HORIZONTAL DIRECTIONAL DRILL ANALYSIS
FRANKSTOWN BRANCH JUNIATA RIVER CROSSING
PADEP SECTION 105 PERMIT NO.: E07-459
PA-BL-0122.0000-WX & PA-BL-0122.0000-WX -16
(SPLP HDD No. S2-0140)

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This reanalysis of the horizontal directional drill (HDD) installation of a 16-inch and 20-inch diameter pipeline crossing under the Juniata River has been completed in accordance with paragraphs 4 and 5 of the Stipulated Order (Order) issued under Environmental Hearing Board Docket No. 2017-009-L. This HDD is number 10 on the list of HDDs included on Exhibit 2 of the Order.

PIPE INFORMATION

20-Inch: 0.456 wall thickness; X-65
16-Inch: 0.438 wall thickness; X-70

Pipe stress allowances are an integral part of the design calculations performed for each HDD.

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 2,965 foot (ft)
- Entry/Exit angle: 10-18 degrees
- Maximum Depth of cover: 85 ft
- Depth below river: 46 ft
- Pipe design radius: 2,000 ft

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 2,970 ft
- Entry/Exit angle: 10-18 degrees
- Maximum Depth of cover: 100 ft
- Depth below river: 46 ft
- Pipe design radius: 1,600 ft

GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (BTGS, 2001 and Sevon, 2000), the HDD location is in the Appalachian Mountain Section of the Ridge and Valley Physiographic Province of Pennsylvania, underlain by sedimentary rocks consisting of sandstone, siltstone, shale, limestone, and dolomite. Local topography is characterized by long narrow ridges and broad to narrow valleys, with some karst terrain. (Sevon, 2000).

Karst geology is present at this HDD location, and pursuant to the Stipulated Order the use of geophysical surveys should be considered in karst areas. The use of geophysical surveys during re-evaluation was considered but ultimately not implemented at the Juniata River HDD location because the results of geophysical surveys will not provide additional information that will reduce the risk of an IR. Based on recent geophysical assessments performed by SPLP at other HDD locations in karst formations, the range of quality data acquisition has varied from 20 – 60 ft below ground surface (bgs). As discussed below, this HDD has been redesigned and the profile is now 103 ft under the river bed, and is 100 ft or more below the ground surface for a majority of the HDD profile. Accordingly, no valuable data can be acquired that would provide further information for the planning of this HDD and prevention of IRs.

Attachment 1 provides an extensive discussion on the geology, hydrogeology and results of the geotechnical investigation performed at this location.

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

Based on published geologic and hydrogeologic information, and evaluation of geotechnical borings from the site, the Juniata River HDD location is underlain by carbonate and sedimentary rocks of the Hamilton Group, Onondaga and Old Port Formations, Keyser and Tonoloway Formations, Wills Creek Formation, and Bloomsburg and Mifflintown Formations. The hydrogeologic setting is dominated by groundwater flow through secondary openings along geologic features including bedding planes, joints, faults, and fractures. The secondary openings may be enlarged or enhanced by dissolution in underlying carbonate rocks. This is supported by the observation of weathering, fractures, and joints in the geotechnical cores and may be indicative of the high yields reported from some nearby domestic and non-domestic wells. Well records indicate that water bearing zones in water wells close to the site are common to 350 feet bgs in the Hamilton Group, and to 300 feet bgs in the Onondaga and Old Port Formations.

Attachment 1 provides an extensive discussion on the geology, hydrogeology and results of the geotechnical investigation performed at this location.

INADVERTENT RETURN (IR) DISCUSSION

HDD specialists for Sunoco Pipeline, L.P. (SPLP) reviewed the original HDD designs summarized above, and determined that that the design profiles for the 16 and 20-inch HDDs could fail at or before the crossing of the Juniata River. Therefore, as presented and discussed in the conclusions section below, the profile for both the 16 and 20-inch pipelines have been redesigned deeper, incorporating the maximum entry and exit angles allowed by the stress radius of the pipelines, which sharpens the pilot hole entry radius run down to horizontal depth and exit radius return to the land surface. The redesign increases the 20-inch profile depth below the river by 57 ft to a new depth of 103 ft below the river bottom, and increases the 16-inch depth by 48 ft to a new depth of 94 ft below the river bottom.

As shown on Figure 1 - Annular Pressure and Formation Pressure Capacity Curves in Attachment 3, the calculated drilling fluid pressures required for drilling of the pilot hole are below the bedrock fracture pressure for the entirety of the re-designed profile. The results of the geotech investigation evidence that competent rock having moderate integrity and strength commences at 30 ft bgs and improves consistently as the depth below ground increases.

A risk of an IR remains at the undercrossing of the first stream crossing (S-M32) due to the shallow depth of profile at this location and its proximity to the entry point of the HDD; however, this IR potential will be managed by the setting of casing into the profile extending past this feature.

Casing is heavy wall pipe welded into a segment of pre-determined length that is pushed into a pre-drilled hole until it is seated into the bedrock. Based upon the geotechnical core data results at this location, bedrock consisting of mudstone starts at 20 ft bgs. A good quality layer of mudstone is encountered at 30 ft bgs, approximately 60-80 ft into the HDD profile. Casing for the pilot hole will have an internal diameter (ID) 1-2 inches larger in diameter than the intended HDD pilot hole tool, thereby allowing pilot tool insertion and removal for the duration of the pilot hole drilling. The installation of casing at the HDD entry requires drilling a larger diameter pilot hole following the intended profile through the upper substrate materials and into good quality bedrock to establish a "toe" for the casing to be pushed into and achieve a seal against the bedrock face and hole sidewalls. It is not uncommon to inject a slug of loss control materials or grouting at the casing toe at the rock interface to effect a good seal.

Installing casing can result in IR's. At the entry of this HDD, Stream M32 (ephemeral) occurs 49 ft east of the entry point and an IR into Stream M32 is likely during the casing installation. To mitigate an IR into this ephemeral stream, the stream can be flumed across the permanent easement to allow for continued flows if any exist, and sandbag dams set at both ends of the flume such that if an IR occurs within the permanent easement at this location these materials can be contained and removed. IRs outside the permanent easement will be contained, controlled, cleaned and restored in accordance with the SPLP Inadvertent Return Plan.

A unique feature of this HDD is the extreme differences in elevation between the HDD entry and exit point. The entry point is at an elevation of 894 ft, and the exit point is at elevation of 1,373 ft, a difference of 479 ft. Increased drilling pressures will be required to operate the drilling motor as the pilot hole advances upslope towards the exit point. These pressures will be internal to the drilling stem and will not be exhibited in the annulus of the drill or increase the risk of an IR; however, this elevation difference can create a "dry hole" situation in the annulus behind the drilling motor since gravity will induce an accelerated return of drilling fluids back to the entry point. To prevent this "dry hole" situation, drilling fluid characteristics, such as viscosity and cuttings suspension, will have to be monitored by the mud engineer as the pilot hole progresses.

ADJACENT FEATURES ANALYSIS

The crossing of the Juniata River is located in rural Blair County, approximately 4.9 miles east of Hollidaysburg, Pennsylvania. The pipeline route follows parallel to an existing, but out-of-service Lancer pipeline easement. The pipeline alignment re-joins the existing SPLP 8" easement approximately 0.35 miles east of the eastern end of the HDD alignment.

This HDD location is set within a small rural neighborhood and some agricultural land immediately west of the HDD alignment, and east of the river is within unmanaged deciduous woodlands within and surrounding State Game Land 147. The re-aligned profile for this HDD would cross under stream S-M32, wetland M24, wetland M29, the Juniata River (S-M31), and stream S-M38 (west to east). Both wetlands crossed by the HDD are exceptional value due to their proximity to Pennsylvania Fish and Boat Commission wild trout waters.

The reviewing geologists report that west of the Juniata River the groundwater incline is to the northwest. East of the river, groundwater would flow west following the topographic gradient downslope towards the river.

SPLP initiated direct contact by phone and in person with all landowners within 450 ft of the HDD profile. As a result of this effort, five (5) domestic (private) supply wells were identified within 450 ft of the proposed HDD. These wells occur at residences along Juniata Valley Road, and are west, southwest and northwest of the west HDD entry point, and all have had testing performed to establish background data on the water quality in each well. The nearest water well location is 383 ft northwest of the west HDD entry point. The owner of this well did not know the depth to water or total depth of the well. At two adjacent private wells, the static water level was 10 ft bgs, and 12 ft bgs. Neither of these owners knew the total depth of their wells. This HDD re-evaluation has been provided to each landowner within 450 feet of the HDD profile.

Typically, a good drilling mud program forms a "cake wall" around the diameter of the pilot or reamer during drilling process which seals fissures within the profile geology and limits the horizontal and vertical movement of drilling fluids. In addition, controlling the down hole mud weights and pressures should minimize the lateral movement of these materials through the geology. Lastly, as noted previously, casing will be installed down to competent rock into the entry profile to control the movement and returns of drilling fluids and cuttings. As a result an affect to nearby water wells is unlikely given their orientation to this HDD; however SPLP will monitor these wells during the HDD process in accordance with PADEP requirements.

During the entire HDD process, once the pilot hole has progressed east of the river and proceeds upslope towards the exit point, significant quantities of groundwater could be produced that would flow back to the entry point. To control this potential return of water during the HDD, the contractor will have pre-prepared filtration structures and filtration bags in place to capture, filter, and discharge produced water.

ALTERNATIVES ANALYSIS

In accordance with state and federal guidance, SPLP has routed the Project to be co-located with existing pipeline and other utility corridors to avoid new "greenfield" routing alignments, to the maximum extent practical. This avoids and minimizes new and permanent impacts on previously undisturbed land, land use encumbrance, and site-specific and cumulative impacts on land, environmental, and community resources. The Juniata River HDD is co-located within an existing (but out-of-service) pipeline ROW and rerouting would cause new greenfield impacts.

The proposed HDD is an alternative plan of installation to a conventional open trench construction plan. Using the HDD method reduces the risk of new direct impacts to the river, streams, Chapter 93 Exceptional Value wetlands, and associated forested woodland and riparian habitats. Alteration of the current permitted route and plans for installation would not meaningfully reduce the risk of these impacts and would also require major modifications of the state Chapter 102 and Chapter 105 permits, and authorization issued by the U.S. Army Corps of Engineers.

The revised HDD profiles are 2,965 ft and 2,957 ft in horizontal length respectively and includes the crossing of the river, two (2) stream channels, and approximately 325 ft of emergent and forested wetlands.

Open-cut Analysis

SPLP specifications require a minimum of 48-inches of cover over the installed pipelines. To meet these cover requirements, during construction through the stream and wetlands would require a minimum authorized open cut work space 75 ft in width to accommodate the 16 and 20-inch pipelines, allowing for each pipeline to be installed with sufficient separation for integrity management. The assessed area of impact by this open cut plan would directly affect approximately 0.09 acres of state water bottoms, 0.12 acres of emergent wetland, and 1.12 acres of forested wetland.

The open cut crossing of the river would require using geotube dams upstream and downstream of the crossing location. Water flows in the river would have to be pumped around the dammed section using a series of 8-inch pumps of while a trench across the river was excavated. While excavating the river crossing, any consolidated rock in the river bottom within the required depth of trench would have to be shattered using explosives, or if feasible, broken up for excavation using a rock hammer.

Due to the existing saturated ground conditions, a significant volume of produced groundwater would fill all the excavations during the open cut process. These water volumes can be pumped to a discharge filtration structure; however the current feasible filtration ability does not exceed 50 microns; therefore, cloudy water (from suspended fine clay and silt particles) would be discharged downstream regardless of all control methods employed for the entire duration of this crossing until completion.

The crossing distance of the emergent and forested wetlands, which are the most expansive natural features crossed by the HDDs, is beyond the technical limits of a conventional auger bore. The river crossing is not possible by conventional bore due to the restraints of the topography on the east side of the river.

Re-Route Analysis

The pipeline route as currently permitted follows parallel to one (1) existing ROW, however, the pipeline is not in service. The route deviates from the existing SPLP 8" line in this location due to the engineering requirements for an HDD crossing with the larger pipe size in the project. Additionally, the properties where the SPLP 8" ROW is routed now have Land and Water Conservation Fund easements, which do not allow new pipelines to be installed. Rather than create a greenfield crossing through State Game Lands 147 and the remaining woodlands, SPLP took advantage of the break in topography and agricultural lands to co-locate with the Lancer pipeline ROW that is not currently in service. This allowed for the HDD crossing which would be less impactful to the Frankstown Branch Juniata River and associated wetlands. Additionally, the HDD crossing requires significantly less clearing efforts on the hillside on the west of the river and allows the vistas to remain intact. The reroute parallel to the existing SPLP 8" ROW has not had wetland delineations performed, but the river would still be crossed and an HDD would not likely be able to be performed due to the topography along that route and the limited open terrain on the west side of the HDD, adjacent to Juniata Valley Road.

During the PADEP Chapter 105 permit process for the Mariner II East Project, SPLP created and submitted for review a project wide alternatives analysis. The baseline route provided for the pipeline construction to cross every wetland and stream on the project by open cut construction procedures. The alternatives analysis submitted to PADEP conceptually analyzed the feasibility of any alternative to trenched resource crossings (e.g., reroute, bore, HDD). The decision making processes for switching from an open cut to HDD is discussed thoroughly in the previously-submitted alternatives analysis and was an important part of the permit application package of HDD plans as currently permitted. The re-route analysis conducted for the Juniata River HDD confirms the conclusions reached in the previously submitted alternatives analysis.

HORIZONTAL DIRECTIONAL DRILL REDESIGN

Additional geologic investigations have been completed and utilized in the redesign of the planned HDDs. These redesigns adjust the HDD profile deeper to place the HDD pathway through bedrock having better structural integrity than a shallower profile and increase the overall length of the HDD due to pipe design requirements. A summary of the redesign factors is provided below. The original and redesigned HDD plan and profile drawings are provided in Attachment 2.

REVISED HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 2,965 ft
- Entry/Exit angle: 12-20 degrees
- Maximum Depth of cover: 150 ft
- Depth below river: 103 ft
- Pipe design radius: 2,700 ft

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REVISED HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 2,957 ft
- Entry/Exit angle: 16-18 degrees
- Maximum Depth of cover: 140 ft
- Depth below river: 94 ft
- Pipe design radius: 2,100 ft

As shown on Figure 2, the redesigned HDD profile for the 20-inch pipeline is the same length, with a maximum depth of cover increased by 65 ft from the permitted design. The entry/exit angles have been increased from 10-18 degrees to 16-20 degrees allowing for a sharper and quicker descent into competent rock. As shown on Figure 4 the redesigned HDD profile for the 16-inch pipeline is 13 ft shorter, with a depth of cover increased by 40 ft, and designed for a sharp and quick entry and exit from the horizontal depth.

CONCLUSION

HDD specialists and geologists employed by SPLP have investigated the HDD design and subsurface geologic conditions and concluded that the original HDD design for the 16 and 20 inch pipelines, as summarized in the introduction, had a high risk of inadvertent returns (IRs) to the land surface, wetlands, and state waters if implemented; therefore, the HDD for the 16-inch and 20-inch diameter pipeline have been redesigned as set forth above to maximize the potential to complete each HDD without an occurrence of an IR.

Upon the start of these HDDs, SPLP will employ the following HDD best management practices:

- SPLP requires and enforces the use of annular pressure monitoring during the drilling of the pilot holes, which assists in immediate identification of pressure changes indicative of loss of return flows or over pressurization of the annulus to manage development of pressures that can induce an IR;

- SPLP inspectors will ensure that an appropriate diameter pilot tool, relative to the diameter of the drilling pipe, is used to ensure adequate “annulus spacing” around the drilling pipe exits to allow good return flows during the pilot drilling;

- The HDD entry point, which is west of the river, will have the first 60+ ft of the pilot hole cased to prevent an IR into the first designated stream, and to control drilling returns during drilling of the pilot hole phase;

- SPLP will implement short-tripping of the reaming tools as return flow monitoring indicates to ensure an open annulus is maintained to manage the potential inducement of IRs;

- SPLP will require monitoring of the drilling fluid viscosity, such that fissures and fractures in the subsurface are sealed during the drilling process; and

- During the reaming phase, the use of Loss Control Materials can be implemented if indications of a potential IR are noted or an IR is observed.

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ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

RETTEW

We answer to you.

