0.01	Yes	0.00	Yes
974	6.71	1.39%	12,083	83.31	17.26%	523	3.60	0.75%	0.29	Yes	0.07	Yes
664	4.58	0.95%	12,083	83.31	17.26%	560	3.86	0.80%	0.28	Yes	0.06	Yes
521	3.59	0.74%	12,083	83.31	17.26%	594	4.10	0.85%	0.28	Yes	0.06	Yes
3,734	25.74	5.33%	12,083	83.31	17.26%	624	4.30	0.89%	0.34	Yes	0.10	Yes
2,432	16.77	3.47%	12,083	83.31	17.26%	651	4.49	0.93%	0.31	Yes	0.08	Yes
2,477	17.08	3.54%	12,083	83.31	17.26%	576	3.97	0.82%	0.31	Yes	0.09	Yes
2,508	17.29	3.58%	12,083	83.31	17.26%	596	4.11	0.85%	0.32	Yes	0.09	Yes
2,536	17.48	3.62%	12,083	83.31	17.26%	612	4.22	0.87%	0.32	Yes	0.09	Yes
2,560	17.65	3.66%	12,083	83.31	17.26%	624	4.30	0.89%	0.32	Yes	0.09	Yes
2,583	17.81	3.69%	12,083	83.31	17.26%	633	4.36	0.90%	0.32	Yes	0.09	Yes
2,606	17.97	3.72%	12,083	83.31	17.26%	638	4.40	0.91%	0.32	Yes	0.09	Yes
2,627	18.12	3.75%	12,083	83.31	17.26%	640	4.41	0.91%	0.32	Yes	0.09	Yes
2,655	18.30	3.79%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,682	18.49	3.83%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,710	18.68	3.87%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,737	18.87	3.91%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,764	19.06	3.95%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,792	19.25	3.99%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,819	19.44	4.03%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,846	19.62	4.07%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,874	19.81	4.11%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,901	20.00	4.14%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,928	20.19	4.18%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,956	20.38	4.22%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
2,983	20.57	4.26%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
3,010	20.75	4.30%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
3,038	20.94	4.34%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
3,065	21.13	4.38%	0	0.00	0.00%	640	4.41	0.91%	0.05	Yes	0.01	Yes
3,898	26.87	5.57%	12,083	83.31	17.26%	638	4.40	0.91%	0.34	Yes	0.10	Yes
3,421	23.59	4.89%	12,083	83.31	17.26%	633	4.36	0.90%	0.33	Yes	0.10	Yes
3,235	22.31	4.62%	12,083	83.31	17.26%	624	4.30	0.89%	0.33	Yes	0.10	Yes
3,124	21.54	4.46%	12,083	83.31	17.26%	612	4.22	0.87%	0.33	Yes	0.09	Yes
3,043	20.98	4.35%	12,083	83.31	17.26%	596	4.11	0.85%	0.32	Yes	0.09	Yes
2,993	20.64	4.28%	12,083	83.31	17.26%	576	3.97	0.82%	0.32	Yes	0.09	Yes
3,028	20.88	4.33%	12,083	83.31	17.26%	553	3.81	0.79%	0.32	Yes	0.09	Yes
3,059	21.09	4.37%	12,083	83.31	17.26%	526	3.63	0.75%	0.33	Yes	0.09	Yes
3,087	21.29	4.41%	12,083	83.31	17.26%	496	3.42	0.71%	0.33	Yes	0.09	Yes
3,114	21.47	4.45%	12,083	83.31	17.26%	462	3.18	0.66%	0.33	Yes	0.09	Yes
3,139	21.64	4.48%	12,083	83.31	17.26%	425	2.93	0.61%	0.33	Yes	0.09	Yes
3,164	21.81	4.52%	12,083	83.31	17.26%	384	2.65	0.55%	0.33	Yes	0.09	Yes
3,210	22.13	4.59%	0	0.00	0.00%	336	2.31	0.48%	0.06	Yes	0.01	Yes
3,257	22.46	4.65%	0	0.00	0.00%	288	1.98	0.41%	0.06	Yes	0.01	Yes
3,304	22.78	4.72%	0	0.00	0.00%	240	1.65	0.34%	0.06	Yes	0.01	Yes
3,351	23.10	4.79%	0	0.00	0.00%	192	1.32	0.27%	0.06	Yes	0.01	Yes
3,398	23.43	4.85%	0	0.00	0.00%	144	0.99	0.21%	0.06	Yes	0.01	Yes
3,445	23.75	4.92%	0	0.00	0.00%	96	0.66	0.14%	0.06	Yes	0.01	Yes
3,491	24.07	4.99%	0	0.00	0.00%	48	0.33	0.07%	0.06	Yes	0.00	Yes
3,538	24.39	5.05%	0	0.00	0.00%	0	0.00	0.00%	0.06	Yes	0.00	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	1788.73	feet
	545.21	metres
Ground Elevation at Pipe Exit	1758.58	feet
	536.02	metres

	TOTAL PULL LOADS		
Maximum Values	328,792	lb	164.4 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
3,898	26.9	5.57%	12,083	83.3	17.26%	651	4.5	0.93%	0.34	0.10

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	404.5	lbs/ft
	603.26	kg/m
Net Buoyant Weight of pipe	110.0	lbs/ft
	163.99	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m
Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	328,792	lb
	1,463	kN
Factor of Safety	10.8	
Start-up Load Factor	1.5	
Required Pipe Pull Load	314,959	lb
	1,401	kN
Factor of Safety	11.2	

Soil and Mud Properties

Mud Weight	11	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.319	Specific Gravity
Friction Coeff. (GS or rollers)	0.2	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Hammerschmidt
Checked by: G. Duyvestyn
Date: 2/6/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Interstate 80

Reference:
1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		1454+77	44+342	0.0	0.0	1,788.7	545.2	--	--		55,227	lb	**27.6** tons
straight		1454+19	44+324	59.2	18.1	1,776.4	541.5	48.0	1219.2	0.3	64,152	lb	**32.1** tons
straight		1453+62	44+307	118.4	36.1	1,764.1	537.7	48.0	1219.2	0.3	73,077	lb	**36.5** tons
straight		1453+04	44+289	177.7	54.2	1,751.8	534.0	48.0	1219.2	0.3	82,002	lb	**41.0** tons
straight		1452+46	44+271	236.9	72.2	1,739.5	530.2	48.0	1219.2	0.3	90,926	lb	**45.5** tons
straight		1451+88	44+254	296.1	90.3	1,727.2	526.4	48.0	1219.2	0.3	99,851	lb	**49.9** tons
straight		1451+30	44+236	355.3	108.3	1,714.9	522.7	48.0	1219.2	0.3	108,776	lb	**54.4** tons
straight		1450+72	44+218	414.5	126.4	1,702.5	518.9	48.0	1219.2	0.3	117,701	lb	**58.9** tons
straight		1450+14	44+201	473.8	144.4	1,690.2	515.2	48.0	1219.2	0.3	126,625	lb	**63.3** tons
straight		1449+56	44+183	533.0	162.5	1,677.9	511.4	48.0	1219.2	0.3	135,559	lb	**67.8** tons
straight		1448+98	44+165	592.3	180.5	1,665.6	507.7	48.0	1219.2	0.3	144,494	lb	**72.2** tons
straight		1448+40	44+148	651.6	198.6	1,653.3	503.9	48.0	1219.2	0.3	153,428	lb	**76.7** tons
straight		1447+82	44+130	710.9	216.7	1,640.9	500.2	48.0	1219.2	0.3	162,362	lb	**81.2** tons
curve	vertical	1447+20	44+111	773.7	235.8	1,628.4	496.3	48.0	1219.2	0.3	216,337	lb	**108.2** tons
curve	vertical	1446+59	44+093	836.5	255.0	1,617.0	492.9	48.0	1219.2	0.3	206,935	lb	**103.5** tons
curve	vertical	1445+97	44+074	899.4	274.1	1,606.6	489.7	48.0	1219.2	0.3	211,198	lb	**105.6** tons
curve	vertical	1445+35	44+055	962.2	293.3	1,597.3	486.9	48.0	1219.2	0.3	589,345	lb	**294.7** tons
curve	vertical	1444+72	44+036	1,025.0	312.4	1,589.1	484.4	48.0	1219.2	0.3	445,269	lb	**222.6** tons
curve	vertical	1444+10	44+017	1,087.9	331.6	1,582.0	482.2	48.0	1219.2	0.3	460,870	lb	**230.4** tons
curve	vertical	1443+47	43+998	1,150.7	350.7	1,576.0	480.4	48.0	1219.2	0.3	476,702	lb	**238.4** tons
curve	vertical	1442+85	43+979	1,213.5	369.9	1,571.0	478.9	48.0	1219.2	0.3	492,488	lb	**246.2** tons
curve	vertical	1442+22	43+959	1,276.4	389.0	1,567.2	477.7	48.0	1219.2	0.3	508,080	lb	**254.0** tons
curve	vertical	1441+59	43+940	1,339.2	408.2	1,564.5	476.9	48.0	1219.2	0.3	523,400	lb	**261.7** tons
curve	vertical	1440+96	43+921	1,402.0	427.3	1,562.8	476.4	48.0	1219.2	0.3	538,408	lb	**269.2** tons
curve	vertical	1440+34	43+902	1,464.9	446.5	1,562.3	476.2	48.0	1219.2	0.3	553,082	lb	**276.5** tons
straight		1439+66	43+881	1,532.2	467.0	1,562.3	476.2	48.0	1219.2	0.3	563,782	lb	**281.9** tons
straight		1438+99	43+861	1,599.5	487.5	1,562.3	476.2	48.0	1219.2	0.3	574,481	lb	**287.2** tons
straight		1438+32	43+840	1,666.8	508.1	1,562.3	476.2	48.0	1219.2	0.3	585,181	lb	**292.6** tons
straight		1437+64	43+820	1,734.2	528.6	1,562.3	476.2	48.0	1219.2	0.3	595,880	lb	**297.9** tons
straight		1436+97	43+799	1,801.5	549.1	1,562.3	476.2	48.0	1219.2	0.3	606,579	lb	**303.3** tons
straight		1436+30	43+779	1,868.8	569.6	1,562.3	476.2	48.0	1219.2	0.3	617,279	lb	**308.6** tons
straight		1435+62	43+758	1,936.1	590.1	1,562.3	476.2	48.0	1219.2	0.3	627,978	lb	**314.0** tons
straight		1434+95	43+738	2,003.5	610.7	1,562.3	476.2	48.0	1219.2	0.3	638,678	lb	**319.3** tons
straight		1434+28	43+717	2,070.8	631.2	1,562.3	476.2	48.0	1219.2	0.3	649,377	lb	**324.7** tons
straight		1433+60	43+697	2,138.1	651.7	1,562.3	476.2	48.0	1219.2	0.3	660,076	lb	**330.0** tons
straight		1432+93	43+676	2,205.4	672.2	1,562.3	476.2	48.0	1219.2	0.3	670,776	lb	**335.4** tons
straight		1432+26	43+656	2,272.8	692.7	1,562.3	476.2	48.0	1219.2	0.3	681,475	lb	**340.7** tons
straight		1431+58	43+635	2,340.1	713.3	1,562.3	476.2	48.0	1219.2	0.3	692,175	lb	**346.1** tons
straight		1430+91	43+615	2,407.4	733.8	1,562.3	476.2	48.0	1219.2	0.3	702,875	lb	**351.4** tons
straight		1430+24	43+594	2,474.8	754.3	1,562.3	476.2	48.0	1219.2	0.3	713,576	lb	**356.8** tons
straight		1429+56	43+574	2,542.1	774.8	1,562.3	476.2	48.0	1219.2	0.3	724,276	lb	**362.1** tons
curve	vertical	1428+94	43+554	2,604.9	794.0	1,562.8	476.4	48.0	1219.2	0.3	818,347	lb	**409.2** tons
curve	vertical	1428+31	43+535	2,667.7	813.1	1,564.5	476.9	48.0	1219.2	0.3	801,484	lb	**400.7** tons
curve	vertical	1427+68	43+516	2,730.6	832.3	1,567.2	477.7	48.0	1219.2	0.3	808,558	lb	**404.3** tons
curve	vertical	1427+05	43+497	2,793.4	851.4	1,571.0	478.9	48.0	1219.2	0.3	821,089	lb	**410.5** tons
curve	vertical	1426+43	43+478	2,856.2	870.6	1,576.0	480.4	48.0	1219.2	0.3	835,357	lb	**417.7** tons
curve	vertical	1425+80	43+459	2,919.1	889.7	1,582.0	482.2	48.0	1219.2	0.3	850,145	lb	**425.1** tons
curve	vertical	1425+18	43+440	2,981.9	908.9	1,589.1	484.4	48.0	1219.2	0.3	864,968	lb	**432.5** tons
curve	vertical	1424+55	43+421	3,044.7	928.0	1,597.3	486.9	48.0	1219.2	0.3	879,619	lb	**439.8** tons
curve	vertical	1423+93	43+402	3,107.6	947.2	1,606.6	489.7	48.0	1219.2	0.3	894,005	lb	**447.0** tons
curve	vertical	1423+31	43+383	3,170.4	966.3	1,617.0	492.9	48.0	1219.2	0.3	908,086	lb	**454.0** tons
curve	vertical	1422+69	43+364	3,233.2	985.5	1,628.4	496.3	48.0	1219.2	0.3	921,846	lb	**460.9** tons
curve	vertical	1422+08	43+345	3,296.1	1,004.7	1,640.9	500.2	48.0	1219.2	0.3	935,275	lb	**467.6** tons