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Engineers

Environmental Consultants

Surveyors

Landscape Architects

Safety Consultants

October 20, 2017

Mr. Matthew Gordon
Sunoco Pipeline, L.P.
535 Fritztown Road
Sinking Spring, PA 19608

RE: Sunoco Pipeline, L.P. Pipeline Project - Mariner East II
Juniata River Horizontal Directional Drill Location (S2-0140)
Hydrogeological Re-evaluation Report
Frankstown Township, Blair County, Pennsylvania
RETTEW Project No. 096302011

EXECUTIVE SUMMARY

1. The Stipulated Order dated August 8, 2017 requires a re-evaluation of the Juniata River Horizontal Directional Drill (HDD) location, including a geologic report.
2. The Juniata River HDD is underlain by carbonate and sedimentary rocks of the Devonian age Hamilton Group (Dh), Onondaga and Old Port Formations, undivided (Doo), Keyser and Tonoloway Formations, undivided (DSkt), the Silurian age Wills Creek Formation (Swc), and the Bloomsburg and Mifflintown Formations, undivided (Sbm).
3. Geologic mapping, published reports, and field mapping indicate steeply dipping beds with jointing and fracturing.
4. Water-bearing zones generally occur in secondary openings along bedding planes, joints, faults, fractures, and solution openings. Water-bearing zones in the Hamilton Group occur most frequently within 350 feet of the ground surface, and within 300 feet of the ground surface in the Onondaga and Old Port Formations.
5. To date, no HDD operations have started for the 16-inch or 20-inch pipeline.
6. Based on the hydro-structural characteristics of the underlying geology, and proposed HDD profile, the Juniata River HDD is susceptible to the inadvertent return (IR) of drilling fluids during HDD operations for the planned 16-inch and 20-inch drills. The revised HDD profile and HDD best management practices during drilling operations will be used to reduce the risk of an IR.

1.0 INTRODUCTION

The purpose of this report is to describe the geologic and hydrogeologic setting of the Juniata River (S2-0140) HDD location (the site) on the Sunoco Pipeline, L.P. (SPLP) Pennsylvania Pipeline Project - Mariner East II (PPP-ME2) Project. The Juniata River HDD is located in Frankstown Township, Blair County, Pennsylvania (refer to **Figure 1**). The HDD was designed to be drilled under the Juniata River, two small streams (S-M32 and S-M38), and two wetlands. This re-evaluation report is part of the response to the Stipulated Order dated August 8, 2017.

The proposed HDD profile was lengthened and deepened on July 11, 2017 to provide additional protective cover beneath the stream. The HDD entry on the western side of the profile is at an elevation of approximately 896 feet above mean sea level (AMSL) for the proposed 16-inch drill and 894 feet AMSL for the proposed 20-inch drill. The exit on the eastern side of the profile is at an elevation of approximately 1,357 feet AMSL for the proposed 16-inch drill and 1,373 feet AMSL for the proposed 20-inch drill. The inclination of the entry and exit angles has been increased to install the pipe through these protective soils, residual soils, and bedrock; and in closer proximity to the entry and exit points than the original, shallower profile.

Based on the annular pressure and formation pressure capacity curves provided by Directional Project Support (DPS) as part of the overall re-evaluation submittal, the weakest points in the profile are the HDD entry, exit and the crossing of the Juniata River. At the Juniata River crossing, the HDD profile is approximately 94 feet below the river for the proposed 16-inch drill and 103 feet for the proposed 20-inch drill. Copies of the revised HDD profiles are included in **Attachment 1.**

2.0 GEOLOGY AND SOILS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (BTGS, 2001 and Sevon, 2000), the site is in the Appalachian Mountain Section of the Ridge and Valley Physiographic Province of Pennsylvania, underlain by sedimentary rocks consisting of sandstone, siltstone, shale, conglomerate, limestone, and dolomite. Local topography is characterized by long narrow ridges and broad to narrow valleys, with some karst terrane. (Sevon, 2000).

According to the United States Department of Agriculture (USDA) Soil Surveys of Blair County, Pennsylvania, soils within approximately 450 feet of the drill path for HDD S2-0140 consist of 39 separate soil units. A USDA map that depicts the mapped area, along with the soil profile descriptions, is included as **Attachment 2**.

The site geology is mapped west to east as the Devonian age Hamilton Group, Onondaga and Old Port Formations, undivided, Keyser and Tonoloway Formations, undivided, the Silurian age Wills Creek Formation and the Bloomsburg and Mifflintown Formations, undivided, as shown on **Figure 2** (Berg and Dodge, 1981). The Juniata River HDD is located on the west limb of an anticline that has a strike trending northeast-southwest and dipping to the northwest.

The Hamilton Group includes the Mahantango Formation (Dmh) and the Marcellus Formation (Dmr). The Mahantango Formation consists of interbedded shale, siltstone, and sandstone. The Marcellus Formation consists of very dark to black, fissile shale. Joints are well developed, closely spaced, mostly open, and steeply dipping. Permeability is described as moderate. Joint and bedding plane openings provide a secondary porosity of low to moderate magnitude and moderate permeability. Excavation is described as moderately easy to difficult. Drilling rates are moderate to fast. Foundation stability is good when material is excavated to sound bedrock (Geyer and Wilshusen, 1982).

The Onondaga and Old Port Formations, undivided, consist of several rock types. The Onondaga Formation includes of limestone, calcareous shale, and claystone. The Old Port Formation includes sandstone, chert, shale, and limestone. Bedding features in these formations is described as well bedded, with individual strata varying from flaggy to thick and massive. Bedrock fracturing is described as jointed with a blocky pattern that is moderately developed and moderately abundant. The joints are regularly spaced with a moderate distance between fractures that are open and steeply dipping. The joint, bedding and fracture-plane openings provide a secondary porosity of low magnitude and low permeability. Most joints within these units are blocky to seamy, moderately abundant, and open and vertical. Joints are moderately to closely spaced. These rocks are moderately weathered to a deep depth with deeper weathering in the shale units. Weathering results in small- to medium sized blocks. The overlying mantle is thin. From an engineering standpoint, excavation of these formations is difficult, but slope stability is good in the limestone member and fair in the shale member. Foundation stability is good, provided the excavation is to sound material and solution cavities are investigated and mitigated. Surface drainage is good. Secondary porosity of moderate magnitude is provided by joints and bedding plane fractures. Permeability is low to moderate. These rocks reportedly provide good foundation stability (Geyer and Wilshusen, 1982).

The undivided Keyser and Tonoloway Formations consist of dark gray, highly fossiliferous, crystalline to nodular limestone. These formations are well bedded, flaggy to thick, with some massive beds. The joints are platy and some have a blocky pattern. These units are moderately resistant to weathering. Joint and bedding plane openings and solution openings provide moderate secondary porosity. Permeability is described as low to moderate. Bedrock is described as difficult to excavate. Drilling rates are described as fast. Foundation stability is good, assuming an investigation for solution openings is performed, and when material is excavated to sound rock (Geyer and Wilshusen, 1982).

The Wills Creek Formation is an interbedded calcareous shale, siltstone, shaly limestone, and dolomite. The color range of this unit includes multicolored gray, grayish-red, yellowish-gray, and greenish-gray rocks. The formation is moderately well bedded, fissile to thin, moderately weathered and moderately resistant to weathering. Joints are well developed and highly abundant. Joint and bedding plane openings provide moderate secondary porosity. Permeability is described as low. Bedrock is reported to be moderately easy to excavate and drilling rates are reported as fast. Foundation stability is good when material is excavated to sound rock (Geyer and Wilshusen, 1982).

The Bloomsburg and Mifflintown Formations, undivided, are composed of red shale and siltstone with some sandstone and impure limestone. These formations are moderately well bedded and fissile to thin. They are highly weathered near the surface and only slightly resistant to weathering. Joint and bedding plane openings provide low to moderate secondary porosity. Permeability is described as moderate. Bedrock is reported to be moderately easy to excavate and drilling rates are reported to be relatively fast. Foundation stability is good when material is excavated to sound rock (Geyer and Wilshusen, 1982).

3.0 HYDROGEOLOGY

Groundwater at the site occurs in a fractured carbonate and sedimentary bedrock aquifer system within the geology described in Section 2.0. In these rock types of Blair County, water-bearing zones generally occur in the secondary openings along bedding planes, joints, faults and fractures. Most of the water-bearing zones penetrated by wells occur in individual fractures or groups of interconnected fractures that are sufficiently enlarged by solution that readily transport water (Taylor, 1982). In central Pennsylvania, many of the water-bearing rocks such as sandstone alternate with less permeable rocks such as shale. In areas with tilted rock strata or on the flank of an anticline, such as the Juniata HDD, water flows downdip in the permeable formations (Lohman, 1938). At this location, the HDD exit is at a higher elevation and position on the limb of the anticline in contrast to the HDD entry which is at the base of the limb. As a result, it is assumed that primary groundwater flow is downdip and to the northwest.

The review of published data on water wells focused primarily on the Hamilton Group and Onondaga and Old Port Formations underlying the west side of the Juniata HDD, near the residential development along Juniata Valley Road. The depths of 243 domestic and non-domestic water supply wells in the Hamilton Group range from 10 to 685 feet below ground surface (bgs), with yields ranging from 1 to 380 gallons per minute (gpm). The median well depth for domestic wells is 173 feet bgs and 300 feet bgs for non-domestic wells. Median well yields are 12 gpm for domestic wells and 38 gpm for non-domestic wells. Water-bearing zones among 198 wells reported are relatively common to a depth of 350 feet, but are most frequent from 50 to 150 feet. The deepest water-bearing zone was reported at 635 feet bgs (Taylor, 1982).

The depths of 168 reported domestic and non-domestic water wells in the Onondaga and Old Port Formations range from 35 to 500 feet bgs, with yields ranging from 0 to 1,400 gpm. The median well depth for domestic wells is 141 feet and 215 feet for nondomestic wells. Median well yields are 10 gpm for domestic wells and 60 gpm for non-domestic wells. Water-bearing zones among the 88 wells reported are evenly distributed to a depth of 300 feet bgs, and the deepest water-bearing zone was reported at 460 feet bgs (Taylor, 1982).

Well records reviewed within a 0.5-mile radius of the HDD location were obtained from the Pennsylvania Groundwater Information System (PaGWIS). A total of two well records were available and are summarized below. The well locations are shown on **Figures 2 and 3.**

Well No.	Well Use	Casing Depth (feet)	Total Depth (feet)	Water Level (feet)	Yield (gpm)
58809	DOMESTIC	25	230	150	0.5
3686	DOMESTIC	28	198	18	6

4.0 FRACTURE TRACE ANALYSIS

Fracture traces underlying, or in close proximity to, the site were evaluated using historical aerial photographs from the years 1993 through 2016 (Google Earth, 2017), the Frankstown Quadrangle Geologic Maps (Berg and Dodge, 1981), and Plate 1 (Taylor, 1982). The photographs, publications and maps were reviewed to approximate the locations of natural linear fracture trace features or lineaments expressed on the ground surface. The linear features may be the surficial representation of deeper fractures, joints, faults or bedding planes within the subsurface which can transmit groundwater through the fractured bedrock aquifer at the site.

Figures 2 and **3** show the results of the fracture trace analysis overlain on the geologic map of the site and an aerial base map. Eight fracture traces were identified within close proximity to the Juniata HDD that are likely related to the primary geologic structure. Six of the fracture traces trend approximately northeast-southwest, parallel to geologic strike. Two perpendicular fracture traces trend southeast-northwest and may represent joint sets.

5.0 GEOTECHNICAL EVALUATION

Two geotechnical drilling evaluations were performed at the site; one in September and October of 2014 and the other in August of 2017. The 2014 test borings were advanced by hollow-stem augers and NQ-sized wireline rock coring techniques. The 2017 test borings were advanced using the mud rotary method. Soil, residual soil and weathered bedrock were sampled using split-spoon samplers. Geotechnical boring logs are included in **Attachment 1**.

Borings SB-01 and B3-2W were located near the HDD entry on the west side of the profile. Boring SB-03 was located approximately 600 feet east of the HDD entry and on the west bank of the Juniata River. Borings SB-02 and B3-2E were located near the HDD exit. The locations of the borings are depicted on **Figure 2** and **Figure 3.**

In general, the subsurface profile at the site, as observed in the borings, is described as follows:

- Soil and residual soil depths vary from boring to boring; 6.5 feet at SB-01, 30 feet at SB-02, 14.5 feet at SB-03, 8 feet at B3-2W, and 23.5 feet at B3-2E. The residual soils are described as follows:
    - **Boring SB-01**: Sandy SILT (ML) with traces of gravel and weathered shale and fine SAND (SM) with highly weathered shale. Groundwater was observed at 16 feet bgs through the augers.
    - **Boring SB-02**: Sandy SILT (ML) with traces of gravel and weathered shale and fine SAND (SM) with highly weathered shale, and SILT and CLAY (ML/CL) with fine to medium sand and a trace of fine gravel. Groundwater was observed at 16.5 feet bgs through the augers. The boring was terminated at 30 feet bgs.
    - **Boring SB-03:** Augered to refusal at 14.5 feet bgs without sampling.
    - **Boring B3-2E**: Gravelly lean CLAY with sand (CL) and clayey GRAVEL (GC), trace sand with shale fragments. Groundwater was observed at 12.1, 12.0, and 16.0 feet bgs during the drilling process.
    - **Boring B3-2W:** Lean CLAY (CL). Groundwater was observed at 6.0 feet bgs.
- At depths of auger or split-spoon refusal and to total depth of the NQ cores, weathered bedrock and bedrock was encountered and is described as follows:
    - **Boring SB-03:** SB-03 was completed to a total depth of 34.5 feet. Alternating sequences of highly to very fractured gray limestone and calcareous shale were encountered. Rock recoveries were generally good to excellent (90% to 100%) in the core runs. Rock quality designations (RQDs) were very poor to fair (15% to 68%), and generally increased with depth.
    - **Boring B3-2E:** B3-2E was completed to a total depth of 586.8 feet. From 23.5 feet to 109.2 feet, weathered to completely weathered rock was observed in split spoon samples. Four alternating sequences of gray argillaceous limestone and gray and reddish brown to gray shale were encountered from 109.2 feet to the completion depth of 586.8 feet. The limestone is described as thin to medium bedded, with some shale interbeds having close to moderately close joint spacing. Primary joint sets in the limestone are high angle and secondary joint sets are low angle. RQDs in the limestone were fair to excellent (59% to 95%). The lowest RQDs in the limestone were reported from 109.2 feet to 116.8 feet, directly below the weathered to completely weathered rock. The shale is described as thinly bedded with some limestone interbeds and close to moderately close joint spacing. Primary joint sets in the shale are high angle and

secondary joint sets are low angle. RQDs in the limestone were poor to excellent (31% to 100%). The lowest RQDs were reported from 116.8 feet to 246 feet. Below 246 feet, RQDs were good to excellent (79% to 100%).

- **Boring B3-2W:** B3-2W was completed to a depth of 120 feet. From 20 feet to 75 feet, slightly to moderately weathered mudstone was encountered. Less weathered, fresh mudstone was encountered from 75 feet to 120 feet. Joints are closely spaced, moderately dipping to near vertical and infilled with clay. RQDs were very poor to excellent (0% to 95%). There was not a strong correlation observed between depth and RQD.

Unconfined compressive strength testing was performed on core samples and testing results are summarized in the table below.

Boring	Sample Depth (feet bgs)	Compressive Strength (psi)
SB-03	29.5	8,051
B3-2W	43.5	1,138
B3-2W	60	4,423
B3-2W	80	4.074
B3-2W	100	4,690
B3-2W	110	4,772
B2-2E	130	14,372
B2-2E	150	5,173
B2-2E	170	6,398
B2-2E	190	9,126
B2-2E	210	1,035
B2-2E	230	1,400
B2-2E	250	581
B2-2E	330	7,560
B2-2E	351	5,363
B2-2E	390	20,166
B2-2E	410	742
B2-2E	430	2,542
B2-2E	490	6,013
B2-2E	530	1,016

Please note that RETTEW did not oversee or direct the geotechnical drilling program associated with the Juniata River HDD, including but not limited to, the selection of boring locations, determination of location, determination of surface elevation, target depths, observations of rock cores during drilling operations, or preparation of boring logs. The geotechnical reports, boring logs, and core photographs that resulted from these programs were generated by other Sunoco Pipeline, L.P. contractors. RETTEW relied on these reports and incorporated their data into the general geologic and hydrogeologic framework of the analysis of the Juniata HDD in this report.