straight		1421+39	43+324	3,366.8	1,026.2	1,655.6	504.6	48.0	1219.2	0.3	941,124	lb	**470.6** tons
straight		1420+70	43+303	3,437.5	1,047.8	1,670.3	509.1	48.0	1219.2	0.3	946,973	lb	**473.5** tons
straight		1420+00	43+282	3,508.2	1,069.3	1,685.0	513.6	48.0	1219.2	0.3	952,821	lb	**476.4** tons
straight		1419+31	43+261	3,578.9	1,090.9	1,699.7	518.1	48.0	1219.2	0.3	958,670	lb	**479.3** tons
straight		1418+62	43+240	3,649.7	1,112.4	1,714.5	522.6	48.0	1219.2	0.3	964,520	lb	**482.3** tons
straight		1417+93	43+219	3,720.4	1,134.0	1,729.2	527.1	48.0	1219.2	0.3	970,371	lb	**485.2** tons
straight		1417+24	43+198	3,791.2	1,155.6	1,743.9	531.5	48.0	1219.2	0.3	976,221	lb	**488.1** tons
HDD Rig Location		1416+54	43+177	3,861.9	1,177.1	1,758.6	536.0	48.0	1219.2	0.3	982,072	lb	**491.0** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
655	4.51	0.94%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
760	5.24	1.09%	0	0.00	0.00%	181	1.25	0.26%	0.01	Yes	0.00	Yes
866	5.97	1.24%	0	0.00	0.00%	363	2.50	0.52%	0.02	Yes	0.00	Yes
972	6.70	1.39%	0	0.00	0.00%	544	3.75	0.78%	0.02	Yes	0.01	Yes
1,078	7.43	1.54%	0	0.00	0.00%	725	5.00	1.04%	0.02	Yes	0.01	Yes
1,184	8.16	1.69%	0	0.00	0.00%	906	6.25	1.29%	0.02	Yes	0.02	Yes
1,289	8.89	1.84%	0	0.00	0.00%	1,088	7.50	1.55%	0.02	Yes	0.02	Yes
1,395	9.62	1.99%	0	0.00	0.00%	1,269	8.75	1.81%	0.02	Yes	0.03	Yes
1,501	10.35	2.14%	0	0.00	0.00%	1,450	10.00	2.07%	0.03	Yes	0.04	Yes
1,607	11.08	2.30%	0	0.00	0.00%	1,632	11.25	2.33%	0.03	Yes	0.05	Yes
1,713	11.81	2.45%	0	0.00	0.00%	1,813	12.50	2.59%	0.03	Yes	0.06	Yes
1,819	12.54	2.60%	0	0.00	0.00%	1,995	13.75	2.85%	0.03	Yes	0.07	Yes
1,925	13.27	2.75%	0	0.00	0.00%	2,176	15.00	3.11%	0.03	Yes	0.08	Yes
2,565	17.68	3.66%	12,083	83.31	17.26%	2,361	16.28	3.37%	0.32	Yes	0.20	Yes
2,453	16.91	3.50%	12,083	83.31	17.26%	2,529	17.44	3.61%	0.31	Yes	0.21	Yes
2,504	17.26	3.58%	12,083	83.31	17.26%	2,682	18.49	3.83%	0.32	Yes	0.23	Yes
6,986	48.17	9.98%	12,083	83.31	17.26%	2,819	19.43	4.03%	0.40	Yes	0.31	Yes
5,278	36.39	7.54%	12,083	83.31	17.26%	2,496	17.21	3.57%	0.36	Yes	0.29	Yes
5,463	37.67	7.80%	12,083	83.31	17.26%	2,600	17.93	3.71%	0.37	Yes	0.31	Yes
5,651	38.96	8.07%	12,083	83.31	17.26%	2,689	18.54	3.84%	0.37	Yes	0.32	Yes
5,838	40.25	8.34%	12,083	83.31	17.26%	2,762	19.04	3.95%	0.37	Yes	0.34	Yes
6,023	41.53	8.60%	12,083	83.31	17.26%	2,818	19.43	4.03%	0.38	Yes	0.35	Yes
6,205	42.78	8.86%	12,083	83.31	17.26%	2,858	19.71	4.08%	0.38	Yes	0.35	Yes
6,383	44.01	9.12%	12,083	83.31	17.26%	2,883	19.87	4.12%	0.38	Yes	0.36	Yes
6,557	45.21	9.37%	12,083	83.31	17.26%	2,891	19.93	4.13%	0.39	Yes	0.36	Yes
6,683	46.08	9.55%	0	0.00	0.00%	2,891	19.93	4.13%	0.12	Yes	0.22	Yes
6,810	46.95	9.73%	0	0.00	0.00%	2,891	19.93	4.13%	0.12	Yes	0.22	Yes
6,937	47.83	9.91%	0	0.00	0.00%	2,891	19.93	4.13%	0.12	Yes	0.22	Yes
7,064	48.70	10.09%	0	0.00	0.00%	2,891	19.93	4.13%	0.13	Yes	0.23	Yes
7,191	49.58	10.27%	0	0.00	0.00%	2,891	19.93	4.13%	0.13	Yes	0.23	Yes
7,318	50.45	10.45%	0	0.00	0.00%	2,891	19.93	4.13%	0.13	Yes	0.23	Yes
7,444	51.33	10.63%	0	0.00	0.00%	2,891	19.93	4.13%	0.13	Yes	0.23	Yes
7,571	52.20	10.82%	0	0.00	0.00%	2,891	19.93	4.13%	0.14	Yes	0.23	Yes
7,698	53.08	11.00%	0	0.00	0.00%	2,891	19.93	4.13%	0.14	Yes	0.23	Yes
7,825	53.95	11.18%	0	0.00	0.00%	2,891	19.93	4.13%	0.14	Yes	0.23	Yes
7,952	54.83	11.36%	0	0.00	0.00%	2,891	19.93	4.13%	0.14	Yes	0.23	Yes
8,079	55.70	11.54%	0	0.00	0.00%	2,891	19.93	4.13%	0.14	Yes	0.23	Yes
8,205	56.57	11.72%	0	0.00	0.00%	2,891	19.93	4.13%	0.15	Yes	0.24	Yes
8,332	57.45	11.90%	0	0.00	0.00%	2,891	19.93	4.13%	0.15	Yes	0.24	Yes
8,459	58.32	12.08%	0	0.00	0.00%	2,891	19.93	4.13%	0.15	Yes	0.24	Yes
8,586	59.20	12.27%	0	0.00	0.00%	2,891	19.93	4.13%	0.15	Yes	0.24	Yes
9,701	66.89	13.86%	12,083	83.31	17.26%	2,883	19.87	4.12%	0.44	Yes	0.41	Yes
9,501	65.51	13.57%	12,083	83.31	17.26%	2,858	19.71	4.08%	0.44	Yes	0.41	Yes
9,585	66.09	13.69%	12,083	83.31	17.26%	2,818	19.43	4.03%	0.44	Yes	0.40	Yes
9,734	67.11	13.91%	12,083	83.31	17.26%	2,762	19.04	3.95%	0.44	Yes	0.40	Yes
9,903	68.28	14.15%	12,083	83.31	17.26%	2,689	18.54	3.84%	0.45	Yes	0.39	Yes
10,078	69.49	14.40%	12,083	83.31	17.26%	2,600	17.93	3.71%	0.45	Yes	0.38	Yes
10,254	70.70	14.65%	12,083	83.31	17.26%	2,496	17.21	3.57%	0.45	Yes	0.37	Yes
10,427	71.89	14.90%	12,083	83.31	17.26%	2,375	16.37	3.39%	0.46	Yes	0.36	Yes
10,598	73.07	15.14%	12,083	83.31	17.26%	2,238	15.43	3.20%	0.46	Yes	0.35	Yes
10,765	74.22	15.38%	12,083	83.31	17.26%	2,085	14.38	2.98%	0.46	Yes	0.34	Yes
10,928	75.35	15.61%	12,083	83.31	17.26%	1,917	13.22	2.74%	0.47	Yes	0.32	Yes
11,087	76.44	15.84%	12,083	83.31	17.26%	1,732	11.94	2.47%	0.47	Yes	0.30	Yes
11,157	76.92	15.94%	0	0.00	0.00%	1,516	10.45	2.17%	0.20	Yes	0.13	Yes
11,226	77.40	16.04%	0	0.00	0.00%	1,299	8.96	1.86%	0.20	Yes	0.11	Yes
11,295	77.88	16.14%	0	0.00	0.00%	1,083	7.47	1.55%	0.20	Yes	0.10	Yes
11,365	78.36	16.24%	0	0.00	0.00%	866	5.97	1.24%	0.20	Yes	0.09	Yes
11,434	78.83	16.33%	0	0.00	0.00%	650	4.48	0.93%	0.20	Yes	0.08	Yes
11,503	79.31	16.43%	0	0.00	0.00%	433	2.99	0.62%	0.21	Yes	0.07	Yes
11,573	79.79	16.53%	0	0.00	0.00%	217	1.49	0.31%	0.21	Yes	0.06	Yes
11,642	80.27	16.63%	0	0.00	0.00%	0	0.00	0.00%	0.21	Yes	0.05	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	1788.73	feet
	545.21	metres
Ground Elevation at Pipe Exit	1758.58	feet
	536.02	metres