6.0 FIELD OBSERVATIONS

A field investigation was performed by a RETTEW geologist on October 3, 2017 to identify rock outcrops for fracture fabric analysis, possible ground-truthing of fracture traces identified during the desktop evaluation, and to identify potential sensitive receptors to IRs. A roadside outcrop was identified approximately 2.3 miles southwest of the HDD entry along geologic strike as shown on **Figure 2**. The outcrop consists of massive and nodular limestone with shale interbeds of the undivided Keyser and Tonoloway Formations. The average strike of bedding at this outcrop is 212° with an average dip of 44° NW. The strike of the primary joint set is 123° with a dip of 85° SW. A secondary joint set was identified and has a strike of 84° and a dip of 83° S. The field data is consistent with published geologic data, mapping, and fracture traces identified in Section 4.0. No additional sensitive receptors to IRs beyond the previously mapped streams and wetlands were identified during the site reconnaissance.

7.0 GEOPHYSICAL SURVEY CONSIDERATIONS

Karst geology is present at this HDD location, and pursuant to the Stipulated Order the use of geophysical surveys should be considered in karst areas. The use of geophysical surveys during re-evaluation was considered but ultimately not implemented at the Juniata River HDD location because the results of geophysical surveys would not likely provide additional information that would reduce the risk of an IR. In addition, results of geophysical surveys in karst terrains with the resolution necessary to image features that could affect the HDD are typically limited to the uppermost 20 to 50 feet of the ground surface. Based upon our experience working in karst geology, the predominant flaggy to thick and massively bedded limestone units of the Onondaga and Old Port Formations, and Keyser and Tonoloway Formations, are not as highly susceptible to the solution activity present in other more thickly-bedded carbonate geologic formations in Pennsylvania. In addition, the portion of the HDD profile extending through these formations ranges from approximately 50 feet bgs to 94 feet bgs beneath the Juniata River in the center of the profile. In our professional opinion, geophysical surveys would not provide additional information on the formational thickness, interbedded limestone and shale, and thin beds of limestone at depths greater than 50 feet bgs along the HHD profile. Geophysical survey data would not enhance the evaluation or reduce the risk of an IR.

8.0 CONCEPTUAL HYDROGEOLOGIC MODEL AND CONCLUSION

Based on published geologic and hydrogeologic information, and the evaluation of geotechnical borings from the site, the Juniata River HDD location is underlain by carbonate and sedimentary rocks of the Hamilton Group, Onondaga and Old Port Formations, Keyser and Tonoloway Formations, Wills Creek Formation, and Bloomsburg and Mifflintown Formations. The hydrogeologic setting is dominated by groundwater flow through secondary openings along geologic features including bedding planes, joints, faults, and fractures. The secondary openings may be enlarged or enhanced by dissolution in underlying carbonate rocks. This is supported by the observation of weathering, fractures, and joints in the geotechnical cores and may be indicative of the high yields reported from some nearby domestic and non-domestic wells. In addition, field measurements of local geologic structure support the published information with regard to vertical and near vertical joint sets. Well records indicate that water-bearing zones in water wells close to the site are common to 350 feet bgs in the Hamilton Group and to 300 feet bgs in the Onondaga and Old Port Formations.

The originally proposed 16-inch and 20-inch HDD profiles were relatively shallow at the entry and exit points, and passed through both the unconsolidated overburden and fractured bedrock. The weakest point of the profile is beneath the first crossing of the Juniata River where the 16-inch pipe will be 94 feet, and the 20-inch pipe which will be 103, feet below the Juniata River. Based on the hydro-structural characteristics of the underlying geology described in this report and the proposed HDD profiles, the Juniata River HDD site is susceptible to the inadvertent return of drilling fluids during HDD operations. As a result, the HDD profile has been redesigned to allow for deeper crossings beneath the Juniata River. The inclination of the entry and exit angles has been increased to allow the pipe to be installed through the protective soils, residual soils, and bedrock to a deeper depth earlier on the entry trajectory and later along exit trajectory than the original, shallower profile. From a geologic perspective, the deeper profile, in conjunction with the proposed engineering controls and/or drilling best management practices will be used to reduce the risk of an IR.

9.0 REFERENCES

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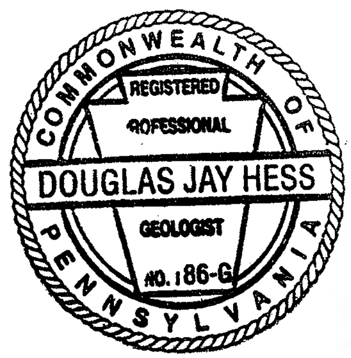
10.0 CERTIFICATION

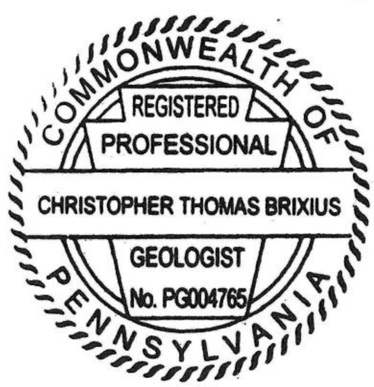
The studies and evaluations presented in this report (other than Section 5) were completed under the direction of a licensed professional geologist (P.G.), and are covered under the P.G. seals that follow.

By affixing my seal to this document, I am certifying that, to my knowledge and belief, the information herein is true and correct. I further certify, that I am licensed to practice in the Commonwealth of Pennsylvania and that it is within my professional expertise to verify the correctness of the information herein.



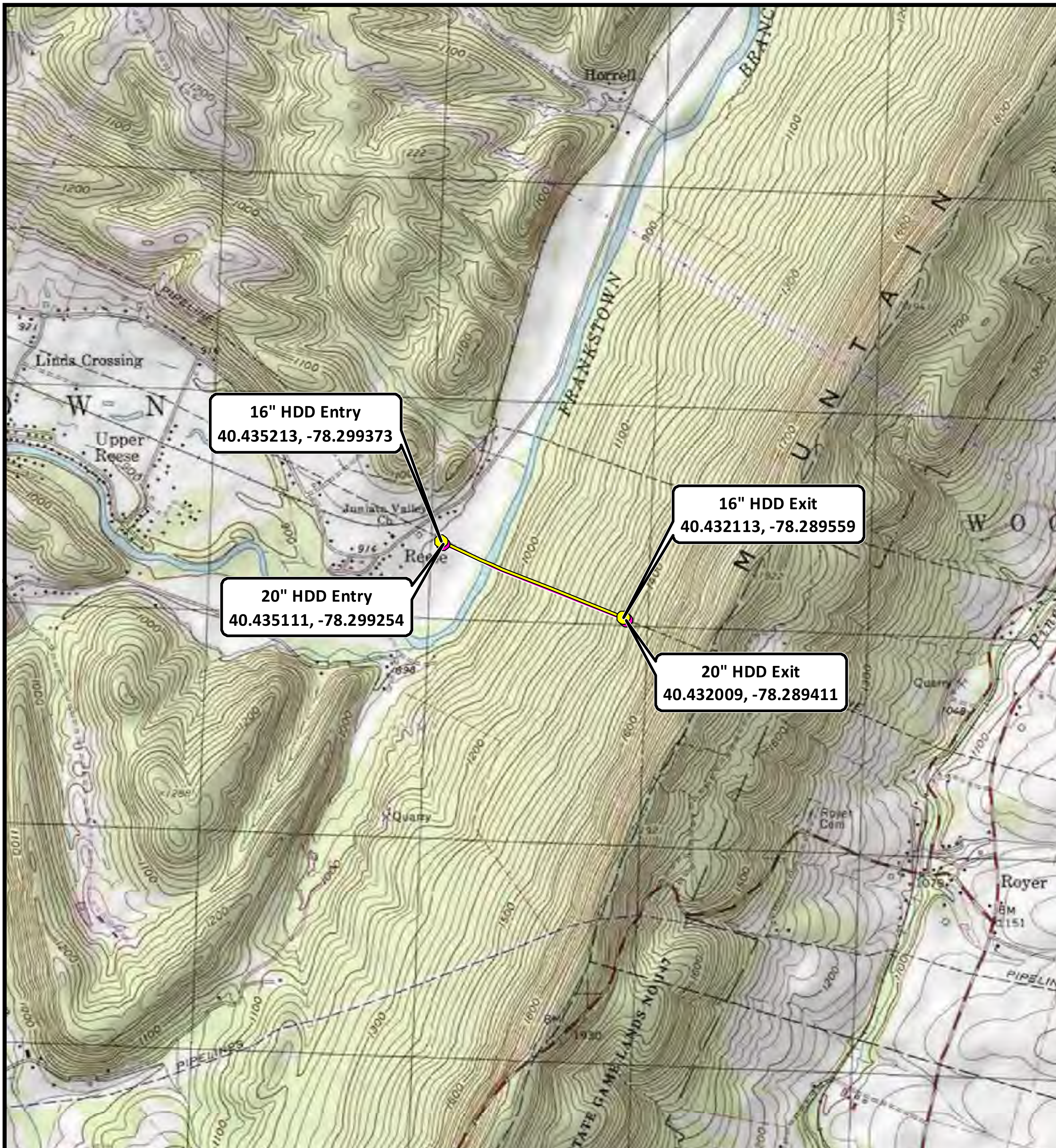
Douglas J. Hess, P.G
License No. PG000186G

Ethan E. Prout, P.G.
License No. PG003884



Christopher T. Brixius, P.G.
License No. PG004765

FIGURES



16" HDD Entry/Exit

20" HDD Entry/Exit

16" HDD Profile

20" HDD Profile

Frankstown, PA USGS 7.5' Topographic Quadrangle

10/20/2017

Sunoco Pipeline, L.P.

Juniata River HDD Location

Figure 1 - Topographic Basemap

Frankstown Township, Blair County, PA

Project No. 096302011

0 1,000 2,000 Feet

1 inch = 2,000 feet

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed

Sunoco Logistics Partners L.P.

RETTEW

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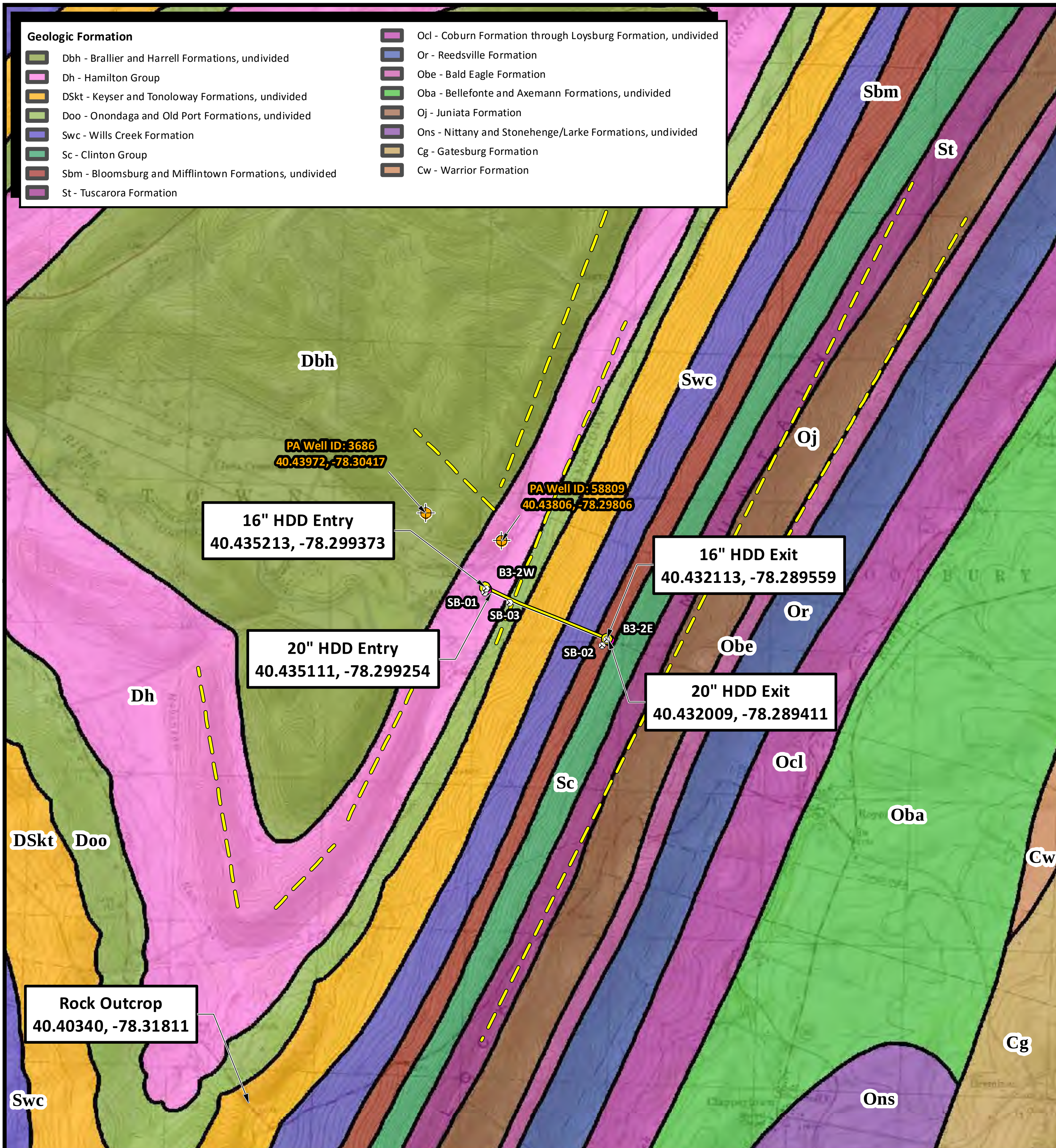

Residential Well
Soil Boring
16" HDD Entry/Exit
20" HDD Entry/Exit
16" HDD Profile
20" HDD Profile
Inferred Fracture Trace

Frankstown, PA USGS 7.5' Topographic Quadrangle

10/20/2017

Sunoco Pipeline, L.P.

Juniata River HDD Location

Figure 2 - Geologic Map

Frankstown Township, Blair County, PA

Project No. 096302011

0 3,000 Feet

1 inch = 3,000 feet

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed

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Residential Well	20" HDD Profile
Soil Boring	Inferred Fracture Trace
16" HDD Entry/Exit	NHD Stream
20" HDD Entry/Exit	Road
16" HDD Profile	Municipal Boundary

10/20/2017

Sunoco Pipeline, L.P.