	TOTAL PULL LOADS		
Maximum Values	982,072	lb	491.0 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
11,642	80.3	16.63%	12,083	83.3	17.26%	2,891	19.9	4.13%	0.47	0.41

Input Pipe Properties

Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	0.0	lbs/ft
	0.00	kg/m
Net Buoyant Weight of pipe	-347.4	lbs/ft
	-518.11	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m
Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	982,072	lb
	4,368	kN
Factor of Safety	3.6	
Start-up Load Factor	1.5	
Required Pipe Pull Load	589,345	lb
	2,622	kN
Factor of Safety	6.0	

Soil and Mud Properties

Mud Weight	12	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.439	Specific Gravity
Friction Coeff. (GS or rollers)	0.2	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

MOTT MACDONALD

Horizontal Directional Drilling
Calculation of Pull Loads and Stresses during Pipe Installation

Calculated by: S. Hammerschmidt
Checked by: G. Duyvestyn
Date: 2/6/2017
Project No: 353754

PROJECT: PennEast Pipeline

HDD CROSSING LOCATION: Interstate 80

Reference:
1. **Installation of Pipelines by Horizontal Directional Drilling, an Engineering Guide, PRCI Publication 2015**
2. **Pipeline Design for Installation by Horizontal Directional Drilling, Manual of Practice, ASCE MREP 108, 2005**

HDD Installation Load Analysis

Segment Type	Type of Curve	Bore Stationing		Installed Length		Bore Elevation		Bore Diameter		Geotechnical Friction Factor	TOTAL PULL LOADS		
		feet	metres	feet	metres	feet	metres	inch	mm				
Pipe Entry Location		1454+77	44+342	0.0	0.0	1,788.7	545.2	--	--		55,227	lb	**27.6** tons
straight		1454+19	44+324	59.2	18.1	1,776.4	541.5	48.0	1219.2	0.3	54,126	lb	**27.1** tons
straight		1453+62	44+307	118.4	36.1	1,764.1	537.7	48.0	1219.2	0.3	53,025	lb	**26.5** tons
straight		1453+04	44+289	177.7	54.2	1,751.8	534.0	48.0	1219.2	0.3	51,924	lb	**26.0** tons
straight		1452+46	44+271	236.9	72.2	1,739.5	530.2	48.0	1219.2	0.3	50,822	lb	**25.4** tons
straight		1451+88	44+254	296.1	90.3	1,727.2	526.4	48.0	1219.2	0.3	49,721	lb	**24.9** tons
straight		1451+30	44+236	355.3	108.3	1,714.9	522.7	48.0	1219.2	0.3	48,620	lb	**24.3** tons
straight		1450+72	44+218	414.5	126.4	1,702.5	518.9	48.0	1219.2	0.3	47,519	lb	**23.8** tons
straight		1450+14	44+201	473.8	144.4	1,690.2	515.2	48.0	1219.2	0.3	46,417	lb	**23.2** tons
straight		1449+56	44+183	533.0	162.5	1,677.9	511.4	48.0	1219.2	0.3	45,315	lb	**22.7** tons
straight		1448+98	44+165	592.3	180.5	1,665.6	507.7	48.0	1219.2	0.3	44,212	lb	**22.1** tons
straight		1448+40	44+148	651.6	198.6	1,653.3	503.9	48.0	1219.2	0.3	43,110	lb	**21.6** tons
straight		1447+82	44+130	710.9	216.7	1,640.9	500.2	48.0	1219.2	0.3	42,008	lb	**21.0** tons
curve	vertical	1447+20	44+111	773.7	235.8	1,628.4	496.3	48.0	1219.2	0.3	80,775	lb	**40.4** tons
curve	vertical	1446+59	44+093	836.5	255.0	1,617.0	492.9	48.0	1219.2	0.3	56,498	lb	**28.2** tons
curve	vertical	1445+97	44+074	899.4	274.1	1,606.6	489.7	48.0	1219.2	0.3	46,247	lb	**23.1** tons
curve	vertical	1445+35	44+055	962.2	293.3	1,597.3	486.9	48.0	1219.2	0.3	320,941	lb	**160.5** tons
curve	vertical	1444+72	44+036	1,025.0	312.4	1,589.1	484.4	48.0	1219.2	0.3	213,379	lb	**106.7** tons
curve	vertical	1444+10	44+017	1,087.9	331.6	1,582.0	482.2	48.0	1219.2	0.3	207,827	lb	**103.9** tons
curve	vertical	1443+47	43+998	1,150.7	350.7	1,576.0	480.4	48.0	1219.2	0.3	203,011	lb	**101.5** tons
curve	vertical	1442+85	43+979	1,213.5	369.9	1,571.0	478.9	48.0	1219.2	0.3	198,668	lb	**99.3** tons
curve	vertical	1442+22	43+959	1,276.4	389.0	1,567.2	477.7	48.0	1219.2	0.3	198,631	lb	**99.3** tons
curve	vertical	1441+59	43+940	1,339.2	408.2	1,564.5	476.9	48.0	1219.2	0.3	198,887	lb	**99.4** tons
curve	vertical	1440+96	43+921	1,402.0	427.3	1,562.8	476.4	48.0	1219.2	0.3	199,050	lb	**99.5** tons
curve	vertical	1440+34	43+902	1,464.9	446.5	1,562.3	476.2	48.0	1219.2	0.3	199,156	lb	**99.6** tons
straight		1439+66	43+881	1,532.2	467.0	1,562.3	476.2	48.0	1219.2	0.3	199,593	lb	**99.8** tons
straight		1438+99	43+861	1,599.5	487.5	1,562.3	476.2	48.0	1219.2	0.3	200,031	lb	**100.0** tons
straight		1438+32	43+840	1,666.8	508.1	1,562.3	476.2	48.0	1219.2	0.3	200,468	lb	**100.2** tons
straight		1437+64	43+820	1,734.2	528.6	1,562.3	476.2	48.0	1219.2	0.3	200,905	lb	**100.5** tons
straight		1436+97	43+799	1,801.5	549.1	1,562.3	476.2	48.0	1219.2	0.3	201,342	lb	**100.7** tons
straight		1436+30	43+779	1,868.8	569.6	1,562.3	476.2	48.0	1219.2	0.3	201,780	lb	**100.9** tons
straight		1435+62	43+758	1,936.1	590.1	1,562.3	476.2	48.0	1219.2	0.3	202,217	lb	**101.1** tons
straight		1434+95	43+738	2,003.5	610.7	1,562.3	476.2	48.0	1219.2	0.3	202,654	lb	**101.3** tons
straight		1434+28	43+717	2,070.8	631.2	1,562.3	476.2	48.0	1219.2	0.3	203,091	lb	**101.5** tons
straight		1433+60	43+697	2,138.1	651.7	1,562.3	476.2	48.0	1219.2	0.3	203,529	lb	**101.8** tons
straight		1432+93	43+676	2,205.4	672.2	1,562.3	476.2	48.0	1219.2	0.3	203,966	lb	**102.0** tons
straight		1432+26	43+656	2,272.8	692.7	1,562.3	476.2	48.0	1219.2	0.3	204,403	lb	**102.2** tons
straight		1431+58	43+635	2,340.1	713.3	1,562.3	476.2	48.0	1219.2	0.3	204,840	lb	**102.4** tons
straight		1430+91	43+615	2,407.4	733.8	1,562.3	476.2	48.0	1219.2	0.3	205,278	lb	**102.6** tons
straight		1430+24	43+594	2,474.8	754.3	1,562.3	476.2	48.0	1219.2	0.3	205,715	lb	**102.9** tons
straight		1429+56	43+574	2,542.1	774.8	1,562.3	476.2	48.0	1219.2	0.3	206,152	lb	**103.1** tons
curve	vertical	1428+94	43+554	2,604.9	794.0	1,562.8	476.4	48.0	1219.2	0.3	277,983	lb	**139.0** tons
curve	vertical	1428+31	43+535	2,667.7	813.1	1,564.5	476.9	48.0	1219.2	0.3	239,292	lb	**119.6** tons
curve	vertical	1427+68	43+516	2,730.6	832.3	1,567.2	477.7	48.0	1219.2	0.3	225,129	lb	**112.6** tons
curve	vertical	1427+05	43+497	2,793.4	851.4	1,571.0	478.9	48.0	1219.2	0.3	217,137	lb	**108.6** tons
curve	vertical	1426+43	43+478	2,856.2	870.6	1,576.0	480.4	48.0	1219.2	0.3	211,647	lb	**105.8** tons
curve	vertical	1425+80	43+459	2,919.1	889.7	1,582.0	482.2	48.0	1219.2	0.3	207,439	lb	**103.7** tons
curve	vertical	1425+18	43+440	2,981.9	908.9	1,589.1	484.4	48.0	1219.2	0.3	203,989	lb	**102.0** tons
curve	vertical	1424+55	43+421	3,044.7	928.0	1,597.3	486.9	48.0	1219.2	0.3	201,038	lb	**100.5** tons
curve	vertical	1423+93	43+402	3,107.6	947.2	1,606.6	489.7	48.0	1219.2	0.3	198,442	lb	**99.2** tons
curve	vertical	1423+31	43+383	3,170.4	966.3	1,617.0	492.9	48.0	1219.2	0.3	196,115	lb	**98.1** tons
curve	vertical	1422+69	43+364	3,233.2	985.5	1,628.4	496.3	48.0	1219.2	0.3	194,002	lb	**97.0** tons
curve	vertical	1422+08	43+345	3,296.1	1,004.7	1,640.9	500.2	48.0	1219.2	0.3	193,723	lb	**96.9** tons
straight		1421+39	43+324	3,366.8	1,026.2	1,655.6	504.6	48.0	1219.2	0.3	194,975	lb	**97.5** tons
straight		1420+70	43+303	3,437.5	1,047.8	1,670.3	509.1	48.0	1219.2	0.3	196,228	lb	**98.1** tons
straight		1420+00	43+282	3,508.2	1,069.3	1,685.0	513.6	48.0	1219.2	0.3	197,480	lb	**98.7** tons
straight		1419+31	43+261	3,578.9	1,090.9	1,699.7	518.1	48.0	1219.2	0.3	198,733	lb	**99.4** tons
straight		1418+62	43+240	3,649.7	1,112.4	1,714.5	522.6	48.0	1219.2	0.3	199,986	lb	**100.0** tons
straight		1417+93	43+219	3,720.4	1,134.0	1,729.2	527.1	48.0	1219.2	0.3	201,238	lb	**100.6** tons
straight		1417+24	43+198	3,791.2	1,155.6	1,743.9	531.5	48.0	1219.2	0.3	202,491	lb	**101.2** tons
HDD Rig Location		1416+54	43+177	3,861.9	1,177.1	1,758.6	536.0	48.0	1219.2	0.3	203,744	lb	**101.9** tons