Juniata River HDD Location

Figure 3 - Aerial Basemap

Frankstown Township, Blair County, PA

Project No. 096302011

0 2,500 Feet

1 inch = 2,500 feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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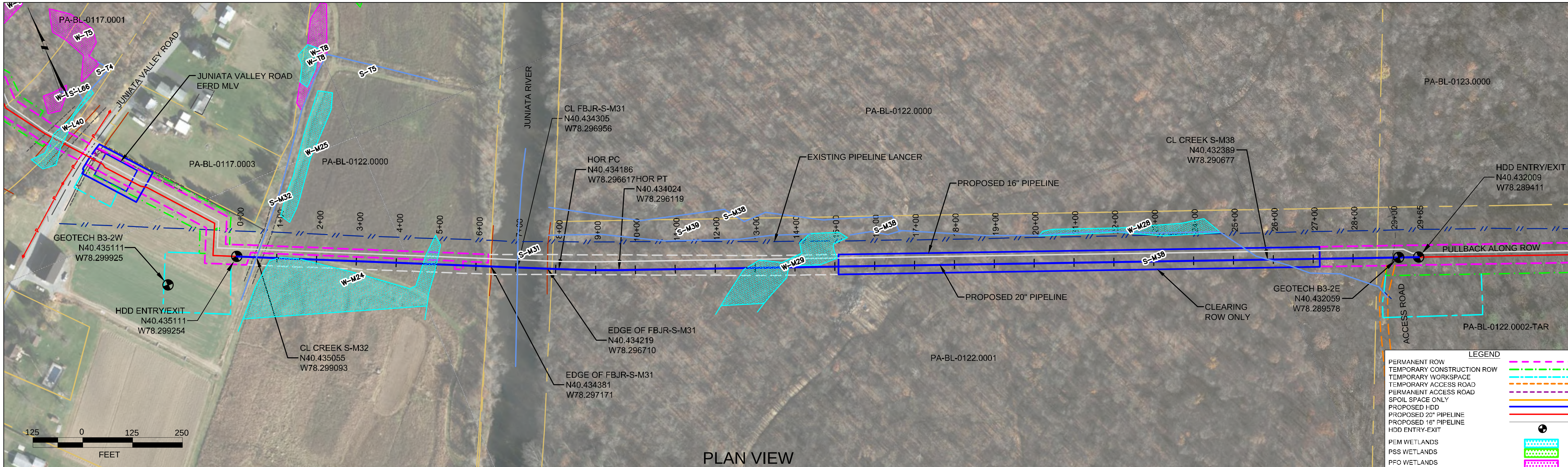
RETTEW

ATTACHMENT 1
GEOTECHNICAL BORING LOGS



PLAN VIEW

BLAIR COUNTY, PENNSYLVANIA - FRANKSTOWN TOWNSHIP
S2-0140

PROFILE VIEW

GEOTECH B3-2E

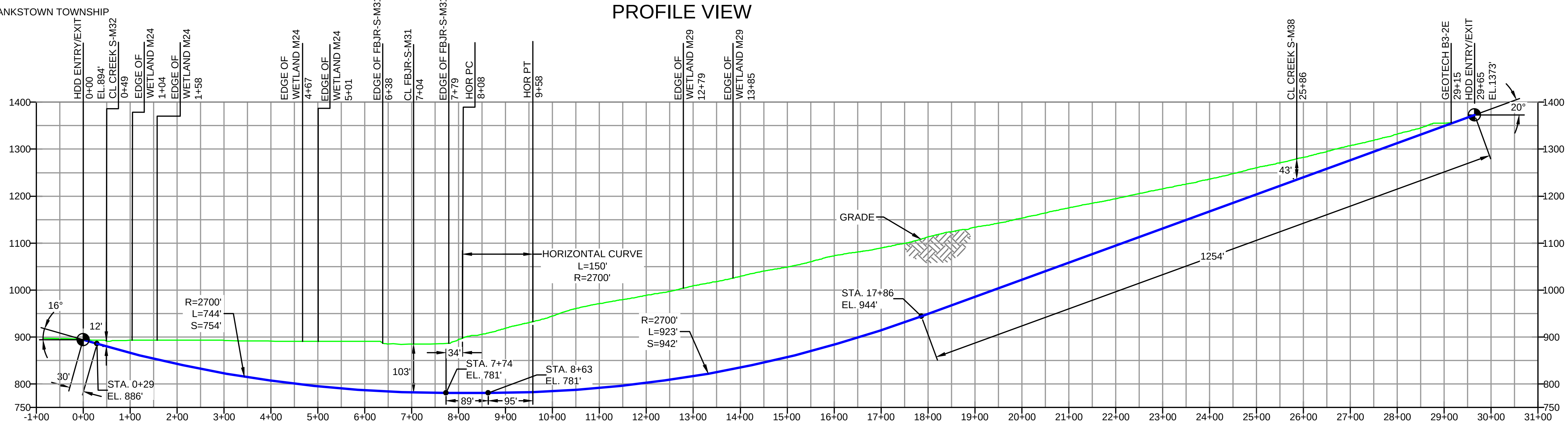
- NG EL. 1356'
- GRAVEL (0.0' - 0.7')
- GROUNDWATER (12.0')
- LEAN CLAY W/ SAND CL (0.7' - 13.5')
- GC (13.5' - 23.5')
- WEATHERED ROCK LIMESTONE (23.5' - 586.8')
- BORING TERMINATED EL.769'

NOTE: REFER TO TEST BORING LOG B3-2E TERRACON INC. PROJECT # J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B3-2W

- NG EL. 898'
- GROUNDWATER (6.0')
- LEAN CLAY CL (0.0' - 8.0')
- MUDSTONE (8.0' - 120.0')
- BORING TERMINATED EL.778'

NOTE: REFER TO TEST BORING LOG B3-2W TERRACON INC. PROJECT # J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 2965'
   HDD PIPE LENGTH (S=): 3067'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.
14. CONTRACTOR IS REQUIRED TO USE DRILLING FLUID / MUD WITH A UNIT WEIGHT OF 9.5 PPG OR LESS.

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-3.51	TO	ES-3.53	EROSION & SEDIMENT PLAN
SHEET 33	TO	SHEET 34	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	INCREASED VERTICAL CURVE RADIUS - DESIGN CHANGE PER MICHELS	MRS	10/19/17	RMB	10/19/17	CAG	10/19/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ADDED GEOTECH INFO	MRS	09/04/15	RMB	09/04/15	AAW	09/04/15
B	ISSUED FOR BID	JAM	07/31/15	RMB	07/31/15	AAW	07/31/15

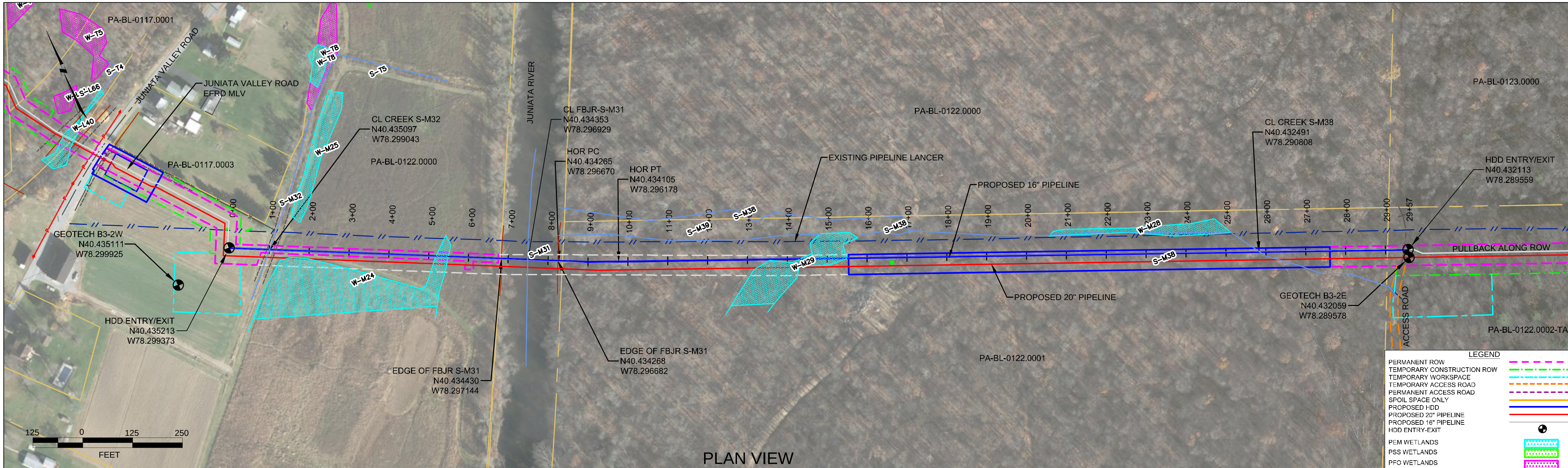
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

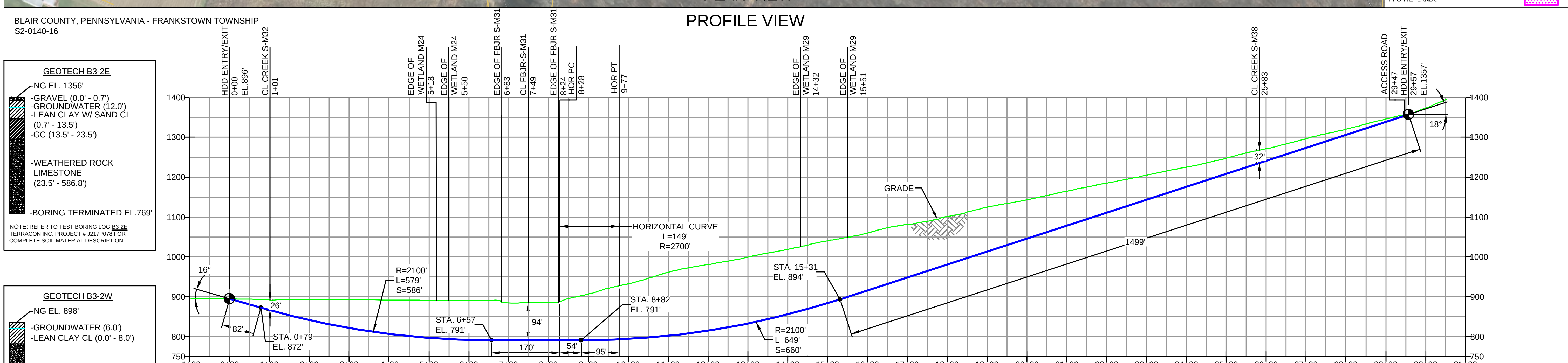
SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
JUNIATA RIVER
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'
DWG. NUMBER: PA-BL-0122.0000-WX



BLAIR COUNTY, PENNSYLVANIA - FRANKSTOWN TOWNSHIP
S2-0140-16



DESIGN AND CONSTRUCTION:
1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 2957'
   HDD PIPE LENGTH (S=): 3051'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.
14. CONTRACTOR IS REQUIRED TO USE DRILLING FLUID / MUD WITH A UNIT WEIGHT OF 9.5 PPG OR LESS.

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-3.51	TO	ES-3.53	EROSION & SEDIMENT PLAN
SHEET 33	TO	SHEET 34	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	INCREASED VERTICAL CURVE RADIUS - DESIGN CHANGE PER MICHELS	MRS	10/19/17	RMB	10/19/17	CAG	10/19/17
EP2	REVISED PER PADEP COMMENTS RECEVIED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/09/16	RMB	05/09/16	AAW	05/09/16
EP		MRS	11/23/15	RMB	11/23/15	AAW	11/23/15
B	ADDED GEOTECH INFO	MRS	09/04/15	RMB	09/04/15	AAW	09/04/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	08/31/15

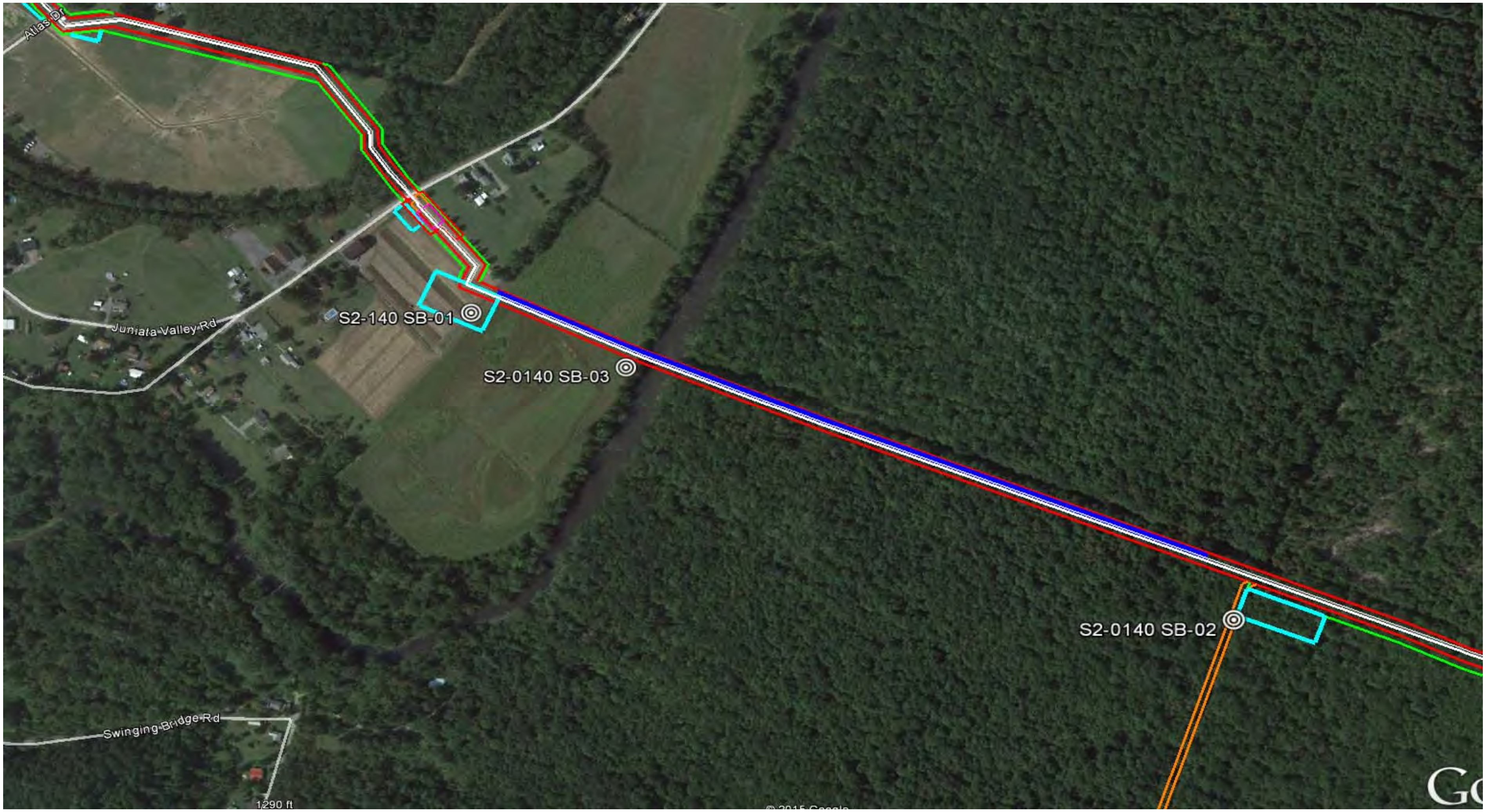
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
JUNIATA RIVER
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' | DWG. NO. PA-BL-0122.0000-WX-16



LEGEND:

Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S2-0140
BLAIR COUNTY, FRANKSTOWN TOWNSHIP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT

TETRA TECH
240 Continental Drive, Suite 200
Newark, Delaware 19713
302.738.7551
fax: 302.454.5988

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406	
Project Location:	JUNIATA VALLEY ROAD, HOLLISDAYSBURG, PA			Page 1 of 1	
HDD No.:	S2-0140	Dates(s) Drilled: 10-11-14		Inspector:	E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 16.0		Total Depth (ft):	28.3
Boring Location Coordinates:		40°26'5.52"N		78°17'57.77"W	

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.3			TOPSOIL (4").					
1	3.0	5.0	0.3		18	ML	LIGHT BROWN TO ORANGE BROWN SANDY SILT, TRACES OF	4	14	24	36	**38**
				6.5			QUARTZ GRAVEL AND OXIDIZED WEATHERED SHALE. USCS: ML					
2	8.0	8.9	6.5		10	SM	DR WEATHERED TO A LIGHT GRAY FINE SAND WITH SOME SILT.	7	50/5"			**>50**
3	13.0	13.9			10		HIGHLY WEATHERED GRAY TO DARK GRAY SHALE. WEATHERED TO	6	50/5"			**>50**
							A FINE SAND CONSISTENCY.					
4	18.0	18.7			9		HIGHLY WEATHERED GRAY TO DARK GRAY SHALE. WEATHERED TO	8	50/3"			**>50**
							A FINE SAND CONSISTENCY WITH UNWEATERED GRAVEL.					
5	23.0	23.7			7		HIGHLY WEATHERED GRAY TO DARK GRAY SHALE. WEATHERED TO	12	50/3"			**>50**
							A FINE SAND CONSISTENCY WITH UNWEATERED GRAVEL.					
6	28.0	28.3			3		HIGHLY WEATHERED GRAY TO DARK GRAY SHALE. WEATHERED TO	50/3"				**>50**
				30.0			A FINE SAND CONSISTENCY WITH UNWEATERED GRAVEL.					
							WET ON SPOON AT 18.3'.					
							WATER LEVEL THRU AUGERS AT 16'.					
							CAVED AT 27.5'					
							WATER LEVEL ON CAVE AT 15'					

Notes/Comments:

Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

Strata (USCS) Designations are approximated based on visual review, except where indicated in Description of Materials.

* Number of blows of 140 lb. Hammer dropped 30 in. required to drive 2 in. split-spoon sampler in 6 in. increments.
N: Number of blows to drive spoon from 6" to 18" interval.