HDD Installation Stress Analysis

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	CombinedTensile and Bending <1.0	Combined Tensile, Bending and Hoop Factor	Combined Tensile, Bending and Hoop <1.0
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS				
655	4.51	0.94%	0	0.00	0.00%	0	0.00	0.00%	0.01	Yes	0.00	Yes
642	4.42	0.92%	0	0.00	0.00%	55	0.38	0.08%	0.01	Yes	0.00	Yes
629	4.33	0.90%	0	0.00	0.00%	111	0.76	0.16%	0.01	Yes	0.00	Yes
616	4.24	0.88%	0	0.00	0.00%	166	1.14	0.24%	0.01	Yes	0.00	Yes
602	4.15	0.86%	0	0.00	0.00%	221	1.52	0.32%	0.01	Yes	0.00	Yes
589	4.06	0.84%	0	0.00	0.00%	276	1.91	0.39%	0.01	Yes	0.00	Yes
576	3.97	0.82%	0	0.00	0.00%	332	2.29	0.47%	0.01	Yes	0.00	Yes
563	3.88	0.80%	0	0.00	0.00%	387	2.67	0.55%	0.01	Yes	0.00	Yes
550	3.79	0.79%	0	0.00	0.00%	442	3.05	0.63%	0.01	Yes	0.00	Yes
537	3.70	0.77%	0	0.00	0.00%	497	3.43	0.71%	0.01	Yes	0.00	Yes
524	3.61	0.75%	0	0.00	0.00%	553	3.81	0.79%	0.01	Yes	0.01	Yes
511	3.52	0.73%	0	0.00	0.00%	608	4.19	0.87%	0.01	Yes	0.01	Yes
498	3.43	0.71%	0	0.00	0.00%	663	4.57	0.95%	0.01	Yes	0.01	Yes
958	6.60	1.37%	12,083	83.31	17.26%	720	4.96	1.03%	0.29	Yes	0.07	Yes
670	4.62	0.96%	12,083	83.31	17.26%	771	5.32	1.10%	0.28	Yes	0.07	Yes
548	3.78	0.78%	12,083	83.31	17.26%	818	5.64	1.17%	0.28	Yes	0.07	Yes
3,805	26.23	5.44%	12,083	83.31	17.26%	859	5.92	1.23%	0.34	Yes	0.11	Yes
2,530	17.44	3.61%	12,083	83.31	17.26%	761	5.24	1.09%	0.32	Yes	0.10	Yes
2,464	16.99	3.52%	12,083	83.31	17.26%	793	5.46	1.13%	0.31	Yes	0.10	Yes
2,407	16.59	3.44%	12,083	83.31	17.26%	820	5.65	1.17%	0.31	Yes	0.10	Yes
2,355	16.24	3.36%	12,083	83.31	17.26%	842	5.80	1.20%	0.31	Yes	0.10	Yes
2,355	16.23	3.36%	12,083	83.31	17.26%	859	5.92	1.23%	0.31	Yes	0.10	Yes
2,358	16.26	3.37%	12,083	83.31	17.26%	871	6.01	1.24%	0.31	Yes	0.10	Yes
2,360	16.27	3.37%	12,083	83.31	17.26%	879	6.06	1.26%	0.31	Yes	0.10	Yes
2,361	16.28	3.37%	12,083	83.31	17.26%	881	6.07	1.26%	0.31	Yes	0.10	Yes
2,366	16.31	3.38%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,371	16.35	3.39%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,376	16.39	3.39%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,382	16.42	3.40%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,387	16.46	3.41%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,392	16.49	3.42%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,397	16.53	3.42%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,402	16.56	3.43%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,408	16.60	3.44%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,413	16.64	3.45%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,418	16.67	3.45%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,423	16.71	3.46%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,428	16.74	3.47%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,433	16.78	3.48%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,439	16.81	3.48%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
2,444	16.85	3.49%	0	0.00	0.00%	881	6.07	1.26%	0.04	Yes	0.02	Yes
3,295	22.72	4.71%	12,083	83.31	17.26%	879	6.06	1.26%	0.33	Yes	0.11	Yes
2,837	19.56	4.05%	12,083	83.31	17.26%	871	6.01	1.24%	0.32	Yes	0.10	Yes
2,669	18.40	3.81%	12,083	83.31	17.26%	859	5.92	1.23%	0.32	Yes	0.10	Yes
2,574	17.75	3.68%	12,083	83.31	17.26%	842	5.80	1.20%	0.32	Yes	0.10	Yes
2,509	17.30	3.58%	12,083	83.31	17.26%	820	5.65	1.17%	0.32	Yes	0.10	Yes
2,459	16.95	3.51%	12,083	83.31	17.26%	793	5.46	1.13%	0.31	Yes	0.10	Yes
2,418	16.67	3.45%	12,083	83.31	17.26%	761	5.24	1.09%	0.31	Yes	0.09	Yes
2,383	16.43	3.40%	12,083	83.31	17.26%	724	4.99	1.03%	0.31	Yes	0.09	Yes
2,352	16.22	3.36%	12,083	83.31	17.26%	682	4.70	0.97%	0.31	Yes	0.09	Yes
2,325	16.03	3.32%	12,083	83.31	17.26%	636	4.38	0.91%	0.31	Yes	0.09	Yes
2,300	15.86	3.29%	12,083	83.31	17.26%	584	4.03	0.83%	0.31	Yes	0.09	Yes
2,296	15.83	3.28%	12,083	83.31	17.26%	528	3.64	0.75%	0.31	Yes	0.08	Yes
2,311	15.94	3.30%	0	0.00	0.00%	462	3.19	0.66%	0.04	Yes	0.01	Yes
2,326	16.04	3.32%	0	0.00	0.00%	396	2.73	0.57%	0.04	Yes	0.01	Yes
2,341	16.14	3.34%	0	0.00	0.00%	330	2.28	0.47%	0.04	Yes	0.01	Yes
2,356	16.24	3.37%	0	0.00	0.00%	264	1.82	0.38%	0.04	Yes	0.01	Yes
2,371	16.35	3.39%	0	0.00	0.00%	198	1.37	0.28%	0.04	Yes	0.00	Yes
2,386	16.45	3.41%	0	0.00	0.00%	132	0.91	0.19%	0.04	Yes	0.00	Yes
2,400	16.55	3.43%	0	0.00	0.00%	66	0.46	0.09%	0.04	Yes	0.00	Yes
2,415	16.65	3.45%	0	0.00	0.00%	0	0.00	0.00%	0.04	Yes	0.00	Yes

NOTE: Hoop stress taken as an empty pipe for no buoyancy control and with water with buoyancy control

Ground Elevation at Pipe Entry	1788.73	feet
	545.21	metres
Ground Elevation at Pipe Exit	1758.58	feet
	536.02	metres

	TOTAL PULL LOADS		
Maximum Values	277,983	lb	160.5 tons

Tensile (Axial) Stress			Bending Stress			Hoop Stress			Combined Tensile and Bending Factor	Combined Tensile, Bending and Hoop Factor
psi	MPa	% SMYS	psi	MPa	% SMYS	psi	MPa	% SMYS		
3,805	26.2	5.44%	12,083	83.3	17.26%	881	6.1	1.26%	0.34	0.11

Input Pipe Properties

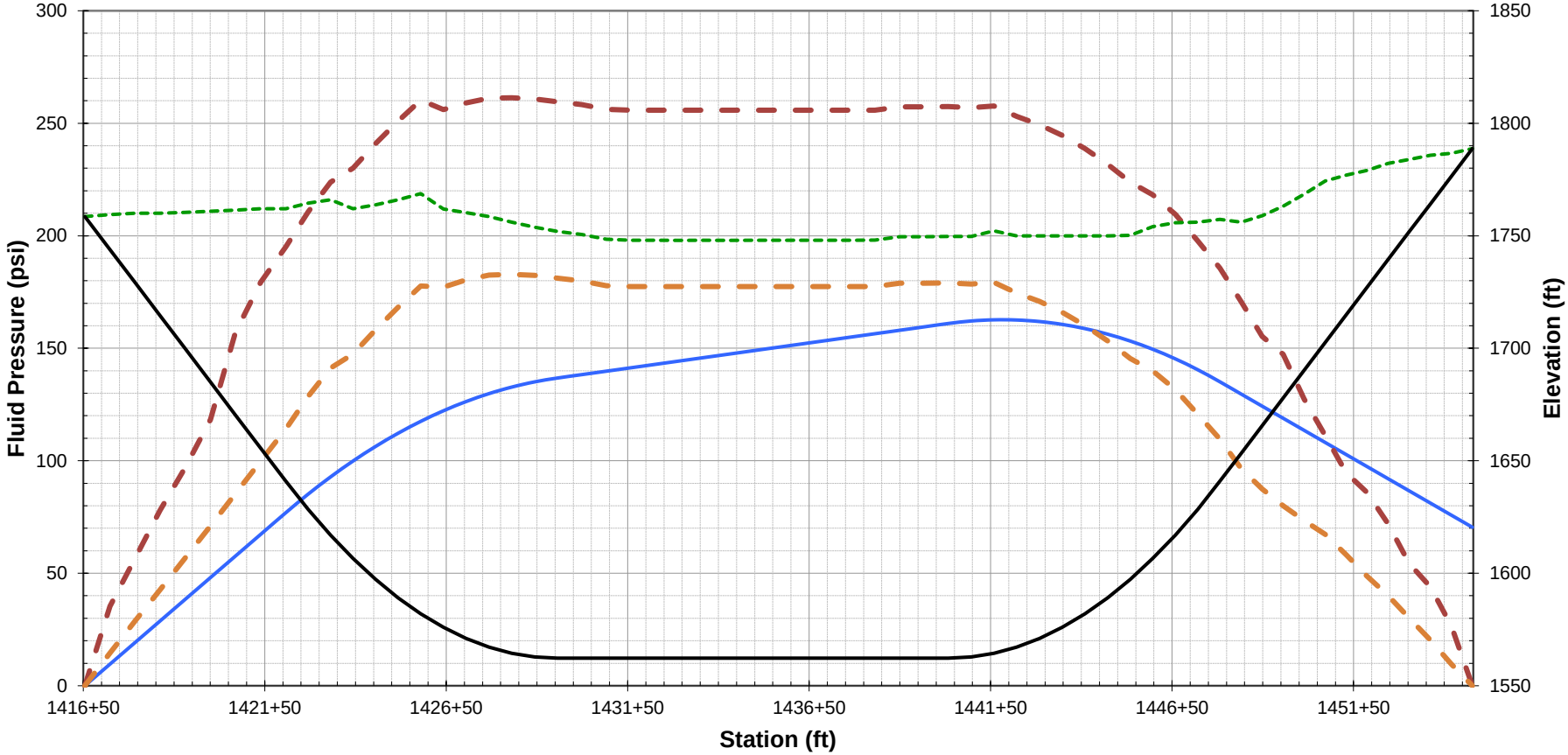
Pipe Outer Diameter	36	in
	914.4	mm
Pipe Wall Thickness	0.762	in
	19.3548	mm
DR	47.2	
Pipe Weight (in air)	287.04	lbs/ft
	428.06	kg/m
Weight of Water in pipe	404.5	lbs/ft
	603.26	kg/m
Net Buoyant Weight of pipe	57.1	lbs/ft
	85.14	kg/m
Young's Modulus of Elasticity	2.90E+07	psi
	199948	MPa
Yield Strength	70,000	psi
	482.6	MPa
Poisson Ratio	0.3	
Drill Pipe Diameter	6.625	in
	168.275	mm
Minimum Radius of Curvature	2,600	ft
	792	m
Ultimate Safe Pull Load	3,542,953	lb
	15,760	kN
Maximum Calculated Pull Load	277,983	lb
	1,237	kN
Factor of Safety	12.7	
Start-up Load Factor	1.5	
Required Pipe Pull Load	320,941	lb
	1,428	kN
Factor of Safety	11.0	

Soil and Mud Properties

Mud Weight	12	ppg of drill fluid and solids (typically 9.5 to 11 lb/gal)
	1.439	Specific Gravity
Friction Coeff. (GS or rollers)	0.2	rollers typically 0.10 to 0.30 (along ground surface is higher range)
Yield Point	24	lb/100ft^2 (Based on HDD experience from previous installations)
	114.912	dyne/cm^2
Plastic Viscosity	16	cP (Based on HDD experience from previous installations)
Drilling mud pumping rate	300	GPM (typically 200 to 300 gpm for soil or 400 to 800 gpm bedrock)
	1.136	m^3/min
Drilling mud pumping rate	1093	GPM (equivalent mud rate accounting for slurry displaced by product pipe installation)
	4.138	m^3/min
Pipe Pullback Rate	15	feet/min (Based on HDD experience)
	4.57	m/min

Appendix D

Hydraulic Fracture Evaluation



Crossing Length (ft)	3,823.0
Bore Diameter (in)	12.250
Drilling Fluid Flow Rate. (gpm)	600
Drilling Fluid Weight (ppg)	10.5
Plastic Viscosity (cP)	16
Yield Point (lb/100SF)	24

PennEast Pipeline
HORIZONTAL DIRECTIONAL DRILLING EVALUATION

MOTT MACDONALD

PennEast Pipeline Project
Interstate 80 Crossing
DRILLING FLUID PRESSURE EVALUATION

Pilot Bore Drilling Fluid Pressure Evaluation

MOTT MACDONALD

Horizontal Directional Drilling
Drilling Fluid Hydraulic Fracture Calculations

Calculated by: S. Hammerschmidt
Checked by: G. Duyvestyn
Date: 2/6/2017
Project No: 353754

PROJECT: PennEast Pipeline

CROSSING LOCATION: Interstate 80

Reference:
1. Latoore, C.A., Wakeley, L.D., and Conroy, P.J., Guidelines for Installation of Utilities Beneath Corps of Engineers Levees using Horizontal Directional Drilling, June 2002, ERDC/GSL TR-02-9
2. HDD Consortium, Horizontal Directional Drilling Good Practices Guidelines, Third Edition, North American Society of Trenchless Technology, 2008.

Geotechnical Inputs

Note that soil type assumes entire soil layer above the bore consists of the same soil type and properties. Need to input appropriate soil properties into evaluation sheet for soils above the bore.

Only Change cells shaded in green
Changing other cells will interfere with calculations

Soil Properties	Soil Type 1 (clayey sand)	Soil Type 2 (sandstone)	Soil Type 3	Soil Type 4	Soil Type 5
c, soil effective cohesion (psf)	1,000	0			
c, soil effective cohesion (N/m^2 or Pa)	47,880	0	0	0	0
ϕ, soil internal friction angle (deg)	30.0	32.0			
ϕ, soil internal friction angle (rad)	0.5	0.6	0.0	0.0	0.0
E , Young's Modulus (kPa)	35,000	40,000			
E , Young's Modulus (lb/ft^2)	730,990	835,417	0	0	0
ν , Poisson's ratio	0.33	0.33			
G, soil shear modulus (ksf)	275	314	0	0	0
G, soil shear modulus (kPa)	13,158	15,038	0	0	0
G, soil shear modulus (Pa)	13,157,895	15,037,594	0	0	0
γ, soil total unit weight (pcf) below water table	135	140			
γ, soil total unit weight (kN/m^3) below water table	21.2	22.0	0.0	0.0	0.0
γ, soil total unit weight (pcf) above water table	125	130			
γ, soil total unit weight (kN/m^3) above water table	19.6	20.4	0.0	0.0	0.0
Top Elevation Soil Type encountered (feet)					
Top Elevation Soil Type encountered (metre)					
Bottom Elevation Soil Type encountered (feet)					
Bottom Elevation Soil Type encountered (metre)					

HDD Installation Inputs

Drill and Intersect Used	no	yes or no
Target Drill and Intersect Location	4099+50	input stationing in feet (do not enter + sign)
	124+954	Stationing in metres
Drill Rig setup on Pipe Side (Single Rig Option Only). **For Drill and Intersect, this must be "no"**	no	yes or no (must be no for direct and interse
Drill Rig #1 Elevation	1758.6	feet
	536.0	metre
Drill Rig #2 Elevation (Pipe Entry Location)	N/A	feet
	N/A	metre
Recommended Allowable Pressure Factor	1.50	
Total Horizontal Installation Length	3,823.0	feet
	1,165.3	metre
True Installation Length	3,861.9	feet
	1,177.1	metre
Pilot Bore Diameter	12.250	inch
	311.15	mm
Drill Pipe Diameter	6.625	inch
	168.28	mm
Yield Point	24	$lb/100ft^2$
Plastic Viscosity	16	cP
Drilling Fluid Pumping Rate	600	gal/min
	2.27	m^3/min
Calculated Drilling Fluid Velocity	2.306	ft/sec
	0.703	m/sec
Pressure Required for Bore Slurry Flow	0.022	psi per ft of bore
	0.155	kPa per metre of bore
	0.675	psi per 30 ft drill pipe
Drilling Fluid Mud Weight	10.5	ppg
	78.5	lb/ft^3
	1.26	specific gravity

Note: Stationing should be at least every 100 feet and finer detail where required. Check Start and Stop STA for proper direction.