TETRA TECH
240 Continental Drive, Suite 200
Newark, Delaware 19713
302.738.7551
fax: 302.454.5988

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406	
Project Location:	LOCKE MOUNTAIN ROAD, GAME COMMISSION PROPERTY, HOLLIDAYSBURG, PA			Page 1 of 1	
HDD No.:	S2-0140	Dates(s) Drilled: 10-20-14		Inspector:	E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 16.5		Total Depth (ft):	30.0
Boring Location Coordinates:		40°25'54.02"N		78°17'23.82"W	

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
							NO DISCERNABLE TOPSOIL					
1	3.0	5.0	0.0		15	ML	DR WEATHERED TO A MOTTLED (LIGHT BROWN, OR. BROWN, GRAY,	8	10	19	18	**29**
				6.5			REDDISH BRWN) SANDY SILT, TRACE FINE GRAVEL.					
2	8.0	9.5	6.5		7	SM	SAME AS ABOVE, REDDISH BROWN TO WHITE QUARTZ GRAVEL	3	16	50/6"		**56**
							LENSE FROM 9 TO 9.5'.					
3	13.0	15.0			11		DR WEATHERED TO AN ORANGE BROWN (TRACE GRAY) FINE TO	6	7	8	5	**15**
				18.5			MEDIUM SAND WITH SOME SILT, TRACE F-GRAVEL. (USCS: SM)					
4	18.0	20.0	18.5		12	ML/ CL	DR WEATHERED TO A LIGHT BROWN SILT AND CLAY WITH A LITTLE	2	9	11	13	**20**
							FINE TO MEDIUM SAND, TRACE FINE GRAVEL.					
5	23.0	25.0			12		DR WEATHERED TO A LIGHT BROWN SILT AND CLAY WITH A LITTLE	1	5	9	9	**14**
							FINE TO MEDIUM SAND, TRACE FINE GRAVEL. (USCS: ML/CL)					
6	28.0	30.0			13		DR WEATHERED TO A LIGHT BROWN SILT AND CLAY WITH A LITTLE	2	10	20	22	**30**
				30.0			FINE TO MEDIUM SAND, TRACE FINE GRAVEL.					
							WET ON SPOON AT 18'.					
							WATER LEVEL THROUGH AUGERS AT 16.5'.					
							CAVED AT 27'.					
							WATER LEVEL ON CAVE AT 25'.					
							PLACED CONCRETE PLUG					

Notes/Comments:

Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

S4: >4 TSF
S5: 3.0 TSF

Strata (USCS) Designations are approximated based on visual review, except where indicated in Description of Materials.

* Number of blows of 140 lb. Hammer dropped 30 in. required to drive 2 in. split-spoon sampler in 6 in. increments.
N: Number of blows to drive spoon from 6" to 18" interval.

TETRA TECH
240 Continental Drive, Suite 200
Newark, Delaware 19713
302.738.7551
fax: 302.454.5988

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406
Project Location:	JUNIATA VALLEY ROAD, HOLLISDAYSBURG, PA			Page 1 of 1
HDD No.:	S2-0140	Dates(s) Drilled: 09-25-15	Inspector:	E. WATT
Boring No.:	SB-03	Drilling Method: SPT - ASTM D1586	Driller:	K. KERSH
Drilling Contractor:	CONNELLY	Groundwater Depth (ft):	Total Depth (ft):	34.5
Boring Location Coordinates:		40° 26' 3.373" N	78° 17' 50.560" W	

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *	N
							AUGERED CONTINUOUSLY TO REFUSAL AT 14.5'.		
							<u>ROCK CORING</u>		
RUN 1	14.5	19.5	14.5	15.4	60	FRACTURED ROCK	VERY INTENSELY TO INTENSELY FRACTURED GRAY LIMESTONE.	TCR: 100%, SCR: 22%, RQD: 17%	
			15.4	19.0			VERY INTENSELY FRACTURED GRAY CALCEROUS SHALE.		
			19.0				MODERATELY FRACTURED GRAY LIMESTONE.		
RUN 2	19.5	24.5		21.0	60		VERY INTENSELY FRACTURED GRAY LIMESTONE.	TCR: 100%, SCR: 20%, RQD: 15%	
			21.0	23.4			VERY INTENSELY FRACTURED LIMESTONE.		
			23.4				MODERATELY TO INTENSELY FRACTURED GRAY LIMESTONE.		
RUN 3	24.5	29.5		25.7	54		INTENSELY TO VERY INTENSELY FRACTURED GRAY LIMESTONE.	TCR: 90%, SCR: 49%, RQD: 43%	
			25.7				SLIGHTLY TO MODERATELY FRACTURED GRAY LIMESTONE WITH		
				28.0			CALCITE DEPOSITS.		
			28.0	28.3			VERY INTENSELY FRACTURED GRAY CALCEROUS SHALE.		
			28.3	31.9			SLIGHTLY TO MODERATELY FRACTURED GRAY LIMESTONE.		
RUN 4	29.5	34.5	31.9	32.6	60		INTENSELY FRACTURED GRAY LIMESTONE.	TCR: 100%, SCR: 68%, RQD: 68%	
			32.6				UNFRACTURED TO MODERATELY FRACTURED GRAY LIMESTONE		
				34.5			WITH CALCITE DEPOSITS.		
							<u>CORE TESTING RESULTS (DEPTH 29.5-30'):</u>		
							COMPRESSIVE STRENGTH: 8,050 PSI		
							UNIT WEIGHT: 163.1 PCF		

Notes/Comments:

<u>Pocket Pentrometer Testing</u>

DR: DECOMPOSED ROCK

Strata (USCS) Designations are approximated based on visual review, except where indicated in Description of Materials.

* Number of blows of 140 lb. Hammer dropped 30 in. required to drive 2 in. split-spoon sampler in 6 in. increments.
N: Number of blows to drive spoon from 6" to 18" interval.

ROCK CORE DESCRIPTION SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0140

Location	Boring No.	Core Run	Core Depth (ft)		TCR (%)	SCR (%)	RQD (%)	Depth (ft)		Weathering	Classification	Bedding Thickness (ft)	Color	Discontinuity Data
			From	To				From	To					
S2-0140	SB-03	1	14.5	19.5	100	22	17	14.5	34.5	Moderate	Limestone	Massive	Gray	Fractures ranging from 6° to 56°, Avg. 31°; Occasional shaly cleavage to fractures
		2	19.5	24.5	100	20	15							
		3	24.5	29.5	90	49	43							
		4	29.5	34.5	100	68	68							

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0140

HDD No.	Test Boring No.	Sample No.	Depth of Sample (ft.) From	Depth of Sample (ft.) To	Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318) Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	USCS Classif. (ASTM D2487)
S2-0140	SB-01	1	3.0	5.0	10.3	63.1	31	24	7	ML
		2	8.0	8.9	4.3	29.5	-	-	-	-
		4	18.0	18.7	5.9	15.4	-	-	-	-
		6	28.0	28.3	5.1	27.4	-	-	-	-
	SB-02	1	3.0	5.0	12.3	56.4	-	-	-	-
		3	13.0	15.0	16.5	33.1	33	22	11	SM
		4	18.0	20.0	14.5	86.3	-	-	-	-
		5	23.0	25.0	15.2	81.8	35	24	11	ML/CL
		6	28.0	30.0	14.3	91.6	-	-	-	-

Rock Core Testing Results				
Boring No.	Core Run	Approximate Depth (ft)	Compressive Strength (psi)	Unit Weight (pcf)
SB-03	4	29.5 - 30.0	8,050	163.1

Notes:

1) Sample depths based on feet below grade at time of exploration.

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0140

HDD No.	NAME	BORING NO.	REGIONAL GEOLOGY DESCRIPTION	GENERAL TOPOGRAPHIC SETTING	BEDROCK FORMATION	GENERAL ROCK TYPE	APPROX MAX FM THICKNESS (FT)	DEPTH TO ROCK (Ft bgs) based on nearby well drilling logs	NOTES / COMMENTS
S2-0140	Frankstown	SB-01	**Hamilton Group**- The Mahantango Formation and the underlying Marcellus Formation make up the Hamilton Group.	Ridge and Valley	Mahatango (aka Hamilton Group)	Shale-siltstone, laminated, fossiliferous			
		SB-02	**Bloomsburg and Mifflintown Formations**, undivided - The Bloomsburg Formation is predominantly red shale and siltstone. Mifflintown is Interbedded dark-gray shale and medium-gray fossiliferous limestone		Bloomsburg and Mifflintown Formations	predominantly red shale and siltstone.			
		SB-03	**Onondaga and Old Port Formation** (undivided) consists of two members - the upper Selinsgrove Limestone and the lower calcerous Needmore Shale.		Onondaga-Old Port	Limestone and calcareous shale with occasional chert	100-200	4-32	

Note : Source of well log data - http://www.dcnr.state.pa.us/topogeo/groundwater/pagwis/records/index.htm. All other sources as referenced in comments section.

FIELD DESCRIPTION AND LOGGING SYSTEM FOR SOIL EXPLORATION

GRANULAR SOILS
(Sand, Gravel & Combinations)

Density	***N (blows)****
Very Loose	5 or less
Loose	6 to 10
Medium Dense	11 to 30
Dense	31to 50
Very Dense	51 or more

Relative Proportions

Description Term	*Percent*
Trace	1 - 10
Little	11 - 20
Some	21 - 35
And	36 - 50

Particle Size Identification

Boulders	8 in. diameter or more	
Cobbles	3 to 8 in. diameter	
Gravel	Coarse (C)	3 in. to ¾ in. sieve
	Fine (F)	¾ in. to No. 4 sieve
Sand	Coarse (C)	No. 4 to No. 10 sieve (4.75mm-2.00mm)
	Medium (M)	No. 10 to No. 40 sieve (2.00mm – 0.425mm)
	Fine (F)	No. 40 to No. 200 sieve (0.425 – 0.074mm)
Silt/Clay	Less Than a No. 200 sieve (<0.074mm)	

COHESIVE SOILS
(Silt, Clay & Combinations)

Consistency	***N (blows)****
Very Soft	3 or less
Soft	4 to 5
Medium Stiff	6 to 10
Stiff	11 to 15
Very Stiff	16 to 30
Hard	31 or more

Plasticity

Degree of Plasticity	*Plasticity Index*
None to Slight	0 - 4
Slight	5 - 7
Medium	8- 22
High to Very High	> 22

ROCK
(Rock Cores)

Rock Quality Designation (RQD), %	***Rock Quality Description***
0-25	Very Poor
25-50	Poor
50-75	Fair
75-90	Good
90-100	Excellent

****N - Standard Penetration Resistance.*** Driving a 2.0" O.D., 1-3/8" I.D. sampler a distance of 18 inches into undisturbed soil with a 140 pound hammer free falling a distance of 30.0 inches. The number of hammer blows to drive the sampler through each 6 inch interval is recorded; the number of blows required to drive the sampler through the final 12 inch interval is termed the Standard Penetration Resistance (SPR) N-value. For example, blow counts of 6/8/9 (through three 6-inch intervals) results in an SPR N-value of 17 (8+9).

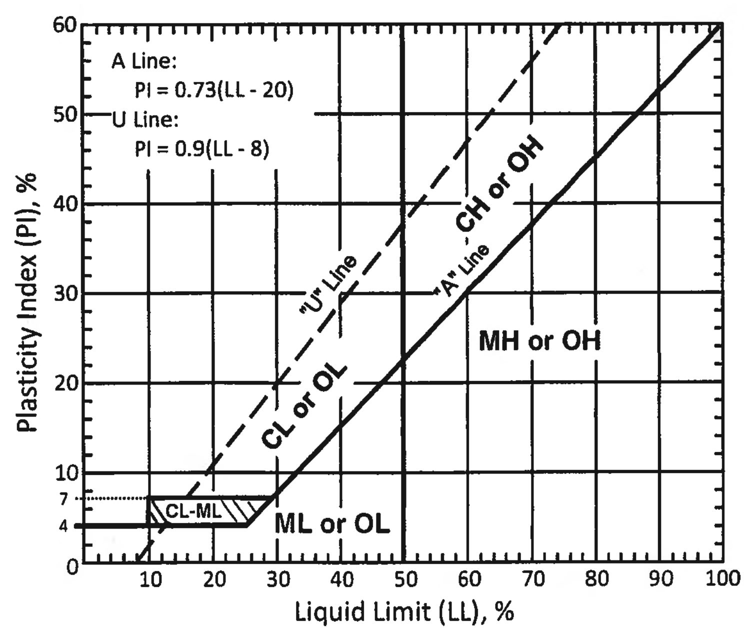
Groundwater observations were made at the times indicated. Groundwater elevations fluctuate throughout a given year, depending on actual field porosity and variations in seasonal and annual precipitation.

UNIFIED SOIL CLASSIFICATION SYSTEM [Casagrande (1948)]

Major Divisions			Group Symbols	Typical Descriptions	Laboratory Classifications		
Coarse Grained Soils (More than half of material is larger than No. 200 sieve)	Gravels More than half of coarse fraction is larger than No. 4 sieve size	Clean gravel (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine Percentage of sand and gravel from grain size curve. Depending on Percentage of fines (fraction smaller than No. 200 sieve), coarse-grained soils are classified as follows: 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(1)	$C_u=\frac{D_{60}}{D_{10}}$ greater than 4: $C_c=\frac{(D_{30})2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting C_u or C_c requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below A Line or I_p less than 4	Limits plotting in hatched zone with I_p between 4 and 7 are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above A line with I_p greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 Sieve)	Clean sands (Little or no fines)	SW	Well graded sands, gravely sands, little or no fines		$C_u=\frac{D_{60}}{D_{10}}$ greater than 6 $C_c=\frac{(D_{30})2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting C_u or C_c requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures		Atterberg limits below A Line or I_p less than 4	Limits Plotting in hatched zone with I_p between 4 and 7 are borderline cases requirlng use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits above A line with I_p greater than 7	

Major Divisions		Group Symbols	Typical Descriptions
Fine–grained soils (More than half of material is smaller than No. 200 sieve)	Silts and clays (Liquid limit less than 50)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays , sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays (Liquid limit greater than 50)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
	Highly organic soils	Pt	Peat and other highly organic soils

For soils plotting nearly on A line use dual symbols i.e ., I_p = 29.5, w_L=60 gives CH-MH. When w_L is near 50 use CL-CH or ML-MH. Take near as ± 2 percent.



(1) Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example: GW-GC. well-graded gravel-sand mixture with clay binder.

Geotechnical Site Characterization

Mariner East 2 Pipeline Project
Spread 3 – Juniata River
Commonwealth of Pennsylvania
Drawing #PA-BL-0122.0000-WX
PO #20170804-14

October 9, 2017
Terracon Project No. J217P078

Prepared for:
Directional Project Support, Inc.
Magnolia, Texas

Prepared by:
Terracon Consultants, Inc.
Manchester, New Hampshire

October 9, 2017

Directional Project Support, Inc.
33311 Lois Lane, Suite A
Magnolia, TX 77354

Attn: Mr. Robert Sessions
P: (318) 542 6657
E: fielduspl@Hotmail.com

Re: Geotechnical Site Characterization
Mariner East 2 Pipeline Project
Spread 3 – Juniata River
Commonwealth of Pennsylvania
Drawing #PA-BL-0122.0000-WX
PO #20170804-14
Terracon Project No. J217P078

Dear Mr. Sessions:

This letter provides a summary of the bedrock characterization for the Mariner East 2 Pipeline Project crossing to be located at Juniata River (Drawing #PA-BL-0122.0000-WX) in the Commonwealth of Pennsylvania. Our services were performed in general accordance with our proposal number PJ2175108 dated July 28, 2017. Our scope of services included advancing two borings, designated as B3-2W and B3-2E, visual classification and photography of the rock core samples, and laboratory testing of representative rock samples.

Test borings, B3-2W and B3-2E were drilled between August 14 and 29, 2017 to depths of 120 and 586.8 feet, respectively as shown on the attached **Test Boring Location Plan**. Bedrock typically consisted of mudstone at B3-2W and interlayered sedimentary rock comprised of limestone and shale at B3-2E. Final test boring logs documenting overburden soil and bedrock conditions as well as photographs of the rock core samples are attached.

Rock compressive strength testing was performed on samples from approximately 20-foot intervals within the bedrock strata at each boring location. Unconfined compressive strength test results are shown on the attached reports.