Type 1 , Type 2, Type 3, Type 4, Type 5 or leave blank

Location	Bore Stationing		Drilled Length wrt Drill Rig(s) and Locations (True Bore Length)		Bore Elevation		Ground Surface Elevation		Water Table Elevation		Depth of Cover		Soil Type	Maximum Allowable Drilling Fluid Pressure		Estimated Bore Fluid Pressure for Drilling Fluid Flow		Factor of Safety	Estimated Hydrostatic Fluid Pressure Within Bore		Factor of Safety	Estimated Bore Fluid Pressure for Drilling Fluid Flow and Hydrostatic Column		Factor of Safety
	feet	metre	feet	metre	feet	metre	feet	metre	feet	metre	feet	metre		psi	kPa	psi	kPa		psi	kPa		psi	kPa	
Pipe Exit Side	1416+54	43+177	0.0	0.0	1,758.6	536.0	1,758.6	536.0	1,743.6	531.4	0.0	0.0	Type 1	0.0	0.0	0.00	0.0	--	0.00	0.00	--	0.00	0.0	--
	1417+24	43+198	70.7	21.6	1,743.9	531.5	1,759.4	536.3	1,744.4	531.7	15.5	4.7	Type 1	159.0	1096.4	1.6	11.0	99.91	8.0	55.3	19.82	9.6	66.3	16.54
	1417+93	43+219	141.5	43.1	1,729.2	527.1	1,760.0	536.4	1,745.0	531.9	30.8	9.4	Type 1	226.8	1563.5	3.2	21.9	71.24	16.0	110.6	14.13	19.2	132.6	11.79
	1418+62	43+240	212.2	64.7	1,714.5	522.6	1,760.0	536.4	1,745.0	531.9	45.5	13.9	Type 1	273.2	1883.7	4.8	32.9	57.22	24.1	165.9	11.35	28.8	198.9	9.47
	1419+31	43+261	283.0	86.3	1,699.7	518.1	1,760.4	536.6	1,745.4	532.0	60.6	18.5	Type 1	315.2	2173.5	6.4	43.9	49.52	32.1	221.2	9.82	38.5	265.1	8.20
	1420+00	43+282	353.7	107.8	1,685.0	513.6	1,760.8	536.7	1,745.8	532.1	75.8	23.1	Type 1	354.8	2446.4	8.0	54.9	44.59	40.1	276.5	8.85	48.1	331.4	7.38
	1420+70	43+303	424.4	129.4	1,670.3	509.1	1,761.4	536.9	1,746.4	532.3	91.0	27.7	Type 1	392.6	2707.1	9.5	65.8	41.12	48.1	331.8	8.16	57.7	397.7	6.81
	1421+39	43+324	495.1	150.9	1,655.6	504.6	1,762.0	537.1	1,747.0	532.5	106.4	32.4	Type 2	448.1	3089.5	11.1	76.8	40.22	56.1	387.1	7.98	67.3	463.9	6.66
	1422+08	43+345	565.9	172.5	1,640.9	500.2	1,762.0	537.1	1,747.0	532.5	121.1	36.9	Type 2	487.6	3362.1	12.7	87.8	38.30	64.2	442.4	7.60	76.9	530.2	6.34
	1422+69	43+364	628.7	191.6	1,628.4	496.3	1,764.5	537.8	1,749.5	533.3	136.1	41.5	Type 2	526.7	3631.6	14.1	97.5	37.24	71.0	489.5	7.42	85.1	587.0	6.19
	1423+31	43+383	691.5	210.8	1,617.0	492.9	1,766.0	538.3	1,751.0	533.7	149.1	45.4	Type 2	559.4	3857.2	15.6	107.3	35.96	77.2	532.6	7.24	92.8	639.9	6.03
	1423+93	43+402	754.3	229.9	1,606.6	489.7	1,762.0	537.1	1,747.0	532.5	155.4	47.4	Type 2	575.2	3966.0	17.0	117.0	33.89	82.9	571.6	6.94	99.9	688.6	5.76
	1424+55	43+421	817.2	249.1	1,597.3	486.9	1,763.8	537.6	1,748.8	533.0	166.5	50.8	Type 2	602.4	4153.1	18.4	126.8	32.76	88.0	606.5	6.85	106.4	733.3	5.66
	1425+18	43+440	880.0	268.2	1,589.1	484.4	1,766.0	538.3	1,751.0	533.7	176.9	53.9	Type 2	627.3	4324.9	19.8	136.5	31.68	92.4	637.3	6.79	112.2	773.9	5.59
	1425+80	43+459	942.8	287.4	1,582.0	482.2	1,768.7	539.1	1,753.7	534.5	186.8	56.9	Type 2	650.6	4486.0	21.2	146.3	30.67	96.3	664.1	6.76	117.5	810.3	5.54
	1426+43	43+478	1,005.7	306.5	1,576.0	480.4	1,761.9	537.0	1,756.9	535.5	186.0	56.7	Type 2	640.1	4413.2	22.6	156.0	28.29	99.6	686.7	6.43	122.2	842.7	5.24
	1427+05	43+497	1,068.5	325.7	1,571.0	478.9	1,760.2	536.5	1,755.2	535.0	189.2	57.7	Type 2	647.7	4465.8	24.0	165.8	26.94	102.3	705.3	6.33	126.3	871.0	5.13
	1427+68	43+516	1,131.3	344.8	1,567.2	477.7	1,758.6	536.0	1,753.6	534.5	191.4	58.3	Type 2	652.9	4501.6	25.5	175.5	25.65	104.4	719.7	6.25	129.8	895.2	5.03
	1428+31	43+535	1,194.2	364.0	1,564.5	476.9	1,756.0	535.2	1,751.0	533.7	191.6	58.4	Type 2	653.3	4504.5	26.9	185.2	24.32	105.9	730.0	6.17	132.7	915.2	4.92
	1428+94	43+554	1,257.0	383.1	1,562.8	476.4	1,753.8	534.6	1,748.8	533.0	191.0	58.2	Type 2	652.0	4495.4	28.3	195.0	23.05	106.8	736.2	6.11	135.1	931.2	4.83
	1429+56	43+574	1,319.8	402.3	1,562.3	476.2	1,751.9	534.0	1,746.9	532.5	189.7	57.8	Type 2	648.9	4473.7	29.7	204.7	21.85	107.1	738.2	6.06	136.8	943.0	4.74
	1430+24	43+594	1,387.2	422.8	1,562.3	476.2	1,750.6	533.6	1,745.6	532.1	188.3	57.4	Type 2	645.7	4452.0	31.2	215.2	20.69	107.1	738.2	6.03	138.3	953.4	4.67
	1430+91	43+615	1,454.5	443.3	1,562.3	476.2	1,748.4	532.9	1,743.4	531.4	186.2	56.7	Type 2	640.5	4416.4	32.7	225.6	19.57	107.1	738.2	5.98	139.8	963.9	4.58
	1431+58	43+635	1,521.8	463.9	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	34.2	236.1	18.68	107.1	738.2	5.97	141.3	974.3	4.53
	1432+26	43+656	1,589.2	484.4	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	35.8	246.5	17.89	107.1	738.2	5.97	142.8	984.8	4.48
	1432+93	43+676	1,656.5	504.9	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	37.3	257.0	17.16	107.1	738.2	5.97	144.3	995.2	4.43
	1433+60	43+697	1,723.8	525.4	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	38.8	267.4	16.49	107.1	738.2	5.97	145.9	1005.7	4.38
	1434+28	43+717	1,791.1	545.9	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	40.3	277.9	15.87	107.1	738.2	5.97	147.4	1016.1	4.34
	1434+95	43+738	1,858.5	566.5	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	41.8	288.3	15.30	107.1	738.2	5.97	148.9	1026.5	4.30
	1435+62	43+758	1,925.8	587.0	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	43.3	298.7	14.76	107.1	738.2	5.97	150.4	1037.0	4.25
	1436+30	43+779	1,993.1	607.5	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	44.8	309.2	14.26	107.1	738.2	5.97	151.9	1047.4	4.21
	1436+97	43+799	2,060.4	628.0	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	46.4	319.6	13.80	107.1	738.2	5.97	153.4	1057.9	4.17
	1437+64	43+820	2,127.8	648.5	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.7	56.6	Type 2	639.5	4409.5	47.9	330.1	13.36	107.1	738.2	5.97	154.9	1068.3	4.13
	1438+32	43+840	2,195.1	669.1	1,562.3	476.2	1,748.0	532.8	1,743.0	531.3	185.8	56.6	Type 2	639.6	4410.0	49.4	340.5	12.95	107.1	738.2	5.97	156.5	1078.8	4.09
	1438+99	43+861	2,262.4	689.6	1,562.3	476.2	1,749.5	533.3	1,744.5	531.7	187.3	57.1	Type 2	643.2	4434.8	50.9	351.0	12.64	107.1	738.2	6.01	158.0	1089.2	4.07
	1439+66	43+881	2,329.7	710.1	1,562.3	476.2	1,749.6	533.3	1,744.6	531.8	187.3	57.1	Type 2	643.4	4435.8	52.4	361.4	12.27	107.1	738.2	6.01	159.5	1099.7	4.03
	1440+34	43+902	2,397.1	730.6	1,562.3	476.2	1,749.7	533.3	1,744.7	531.8	187.4	57.1	Type 2	643.5	4436.9	53.9	371.8	11.93	107.1	738.2	6.01	161.0	1110.1	4.00
	1440+96	43+921	2,459.9	749.8	1,562.8	476.4	1,749.8	533.3	1,744.8	531.8	186.9	57.0	Type 2	642.4	4429.2	55.3	381.6	11.61	106.8	736.2	6.02	162.1	1117.8	3.96
	1441+59	43+940	2,522.7	768.9	1,564.5	476.9	1,752.2	534.1	1,747.2	532.5	187.7	57.2	Type 2	644.2	4441.9	56.8	391.3	11.35	105.9	730.0	6.08	162.6	1121.3	3.96
	1442+22	43+959	2,585.5	788.1	1,567.2	477.7	1,750.0	533.4	1,745.0	531.9	182.8	55.7	Type 2	632.6	4361.4	58.2	401.1	10.87	104.4	719.7	6.06	162.6	1120.8	3.89
	1442+85	43+979	2,648.4	807.2	1,571.0	478.9	1,750.0	533.4	1,745.0	531.9	179.0	54.6	Type 2	623.4	4298.1	59.6	410.8	10.46	102.3	705.3	6.09	161.9	1116.1	3.85
	1443+47	43+998	2,711.2	826.4	1,576.0	480.4	1,750.0	533.4	1,745.0	531.9	174.0	53.0	Type 2	611.5	4216.2	61.0	420.6	10.02	99.6	686.7	6.14	160.6	1107.3	3.81
	1444+10	44+017	2,774.0	845.5	1,582.0	482.2	1,750.0	533.4	1,745.0	531.9	168.0	51.2	Type 2	596.9	4115.2	62.4	430.3	9.56	96.3	664.1	6.20	158.7	1094.4	3.76
	1444+72	44+036	2,836.9	864.7	1,589.1	484.4	1,750.0	533.4	1,745.0	531.9	160.9	49.0	Type 2	579.4	3994.6	63.8	440.1	9.08	92.4	637.3	6.27	156.3	1077.4	3.71
	1445+35	44+055	2,899.7	883.8	1,597.3	486.9	1,750.2	533.5	1,745.2	531.9	152.9	46.6	Type 2	559.4	3857.2	65.2	449.8	8.57	88.0	606.5	6.36	153.2	1056.3	3.65
	1445+97	44+074	2,962.5	903.0	1,606.6	489.7	1,754.0	534.6	1,749.0	533.1	147.4	44.9	Type 2	545.6	3762.1	66.7	459.6	8.19	82.9	571.6	6.58	149.6	1031.1	3.65
	1446+59	44+093	3,025.4	922.1	1,617.0	492.9	1,755.8	535.2	1,750.8	533.7	138.9	42.3	Type 2	523.8	3611.5	68.1	469.3	7.70	77.2	532.6	6.78	145.3	1001.9	3.60
	1447+20	44+111	3,088.2	941.3	1,628.4	496.3	1,756.0	535.2	1,751.0	533.7	127.6	38.9	Type 2	494.3	3408.4	69.5	479.1	7.11	71.0	489.5	6.96	140.5	968.6	3.52
	1447+82	44+130	3,151.0	960.4	1,640.9	500.2	1,757.3	535.6	1,752.3	534.1	116.3	35.5	Type 2	464.2	3200.5	70.9	488.8	6.55	64.2	442.4	7.23	135.1	931.2	3.44
	1448+40	44+148	3,210.3	978.5	1,653.3	503.9	1,756.1	535.3	1,751.1	533.7	102.8	31.3	Type 2	426.8	2942.9	72.2	498.0	5.91	57.4	396.1	7.43	129.7	894.1	3.29
	1448+98	44+165	3,269.6	996.6	1,665.6	507.7	1,758.8	536.1	1,753.8	534.6	93.3	28.4	Type 1	388.0	2675.5	73.6	507.2	5.27	50.7	349.7	7.65	124.3	856.9	3.12
	1449+56	44+183	3,328.9	1,014.7	1,677.9	511.4	1,763.2	537.4	1,758.2	535.9	85.3	26.0	Type 1	368.2	2538.4	74.9	516.4	4.92	44.0	303.4	8.37	118.9	819.8	3.10
	1450+14	44+201	3,388.2	1,032.7	1,690.2	515.2	1,768.5	539.0	1,763.5	537.5	78.2	23.8	Type 1	350.3	2415.4	76.2	525.6	4.60	37.3	257.0	9.40	113.5	782.6	3.09
	1450+72	44+218	3,447.4	1,050.8	1,702.5	518.9	1,774.3	540.8	1,769.3	539.3	71.7	21.9	Type 1	333.5	2299.5	77.6	534.8	4.30	30.6	210.7	10.91	108.1	745.5	3.08
	1451+30	44+236	3,506.6	1,068.8	1,714.9	522.7	1,776.9	541.6	1,771.9	540.1	62.1	18.9	Type 1	307.7	2121.6	78.9	544.0	3.90	23.8	164.4	12.90	102.7	708.4	3.00
	1451+88	44+254	3,565.8	1,086.9	1,727.2	526.4	1,779.0	542.3	1,774.0	540.7	51.9	15.8	Type 1	279.2	1924.9	80.2	553.2	3.48	17.1	118.1	16.30	97.4	671.3	2.87
	1452+46	44+271	3,625.0	1,104.9	1,739.5	530.2	1,782.1	543.2	1,777.1	541.7	42.7	13.0	Type 1	251.8	1736.2	81.6	562.3	3.09	10.4	71.8	24.18	92.0	634.2	2.74
	1453+04	44+289	3,684.3	1,123.0	1,751.8	534.0	1,783.9	543.7	1,778.9	542.2	32.1	9.8	Type 1	217.4	1499.0	82.9	571.5	2.62	3.7	25.5	58.76	86.6	597.0	2.51
	1453+62	44+307	3,743.5	1,141.0	1,764.1	537.7	1,785.8	544.3	1,780.8	542.8	21.7	6.6	Type 1	175.7	1211.6	84.2	580.7	2.09	-3.0	-20.8	-58.27	81.2	559.9	2.16
	1454+19	44+324	3,802.7	1,159.1	1,776.4	541.5	1,786.6	544.6	1,781.6	543.0	10.2	3.1	Type 1	105.9	729.9	85.6	589.9	1.24	-9.7	-67.1	-10.88	75.8	522.8	1.40
Pipe Entry Side	1454+77	44+342	3,861.9	1,177.1	1,788.7	545.2	1,788.7	545.2	1,783.7	543.7	0.0	0.0	Type 1	0.0	0.0	86.9	599.1	--	-16.4	-113.4	--	70.4	485.7	--

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