When laboratory soil testing results are available, we will submit a complete data report for the subject crossing. In the meantime, if you have questions, or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.

Marc A. Gullison, E.I.T.
Staff Geotechnical Engineer

Lawrence J. Dwyer, P.E. (CT 15120)
Principal

Attch:

TEST BORING LOCATION PLAN
EXPLORATION RESULTS (Boring Logs, Laboratory Data, Rock Core Photographs)
SUPPORTING INFORMATION (Unified Soil Classification System, Description of Rock Properties)

TEST BORING LOCATION PLAN

N

APPROXIMATE BORING LOCATION

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

Project Manager: JGS	Project No. J217P078
Drawn by: SBL	Scale: N.T.S.
Checked by: LJD	File Name: J217P078 BLP
Approved by: LJD	Date: September. 2017

Terracon
Consulting Engineers & Scientists

201 Hammer Mill Road Rocky Hill, Ct 06067
PH. (860) 721-1900 FAX. (860) 721-1939

TEST BORING LOCATION PLAN

Juniata River HDD Cores B3-2W and B3-2E
PA-BL-0122.0000-WX
Blair County, Pennsylvania

Exhibit
A-2

EXPLORATION RESULTS

BORING LOG NO. B3-2W Juniata River West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

LOCATION
Latitude: 40.435111° Longitude: -78.2999254°
Approximate Surface Elev: 898 (Ft.) +/-

Depth	Material Description	Elevation (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	LEAN CLAY (CL), olive-brown to orange and brown, soft		0–1.5		SPT	13	2-2-2 N=4			2.25
8.0	Similar, red and brown, very stiff	890+/-	5–6.5	▽ 6'	SPT	17	5-8-9 N=17			3.75
	Weathered rock with clay, grayish - brown, friable Advance roller bit to 20 feet to begin coring		10–11.5		SPT	3	50/3"			
20.0		878+/-	15		SPT	2	50/2"			
25.0	Run 1, Soft, moderately weathered, grayish-black argillaceous MUDSTONE, moderately dipping close joints in-filled with clay	873+/-	20–25		Core	50		0	2.75 2.25 2.25 3.25 3.25	
30.0	Run 2, Similar to above	868+/-	25–30		Core	46		27	2.75 2.25 2.25 2.5 2.75	
35.0	Run 3, Medium hard, slightly weathered, grayish-black argillaceous MUDSTONE, moderately dipping close joints	863+/-	30–35		Core	60		70	2.5 2.5 2.5 2.5 2.5	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
▽ *6' WD*
0' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/14/2017	Boring Completed: 8/15/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B3-2W Juniata River West

PROJECT: Mariner East Pipeline Borings

**CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354**

SITE: Spread 3

LOCATION
Latitude: 40.435111° Longitude: -78.2999254°

Approximate Surface Elev: 898 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
40.0	Run 4, Similar to above	858+/-	40			60		55	2.5 1.75 1.75 2.0 2.0	
45.0	Run 5, Similar to above	853+/-	45			51		60	3.0 3.5 3.75 3.5 3.75	
50.0	Run 6, Similar to above	848+/-	50			56		88	2.75 2.75 2.5 2.5 2.5	
55.0	Run 7, Similar to above, moderately dipping to vertical joints	843+/-	55			57		75	2.5 2.0 2.0 2.0 2.0	
60.0	Run 8, Similar to above	838+/-	60			57		83	2.0 2.0 2.0 2.0 2.25	
65.0	Run 9, Similar to above, 64-65 feet : severely fractured zone	833+/-	65			60		83	2.0 1.75 1.75 1.75 2.0	
70.0	Run 10, Similar to above	828+/-	70			60		95	2.0 2.25 2.25 2.0 2.0	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
6' WD
0' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/14/2017	Boring Completed: 8/15/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B3-2W Juniata River West

PROJECT: Mariner East Pipeline Borings

SITE: Spread 3

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

LOCATION

Latitude: 40.435111° Longitude: -78.2999254°

Approximate Surface Elev: 898 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
75.0	Run 11, Similar to above	823+/-	75			60		95	2.0 2.0 2.0 2.0 2.25	
80.0	Run 12, Similar to above	818+/-	80			60		91	2.0 2.0 2.0 2.0 2.0	
85.0	Run 13, Medium hard, fresh, grayish-black argillaceous CALCAREOUS MUDSTONE, moderately dipping close joints in-filled with clay 83-85 feet : severely fractured zone	813+/-	85			53		45	3.0 3.25 3.25 3.0 3.25	
90.0	Run 14, Similar to above	808+/-	90			60		83	3.0 3.5 3.5 3.25 3.25	
95.0	Run 15, Similar to above	803+/-	95			60		62	3.0 2.75 2.75 2.75 2.5	
100.0	Run 16, Similar to above	798+/-	100			60		52	3.0 3.25 5.0 4.5 3.5	
105.0	Run 17, Similar to above, moderately dipping to vertical joints	793+/-	105			50		43	2.75 2.75 2.75 2.75 2.5	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method: Mud rotary with wireline Abandonment Method: Grouted to surface	See Exhibit A-3 for description of field procedures. See Appendix B for description of laboratory procedures and additional data (if any). See Appendix C for explanation of symbols and abbreviations.	Notes:

WATER LEVEL OBSERVATIONS

▽	6' WD
	0' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/14/2017	Boring Completed: 8/15/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B3-2W Juniata River West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 3

LOCATION

Latitude: 40.435111° Longitude: -78.2999254°

Approximate Surface Elev: 898 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 18, Similar to above 110.0	788+/-	110			60		83	2.75 2.75 2.5 2.75 2.75	
Run 19, Similar to above 115.0	783+/-	115			60		87	2.75 2.75 2.5 2.5 2.25	
Run 20, Similar to above 120.0	778+/-	120			58		29	2.75 2.5 2.5 2.5 2.5	

Boring Terminated at 120 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
6' WD
0' AB

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/14/2017	Boring Completed: 8/15/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
0.7	Gravel/cobbles	1355.5+/-								
	GRAVELLY LEAN CLAY WITH SAND (CL), brown, very stiff									
			5		X	18	7-7-9 N=16			
			10		X	14	6-7-16 N=23			
				▼						
13.5		1342.5+/-								
	CLAYEY GRAVEL (GC), trace sand, with shale fragments, medium dense		15		X	12	3-5-9 N=14			
				▽						
			20		X	12	10-7-11 N=18			
23.5		1332.5+/-								
	Brown to gray, very severely to completely weathered rock, friable, dense to very dense		25		X	12	13-24-35 N=59			
			30		X	14	19-27-38 N=65			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

▽ *16' 8/22/17*
▽ *12.1' 8/23/17*
▼ *12' 8/29/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 3

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Brown to gray, very severely to completely weathered rock, friable, dense to very dense *(continued)*								
	35		X	18	22-26-42 N=68			
	40		X	12	20-23-30 N=53			
	45		X	11	32-50/5"			
	50		X	15	24-38-42 N=80			
	55		X	15	20-28-36 N=64			
	60		X	10	34-50/4"			

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

- *16' 8/22/17*
- *12.1' 8/23/17*
- *12' 8/29/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

GRAPHIC LOG	DEPTH / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Brown to gray, very severely to completely weathered rock, friable, dense to very dense *(continued)*								
				X	15	32-44-50/5"			
		65							
				X	15	30-38-50/4"			
		70							
				X	13	40-36-42 N=78			
		75							
				X	13	13-23-26 N=49			
		80							
				X	16	15-26-37 N=63			
		85							
				X	10	14-24-13 N=37			
		90							

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

- ▽ *16' 8/22/17*
- ▽ *12.1' 8/23/17*
- ▼ *12' 8/29/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 3

LOCATION
Latitude: 40.432059° Longitude: -78.289578°
Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Brown to gray, very severely to completely weathered rock, friable, dense to very dense *(continued)*		95			15	34-12-25 N=37			
98.5	Soft to moderately hard, very severely weathered, dark gray, carbonaceous LIMESTONE	1257.5+/-	100			0	50/3"			
			105			3	50/3"			
109.2	Run 1, Hard, slightly weathered, gray, argillaceous LIMESTONE, thinly bedded, close to moderately close joint spacing, primary joint set: high angle, planar, fresh, slightly open	1247+/-	110			2	50/2"			
						32		59	3.25 2.25	
111.8	Run 2, Similar At 112.1 to 113.1 feet: high angle, slightly open, planar, iron stained joint	1244+/-	115			60		66	3.25 2.25 2 2.5 2.25	
116.8		1239+/-	120			120			1.5 3.25	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
- *16' 8/22/17*
- *12.1' 8/23/17*
- *12' 8/29/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 3

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 3, Moderately hard to hard, slightly weathered, dark gray, fine-grained, carbonaceous SHALE, very thinly bedded, primary joint set: high angle, close to moderately close, smooth, planar, fresh, slightly open At 117.8 feet: iron staining At 121.9 to 125.3 feet: high angle, clay filled joint *(continued)* 126.8	1229+/-	125			120		63	2 1.75 1.75 1.5 1.5 1.75 2 1.5	
Run 4, Similar to 128.2 feet At 128.2 feet: Moderately hard to hard, slightly weathered, dark gray, fine grained SHALE, very thin bedding, interbedded with limestone, primary joint set: high angle, moderately close joint spacing, smooth, planar, fresh, slightly open; secondary joint set, low angle, close joint spacing, rough, planar, fresh, open At 132.6 to 133 feet: high angle iron-stained joint At 135.3 to 135.7 feet: high angle calcite filled joint 136.8	1219+/-	130 135			120		57	1.75 1.75 1.75 1.5 1.75 2.25 2.25 2.5 3.5 2	
Run 5, Similar At 140.2 to 141.3 feet: low angle iron-stained joint 146.8	1209+/-	140 145			120		54	2 1.75 1.5 1.25 1.5 2.75 1.5 1.75 1.5 1.5	
Run 6, Similar At 155.6 to 156.2 feet: high angle, open, iron-stained joint		150			120			1.75 1.25	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 3

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 6, Similar At 155.6 to 156.2 feet: high angle, open, iron-stained joint *(continued)* 156.8	1199+/-	155			120		63	1.5 1.25 1.25 1.25 1.5 1.5 1.5 1.5	
Run 7, Similar At 159.0 to 159.3 feet: highly fractured zone 166.8	1189+/-	160 165			120		50	2 2 2.75 1.5 1.25 1.25 1.5 1.25 3 2.25	
Run 8, Similar 176.8	1179+/-	170 175			120		43	1.5 1.25 2 1.5 2.75 2 2.5 2 3.5 2.75	
Run 9, Similar At 178.7 to 179.2 feet: high angle, clay-filled joint		180			120			2.5 1.25	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017 | Boring Completed: 8/29/2017
Drill Rig: Acker Renegade | Driller: Terracon/Willie D.
Project No.: J217P078

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 3

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

LOCATION
Latitude: 40.432059° Longitude: -78.289578°
Approximate Surface Elev: 1356 (Ft.) +/-

GRAPHIC LOG	DEPTH / Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 9, Similar At 178.7 to 179.2 feet: high angle, clay-filled joint *(continued)*		185			120		62	1.75 2.25 1.5 1.5 2 1.75 1.5 1.25	
	186.8	1169+/-								
	Run 10, Similar		190 195			120		31	1.5 2 2.5 1.5 2.5 1.75 2 2.5 1.5 1.5	
	196.8	1159+/-								
	Run 11, Similar		200 205			120		63	1.75 2.5 1.5 1.5 2 1.75 2.25 2 2.5 1.75	
	206.8	1149+/-								
	Run 12, Similar At 209.0 to 209.7 feet: broken zone		210			120			2 1.75	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
- *16' 8/22/17*
- *12.1' 8/23/17*
- *12' 8/29/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 3

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

GRAPHIC LOG	DEPTH / DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 12, Similar At 209.0 to 209.7 feet: broken zone *(continued)*		215			120		71	1.25 2 1.75 1 1.5 1.75 1.75 2	
	216.8	1139+/-								
	Run 13, Similar		220 225			120		73	2 2 1.5 1.5 2 1.5 1.5 2 1.75 1.75	
	226.8	1129+/-								
	Run 14, Similar At 223.7 to 228.1 feet: broken zone At 233.8 to 238.4 feet: broken zone		230 235			120		80	1.5 2 2 1.5 1.25 1.5 1.5 1.75 1.5 2	
	236.8	1119+/-								
	Run 15, Moderately hard to hard, slightly weathered, dark gray, fine-grained SHALE, very thin bedding, interbedded with limestone, primary joint set: high angle, moderately close joint spacing, smooth, planar, fresh, slightly open		240			120			1.5 1.25	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

16' 8/22/17

12.1' 8/23/17

12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

GRAPHIC LOG	DEPTH / DESCRIPTION / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 15, Moderately hard to hard, slightly weathered, dark gray, fine-grained SHALE, very thin bedding, interbedded with limestone, primary joint set: high angle, moderately close joint spacing, smooth, planar, fresh, slightly open *(continued)*	245			120		61	1.25 2 1.5 1.25 1.75 1.75 1.5 1.5	
	246.8 — 1109+/-								
	Run 16, Moderately hard to hard, fresh, dark gray, fine-grained, carbonaceous SHALE, very thin bedding, interbedded with siltstone/limestone, primary joint set: high angle, close to moderately close joint spacing, rough, planar, fresh, slightly open; secondary joint set: low angle, moderately close, rough, planar, fresh, open	250, 255			115		90	1.75 1.5 1.25 1.25 1.5 1.25 1.25 1.5 1.5 1.5	
	256.8 — 1099+/-								
	Run 17, Similar	260, 265			120		100	1.25 1.25 1.5 1.25 1.25 1.25 1.25 1 1.25 1.25	
	266.8 — 1089+/-								
	Run 18, Similar	270			120			1.5 1.25	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

LOCATION
Latitude: 40.432059° Longitude: -78.289578°
Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
276.8	Run 18, Similar *(continued)*	1079+/-	275			120		90	1.25, 1.25, 1.75, 1.75, 1.25, 1.5, 1.5, 1.5	
286.8	Run 19, Similar	1069+/-	280, 285			120		90	1.75, 1.25, 1.5, 1.25, 1.25, 1.5, 1.25, 1.75, 1.5, 1.75	
296.8	Run 20, Similar	1059+/-	290, 295			120		100	2.25, 1.25, 1.75, 1.25, 1.5, 1.5, 1.5, 1.75, 1.75, 1.5	
	Run 21, Similar At 297.4 to 297.7 feet: clay-filled zone		300			120			4.25, 2	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
- *16' 8/22/17*
- *12.1' 8/23/17*
- *12' 8/29/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

LOCATION
Latitude: 40.432059° Longitude: -78.289578°
Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 21, Similar At 297.4 to 297.7 feet: clay-filled zone *(continued)*		305			120		79	2 2 2 1.75 2 2.5 2.5 2.5	
306.8	Run 22, Similar	1049+/-	310 315			120		98	1.75 2 1.75 1.25 1.25 1.25 2.25 2.25 2.25 2.25	
316.8	Run 23, Similar	1039+/-	320 325			120		94	1.75 1 1.25 1.25 1.5 1.25 1.5 1.25 1.5 1.5	
326.8	Run 24, Similar At 327.8 to 329.1 feet: calcareous zone	1029+/-	330			120			1.75 1	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
- *16' 8/22/17*
- *12.1' 8/23/17*
- *12' 8/29/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

**CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354**

SITE: Spread 3

LOCATION
Latitude: 40.432059° Longitude: -78.289578°
Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 24, Similar At 327.8 to 329.1 feet: calcareous zone *(continued)* 336.8	1019+/-	335			120		98	1.25 1.25 1.5 1.25 1.5 1.25 1.5 1.5	
Run 25, Similar 346.8	1009+/-	340 345			120		93	1.75 1.5 1.5 1.25 1.5 1.5 1.5 1.25 1.5 1.5	
Run 26, Similar At 356.4 to 356.8 feet: lost recovery 356.8	999+/-	350 355			117		94	1.5 2 2 1.5 1.75 1.75 1.75 1.5 1.5 1.5	
Run 27, Similar		360			120			1.5 1.75	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

LOCATION
Latitude: 40.432059° Longitude: -78.289578°
Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
366.8	Run 27, Similar *(continued)*	989+/-	365			120		97	2 1.5 1.75 1.5 1.5 1.5 1.5 1	
376.8	Run 28, Similar At 367.9 to 368.2 feet: high angle slickensided joints	979+/-	370, 375			120		92	1.5 1.25 1.75 2 1.5 1.25 1.75 1.5 2 2.25	
386.8	Run 29, Similar to 386.2 feet At 386.2 feet: Hard, fresh, gray, argillaceous LIMESTONE, thin to medium bedding, interbedded with shale, primary joint set: high angle, moderately close, rough, planar, fresh, slightly open; secondary joint set: low angle, moderately close, smooth, planar, fresh	969+/-	380, 385			120		95	2.75 2 1.5 1.75 1.75 1.5 1.25 1.25 1.25 1.25	
	Run 30, Similar from 386.2 feet		390			120			2.75 1.75	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 3

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 30, Similar from 386.2 feet *(continued)* 396.8 — 959+/-	395			120		90	1.5 1.25 1.75 1.25 1.75 1.75 2.5 3	
Run 31, Similar 406.8 — 949+/-	400 405			120		90	1.75 1.5 1.75 2 1.75 1.75 2.25 2.75 3 2.75	
Run 32, Similar 416.8 — 939+/-	410 415			120		88	1.75 1.5 2.5 2 2.5 2.5 2.5 2.5 2.5 2	
	420			120			1.75 1.75	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

- *16' 8/22/17*
- *12.1' 8/23/17*
- *12' 8/29/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 3

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
426.8	Run 33, Similar to 422.3 feet At 422.3 feet: Soft to moderately hard, slightly to moderately weathered, reddish brown to gray SHALE, interbedded with siltstone, occasional calcareous nodules, very thinly bedded, primary joint set: high angle, planar, rough, fresh, slightly open; secondary joint set: low angle, planar, smooth, fresh, slightly open *(continued)*	929+/-	425			120		93	2 1.5 2 2.5 2.5 2 2.5 2	
436.8	Run 34, Similar At 431.6 to 432.4 feet: calcareous zone	919+/-	430 435			120		89	1.75 1.5 2 1.25 3.5 1.5 1.75 1.25 2.5 3.5	
446.8	Run 35, Similar At 443.6 to 447.1 feet: calcareous zone	909+/-	440 445			120		92	3.25 2.5 2.5 3.25 2 2.25 2.5 2 1.75 1.75	
	Run 36, Similar		450			120			2 2.5	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

16' 8/22/17

12.1' 8/23/17

12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 3

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
	Run 36, Similar *(continued)*		120	86	2.75 2.75 2.75 2.25 2.5 2.5 2.5 2.5
456.8	Run 37, Similar At 463.8 to 464.2 feet: calcareous zone	899+/-	120	98	2.25 2.25 2.25 2.25 2.25 2.25 2.25 1.75 2.25 2.5
466.8	Run 38, Similar	889+/-	120	98	2.25 3 2.75 2.75 2.5 3 2.5 1.75 2 3
476.8	Run 39, Similar	879+/-	120		2.25 2.75

Depth scale (Ft.): 455, 460, 465, 470, 475, 480

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

- *16' 8/22/17*
- *12.1' 8/23/17*
- *12' 8/29/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 3

LOCATION
Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

GRAPHIC LOG	DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 39, Similar *(continued)* 486.8	869+/-	485			120		94	2.5 1.75 2 2 1.75 2.25 2.5 2.75	
	Run 40, Similar At 493.2 to 494 feet: calcareous zone 496.8	859+/-	490 495			120		80	3 2 2 2 2 2.25 2 2.5 3 3	
	Run 41, Similar 506.8	849+/-	500 505			120		97	2.5 2.25 2.5 1.75 2.25 2.25 2.5 2.25 1.75 2.25	
	Run 42, Similar At 515.0 to 521.8 feet: calcareous zone		510			120			2.25 2.75	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017
Boring Completed: 8/29/2017
Drill Rig: Acker Renegade
Driller: Terracon/Willie D.
Project No.: J217P078

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 3

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 42, Similar At 515.0 to 521.8 feet: calcareous zone *(continued)*		515			120		100	2.5 2.25 1.75 2.5 2.25 1.75 2 2.5	
516.8		839+/-								
	Run 43, Similar		520 525			120		100	2.25 1.75 2.25 2 2 2 1.5 1.75 2 2.5	
526.8		829+/-								
	Run 44, Similar		530 535			120		93	2.25 2.25 2 2.25 2.5 2 2 1.5 1.75 2	
536.8		819+/-								
	Run 45, Similar At 540.4 to 540.9 feet: calcareous zone		540			120			2 2.25	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

16' 8/22/17

12.1' 8/23/17

12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 3

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
546.8	809+/-	Run 45, Similar At 540.4 to 540.9 feet: calcareous zone *(continued)*	545	120		95	2.75 2 2 1.75 1.75 1.75 2.75 3.75	
556.8	799+/-	Run 46, Similar At 546.8 to 547.8 feet: calcareous zone	550 555	120		95	3.25 2.75 2.5 2.75 2 2.25 3 3 2.5 2.75	
566.8	789+/-	Run 47, Similar	560 565	120		98	1.75 1.75 2 2.75 2.5 2.5 2.75 2.25 2.5 3.5	
		Run 48, Similar	570	120			2 2.25	

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

BORING LOG NO. B3-2E Juniata River East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 3

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

LOCATION

Latitude: 40.432059° Longitude: -78.289578°

Approximate Surface Elev: 1356 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 48, Similar *(continued)*		575			120		100	2.75 2 2.25 2.25 2.75 2 2 2.25	
576.8	779+/-								
Run 49, Similar At 577.3 to 578.1 feet: calcareous zone		580 585			120		98	2.25 2.5 2.25 1.75 2 2 2 1.75 2.25 2.25	
586.8	769+/-								

Boring Terminated at 586.8 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

16' 8/22/17
12.1' 8/23/17
12' 8/29/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/21/2017	Boring Completed: 8/29/2017
Drill Rig: Acker Renegade	Driller: Terracon/Willie D.
Project No.: J217P078	

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2W	Lithology :	Mudstone
Sample No.:	1	Moisture Content :	As received
Sample Depth:	43.5 feet	Lab Temperature :	70° F
Sampling Date:	8/14/17	Loading Rate:	55 psi/s
		Time to Failure:	1 min

Diameter:	1.97 in	Maximum Axial Load at Failure:	3,470 lb
Length:	4.47 in	Compressive Strength:	1,138 psi
L/D:	2.27	Compressive Strength:	7.85 Mpa
End Area:	3.05 in^2	Unit Weight	161 pcf

Photograph before the test mistakenly shows 42 feet

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	W. Shedd
Project No.	J217P078		Test Date:	10/7/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2W	Lithology :	Mudstone
Sample No.:	2	Moisture Content :	As received
Sample Depth:	60 feet	Lab Temperature :	70° F
Sampling Date:	8/14/17	Loading Rate:	55 psi/s
		Time to Failure:	4 min

Diameter:	1.93 in	Maximum Axial Load at Failure:	12,940 lb
Length:	3.47 in	Compressive Strength:	4,423 psi
L/D:	1.80	Compressive Strength:	30.50 Mpa
End Area:	2.93 in^2	Unit Weight	166 pcf

Comments : Due to lack of available specimens, the length to diameter ratio of the tested specimen is not conformant with ASTM D7012. The results obtained during testing may differ from those obtained from the test specimens that meet the requirements.

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2W	Lithology :	Mudstone
Sample No.:	3	Moisture Content :	As received
Sample Depth:	80 feet	Lab Temperature :	70° F
Sampling Date:	8/14/17	Loading Rate:	55 psi/s
		Time to Failure:	4 min

Diameter:	1.93 in	Maximum Axial Load at Failure:	11,920 lb
Length:	3.78 in	Compressive Strength:	4,074 psi
L/D:	1.96	Compressive Strength:	28.09 Mpa
End Area:	2.93 in^2	Unit Weight	63 pcf

Comments : Due to lack of available specimens, the length to diameter ratio of the tested specimen is not conformant with ASTM D7012. The results obtained during testing may differ from those obtained from the test specimens that meet the requirements.

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2W	Lithology :	Mudstone
Sample No.:	4	Moisture Content :	As received
Sample Depth:	100 feet	Lab Temperature :	70° F
Sampling Date:	8/14/17	Loading Rate:	55 psi/s
		Time to Failure:	4 min

Diameter:	1.93 in	Maximum Axial Load at Failure:	13,720 lb
Length:	4.49 in	Compressive Strength:	4,690 psi
L/D:	2.33	Compressive Strength:	32.33 Mpa
End Area:	2.93 in^2	Unit Weight	167 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078		Test Date:	10/3/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2W	Lithology :	Mudstone
Sample No.:	5	Moisture Content :	As received
Sample Depth:	110 feet	Lab Temperature :	70° F
Sampling Date:	8/14/17	Loading Rate:	55 psi/s
		Time to Failure:	4 min

Diameter:	1.93 in	Maximum Axial Load at Failure:	13,960 lb
Length:	4.00 in	Compressive Strength:	4,772 psi
L/D:	2.07	Compressive Strength:	32.90 Mpa
End Area:	2.93 in^2	Unit Weight	165 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2W	Lithology :	Mudstone
Sample No.:	6	Moisture Content :	As received
Sample Depth:	119 feet	Lab Temperature :	70° F
Sampling Date:	8/14/17	Loading Rate:	55 psi/s
		Time to Failure:	0 min

Diameter:	N/A in	Maximum Axial Load at Failure:	N/A lb
Length:	N/A in	Compressive Strength:	N/A psi
L/D:	N/A	Compressive Strength:	N/A Mpa
End Area:	N/A in^2	Unit Weight	N/A pcf

Specimen broke during preparation

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/9/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	1	Moisture Content :	As received
Sample Depth:	130 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	14 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	44,700 lb
Length:	4.67 in	Compressive Strength:	14,372 psi
L/D:	2.35	Compressive Strength:	99.09 Mpa
End Area:	3.11 in^2	Unit Weight	169 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

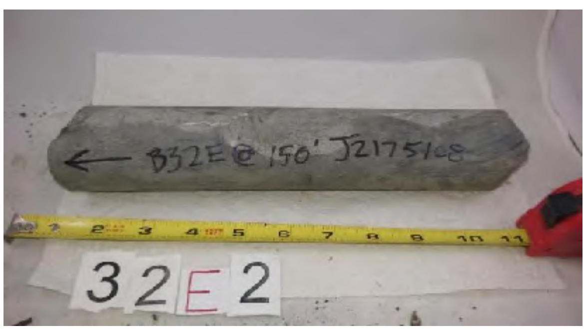
Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	2	Moisture Content :	As received
Sample Depth:	150 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	5 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	16,090 lb
Length:	4.54 in	Compressive Strength:	5,173 psi
L/D:	2.28	Compressive Strength:	35.67 Mpa
End Area:	3.11 in^2	Unit Weight	170 pcf

Before the Test



After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	3	Moisture Content :	As received
Sample Depth:	170 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	6 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	19,700 lb
Length:	4.20 in	Compressive Strength:	6,398 psi
L/D:	2.12	Compressive Strength:	44.11 Mpa
End Area:	3.08 in^2	Unit Weight	74 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	4	Moisture Content :	As received
Sample Depth:	190 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	9 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	28,100 lb
Length:	4.56 in	Compressive Strength:	9,126 psi
L/D:	2.30	Compressive Strength:	62.92 Mpa
End Area:	3.08 in^2	Unit Weight	167 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	5	Moisture Content :	As received
Sample Depth:	210 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	1 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	3,220 lb
Length:	4.50 in	Compressive Strength:	1,035 psi
L/D:	2.26	Compressive Strength:	7.14 Mpa
End Area:	3.11 in^2	Unit Weight	167 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

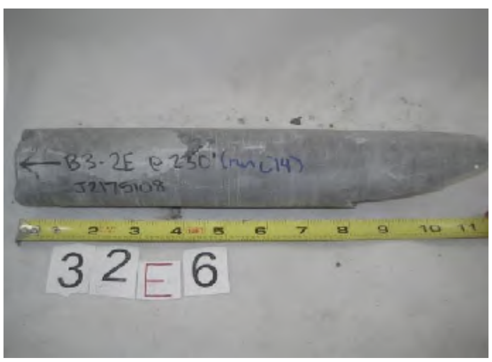
Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	6	Moisture Content :	As received
Sample Depth:	230 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	1 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	4,310 lb
Length:	4.48 in	Compressive Strength:	1,400 psi
L/D:	2.26	Compressive Strength:	9.65 Mpa
End Area:	3.08 in^2	Unit Weight	168 pcf

Before the Test



After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078		Test Date:	10/3/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.: B3-2E

Sample No.: 6

Sample Depth: 230 feet

Sampling Date: 8/21/17

Lithology : Shale

Moisture Content : As received

Lab Temperature : 70° F

Loading Rate: 55 psi/s

Time to Failure: 4 min

Diameter: 1.98 in

Length: 4.05 in

L/D: 2.05

End Area: 3.08 in^2

Maximum Axial Load at Failure: 13,230 lb

Compressive Strength: 4,297 psi

Compressive Strength: 29.62 Mpa

Unit Weight 165 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX

PO # : 20170804-14

Crossing : Juniata River

Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	W. Shedd
Project No	J217P078		Test Date:	10/7/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

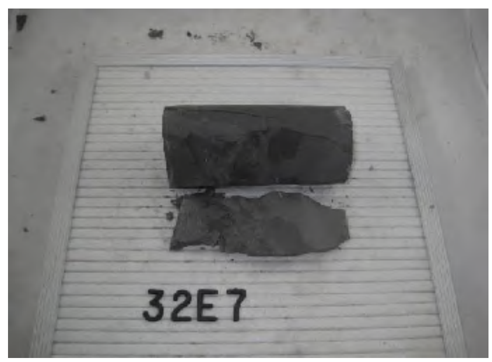
Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	7	Moisture Content :	As received
Sample Depth:	250 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	1 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	1,790 lb
Length:	4.40 in	Compressive Strength:	581 psi
L/D:	2.22	Compressive Strength:	4.01 Mpa
End Area:	3.08 in^2	Unit Weight	170 pcf

Before the Test

Photograph before the test is not available

After the Test



Drawing # :	PA-BL-0122.0000-WX
PO # :	20170804-14
Crossing :	Juniata River
Spread :	Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	8	Moisture Content :	As received
Sample Depth:	270 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	0 min

Diameter:	N/A in	Maximum Axial Load at Failure:	N/A lb
Length:	N/A in	Compressive Strength:	N/A psi
L/D:	N/A	Compressive Strength:	N/A Mpa
End Area:	N/A in^2	Unit Weight	N/A pcf

Specimen broke during preparation. Target depth range is too fractured to assign second test.

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

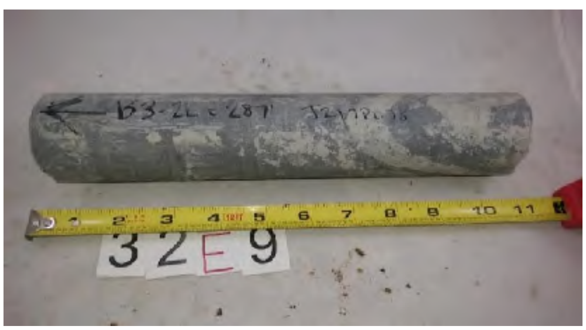
ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	9	Moisture Content :	As received
Sample Depth:	287 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	2 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	7,490 lb
Length:	3.00 in	Compressive Strength:	2,408 psi
L/D:	1.51	Compressive Strength:	16.60 Mpa
End Area:	3.11 in^2	Unit Weight	168 pcf

Comments : Due to lack of available specimens, the length to diameter ratio of the tested specimen is not conformant with ASTM D7012. The results obtained during testing may differ from those obtained from the test specimens that meet the requirements.

Before the Test



After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078		Test Date:	10/3/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	10	Moisture Content :	As received
Sample Depth:	310 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	0 min

Diameter:	N/A in	Maximum Axial Load at Failure:	N/A lb
Length:	N/A in	Compressive Strength:	N/A psi
L/D:	N/A	Compressive Strength:	N/A Mpa
End Area:	N/A in^2	Unit Weight	N/A pcf

Specimen broke during preparation

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

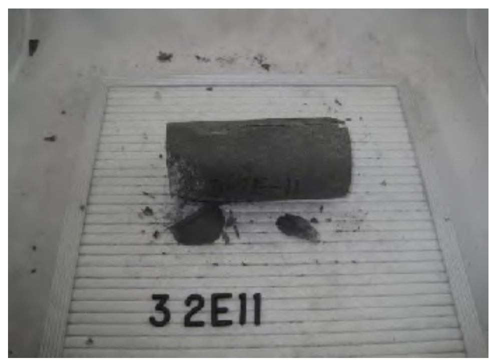
ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	11	Moisture Content :	As received
Sample Depth:	330 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	7 min

Diameter:	2.00 in	Maximum Axial Load at Failure:	23,750 lb
Length:	4.30 in	Compressive Strength:	7,560 psi
L/D:	2.15	Compressive Strength:	52.12 Mpa
End Area:	3.14 in^2	Unit Weight	169 pcf

Before the Test

After the Test



Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

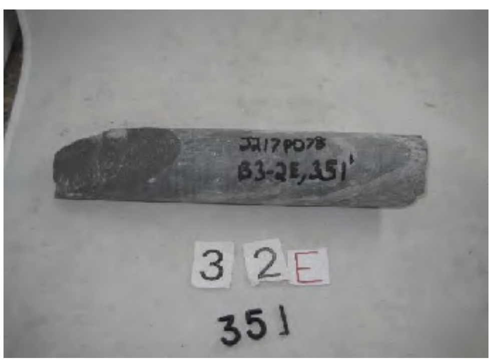
Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	12	Moisture Content :	As received
Sample Depth:	351 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	5 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	16,680 lb
Length:	4.27 in	Compressive Strength:	5,363 psi
L/D:	2.15	Compressive Strength:	36.98 Mpa
End Area:	3.11 in^2	Unit Weight	172 pcf

Before the Test



After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/9/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	13	Moisture Content :	As received
Sample Depth:	370 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	0 min

Diameter:	N/A in	Maximum Axial Load at Failure:	N/A lb
Length:	N/A in	Compressive Strength:	N/A psi
L/D:	N/A	Compressive Strength:	N/A Mpa
End Area:	N/A in^2	Unit Weight	N/A pcf

Specimen broke during preparation

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Limestone
Sample No.:	14	Moisture Content :	As received
Sample Depth:	390 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	18 min

Diameter:	1.91 in	Maximum Axial Load at Failure:	57,780 lb
Length:	4.40 in	Compressive Strength:	20,166 psi
L/D:	2.30	Compressive Strength:	139.04 Mpa
End Area:	2.87 in^2	Unit Weight	193 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078		Test Date:	10/3/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

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ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Limestone
Sample No.:	15	Moisture Content :	As received
Sample Depth:	410 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	1 min

Diameter:	2.00 in	Maximum Axial Load at Failure:	2,330 lb
Length:	4.32 in	Compressive Strength:	742 psi
L/D:	2.16	Compressive Strength:	5.11 Mpa
End Area:	3.14 in^2	Unit Weight	168 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

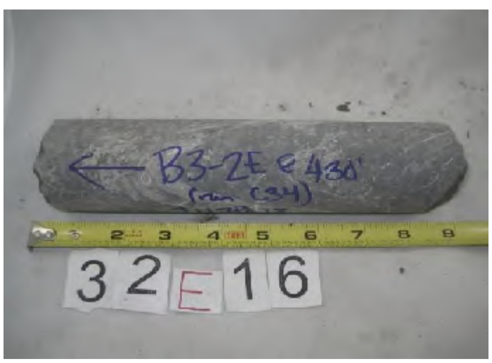
Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	16	Moisture Content :	As received
Sample Depth:	430 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	2 min

Diameter:	2.00 in	Maximum Axial Load at Failure:	7,930 lb
Length:	4.37 in	Compressive Strength:	2,524 psi
L/D:	2.19	Compressive Strength:	17.40 Mpa
End Area:	3.14 in^2	Unit Weight	169 pcf

Before the Test



After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	17	Moisture Content :	As received
Sample Depth:	450 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	0 min

Diameter:	N/A in	Maximum Axial Load at Failure:	N/A lb
Length:	N/A in	Compressive Strength:	N/A psi
L/D:	N/A	Compressive Strength:	N/A Mpa
End Area:	N/A in^2	Unit Weight	N/A pcf

Specimen broke during preparation

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078		Test Date:	10/3/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	18	Moisture Content :	As received
Sample Depth:	472 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	2 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	5,390 lb
Length:	3.17 in	Compressive Strength:	1,733 psi
L/D:	1.59	Compressive Strength:	11.95 Mpa
End Area:	3.11 in^2	Unit Weight	171 pcf

Comments : Due to lack of available specimens, the length to diameter ratio of the tested specimen is not conformant with ASTM D7012. The results obtained during testing may differ from those obtained from the test specimens that meet the requirements.

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

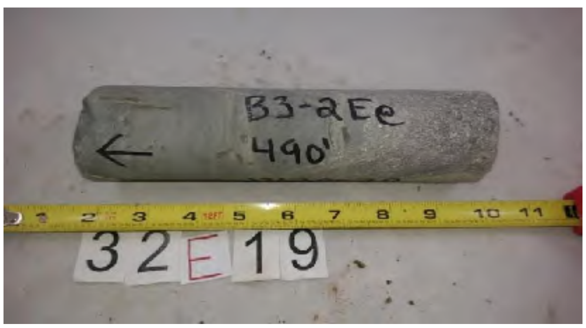
Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/9/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	19	Moisture Content :	As received
Sample Depth:	490 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	6 min

Diameter:	2.00 in	Maximum Axial Load at Failure:	18,890 lb
Length:	4.58 in	Compressive Strength:	6,013 psi
L/D:	2.29	Compressive Strength:	41.46 Mpa
End Area:	3.14 in^2	Unit Weight	172 pcf

Before the Test



After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	20	Moisture Content :	As received
Sample Depth:	510 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	0 min

Diameter:	1.91 in	Maximum Axial Load at Failure:	380 lb
Length:	3.61 in	Compressive Strength:	133 psi
L/D:	1.89	Compressive Strength:	0.91 Mpa
End Area:	2.87 in^2	Unit Weight	209 pcf

Comments : Due to lack of available specimens, the length to diameter ratio of the tested specimen is not conformant with ASTM D7012. The results obtained during testing may differ from those obtained from the test specimens that meet the requirements.

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078		Test Date:	10/3/2017
Location:	Spread 3	77 Sundial Ave., Suite 401 W	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	21	Moisture Content :	As received
Sample Depth:	530 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	1 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	3,160 lb
Length:	4.51 in	Compressive Strength:	1,016 psi
L/D:	2.27	Compressive Strength:	7.01 Mpa
End Area:	3.11 in^2	Unit Weight	172 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	22	Moisture Content :	As received
Sample Depth:	550 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	0 min

Diameter:	N/A in	Maximum Axial Load at Failure:	N/A lb
Length:	N/A in	Compressive Strength:	N/A psi
L/D:	N/A	Compressive Strength:	N/A Mpa
End Area:	N/A in^2	Unit Weight	N/A pcf

Specimen broke during preparation

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	23	Moisture Content :	As received
Sample Depth:	565 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	1 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	4,020 lb
Length:	4.45 in	Compressive Strength:	1,292 psi
L/D:	2.24	Compressive Strength:	8.91 Mpa
End Area:	3.11 in^2	Unit Weight	172 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078	77 Sundial Ave., Suite 401 W	Test Date:	10/3/2017
Location:	Spread 3	Manchester, New Hampshire	Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	24	Moisture Content :	As received
Sample Depth:	575 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	0 min

Diameter:	2.00 in	Maximum Axial Load at Failure:	1,440 lb
Length:	4.53 in	Compressive Strength:	458 psi
L/D:	2.27	Compressive Strength:	3.16 Mpa
End Area:	3.14 in^2	Unit Weight	171 pcf

Before the Test

After the Test

Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/9/2017

ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B3-2E	Lithology :	Shale
Sample No.:	25	Moisture Content :	As received
Sample Depth:	585 feet	Lab Temperature :	70° F
Sampling Date:	8/21/17	Loading Rate:	55 psi/s
		Time to Failure:	4 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	12,990 lb
Length:	4.49 in	Compressive Strength:	4,176 psi
L/D:	2.26	Compressive Strength:	28.80 Mpa
End Area:	3.11 in^2	Unit Weight	172 pcf

Before the Test

After the Test

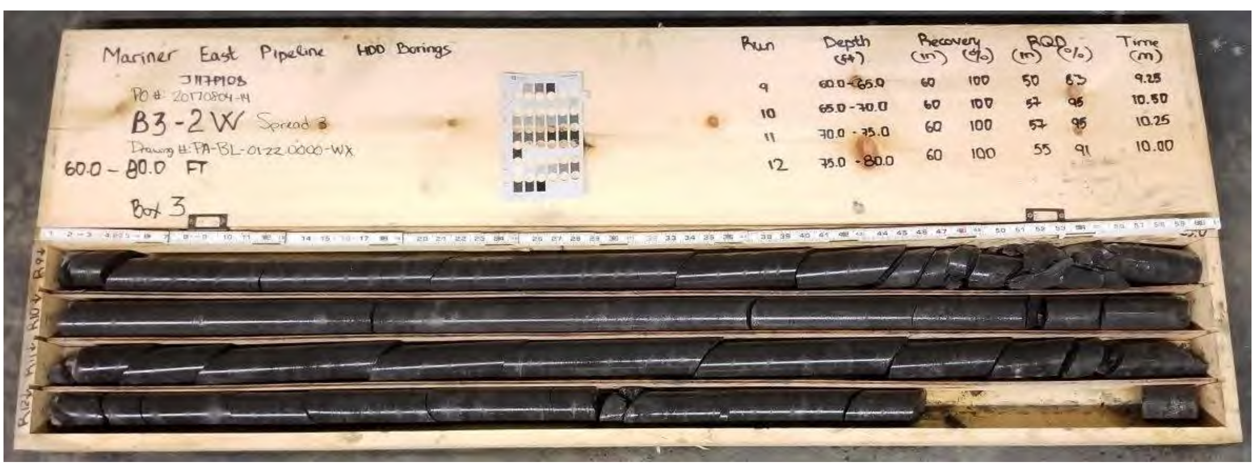
Drawing # : PA-BL-0122.0000-WX
PO # : 20170804-14
Crossing : Juniata River
Spread : Spread 3

Project:	Mariner East Pipeline	Terracon	Performed by:	A.Suprunenko
Project No.	J217P078		Test Date:	10/3/2017
Location:	Spread 3		Reviewed By :	L.Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/9/2017

Terracon

Photograph 1: B3-2W, Samples C-1 to C-4 (20 to 40 feet)

Photograph 2: B3-2W, Samples C-5 to C-8 (40 to 60 feet)



Photograph 3: B3-2W, Samples C-9 to C-12 (60 to 80 feet)

Photograph 4: B3-2W, Samples C-13 to C-16 (80 to 100 feet)

Photograph 5: B3-2W, Samples C-17 to C-20 (100 to 120 feet)

Photograph 1: B3-2E, Samples C-1 to C-3 (109.2 to 126.8 feet)

Photograph 2: B3-2E, Samples C-4 to C-5 (126.8 to 146.8 feet)

Photograph 3: B3-2E, Samples C-6 to C-7 (146.8 to 166.8 feet)

Photograph 4: B3-2E, Samples C-8 to C-9 (166.8 to 186.8 feet)

Photograph 5: B3-2E, Samples C-10 to C-11 (186.8 to 206.8 feet)

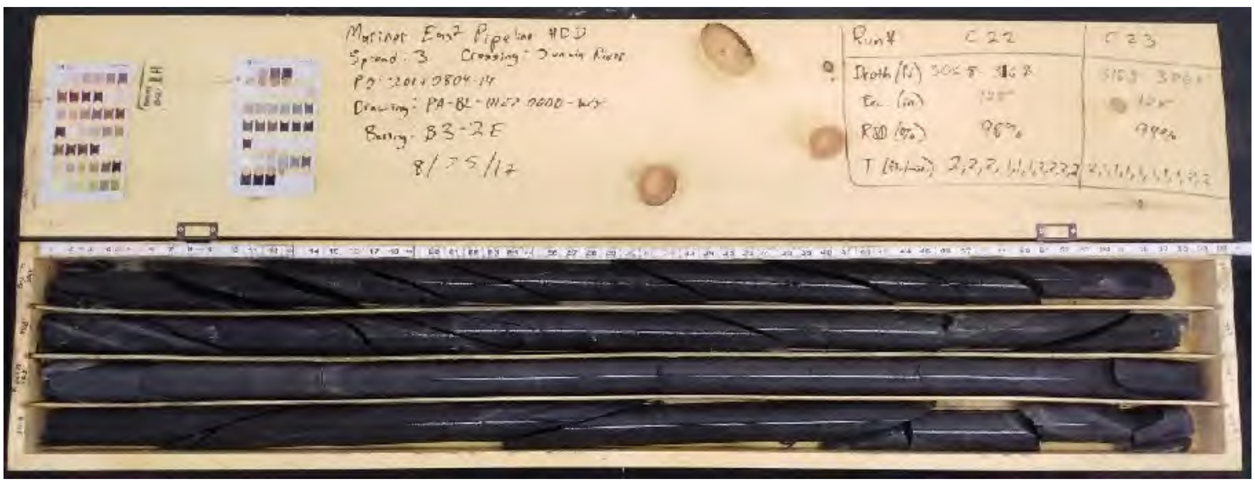
Photograph 6: B3-2E, Samples C-12 to C-13 (206.8 to 226.8 feet)

Photograph 7: B2-3E, Samples C-14 to C-15 (226.8 to 246.8 feet)

Photograph 8: B2-3E, Samples C-16 to C-17 (246.8 to 266.8 feet)

Photograph 9: B3-2E, Samples C-18 to C-19 (266.8 to 286.8 feet)

Photograph 10: B3-2E, Samples C-20 to C-21 (286.8 to 306.8 feet)



Photograph 11: B3-2E, Samples C-22 to C-23 (306.8 to 326.8 feet)

Photograph 12: B2-3E, Samples C-24 to C-25 (326.8 to 346.8 feet)

Photograph 13: B3-2E, Samples C-26 to C-27 (346.8 to 366.8 feet)

Photograph 14: B3-2E, Samples C-28 to C-29 (366.8 to 386.8 feet)

Photograph 15: B3-2E, C-30 to C-31 (386.8 to 406.8 feet)

Photograph 16: B3-2E, Samples C-32 to C-33 (406.8 to 426.8 feet)

Photograph 17: B3-2E, Samples C-34 to C-35 (426.8 to 446.8 feet)

Photograph 18: B3-2E, Samples C-36 to C-37 (446.8 to 466.8 feet)

Photograph 19: B3-2E, Samples C-38 to C-39 (466.8 to 486.8 feet)

Photograph 20: B3-2E, Samples C-40 to C-41 (486.8 to 506.8 feet)

Photograph 21: B3-2E, Samples C-42 to C-43 (506.8 to 526.8 feet)

Photograph 22: B3-2E, Samples C-44 to C-45 (526.8 to 546.8 feet)

Photograph 23: B3-2E, Samples C-46 to C-47 (546.8 to 566.8 feet)

Photograph 24: B3-2E, Samples C-48 to C-49 (566.8 to 586.8 feet)

SUPPORTING INFORMATION

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification: Group Symbol	Soil Classification: Group Name [B]
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu ³ 4 and 1 £ Cc £ 3 [E]	GW	Well-graded gravel [F]
			Cu < 4 and/or 1 > Cc > 3 [E]	GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH	GM	Silty gravel [F,G,H]
			Fines classify as CL or CH	GC	Clayey gravel [F,G,H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	Cu ³ 6 and 1 £ Cc £ 3 [E]	SW	Well-graded sand [I]
			Cu < 6 and/or 1 > Cc > 3 [E]	SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH	SM	Silty sand [G,H,I]
			Fines classify as CL or CH	SC	Clayey sand [G,H,I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots on or above "A"	CL	Lean clay [K,L,M]
			PI < 4 or plots below "A" line [J]	ML	Silt [K,L,M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OL	Organic clay [K,L,M,N]
					Organic silt [K,L,M,O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line	CH	Fat clay [K,L,M]
			PI plots below "A" line	MH	Elastic Silt [K,L,M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH	Organic clay [K,L,M,P]
					Organic silt [K,L,M,Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ³ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ³ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ³ 30% plus No. 200 predominantly sand, add "sandy" to group name.

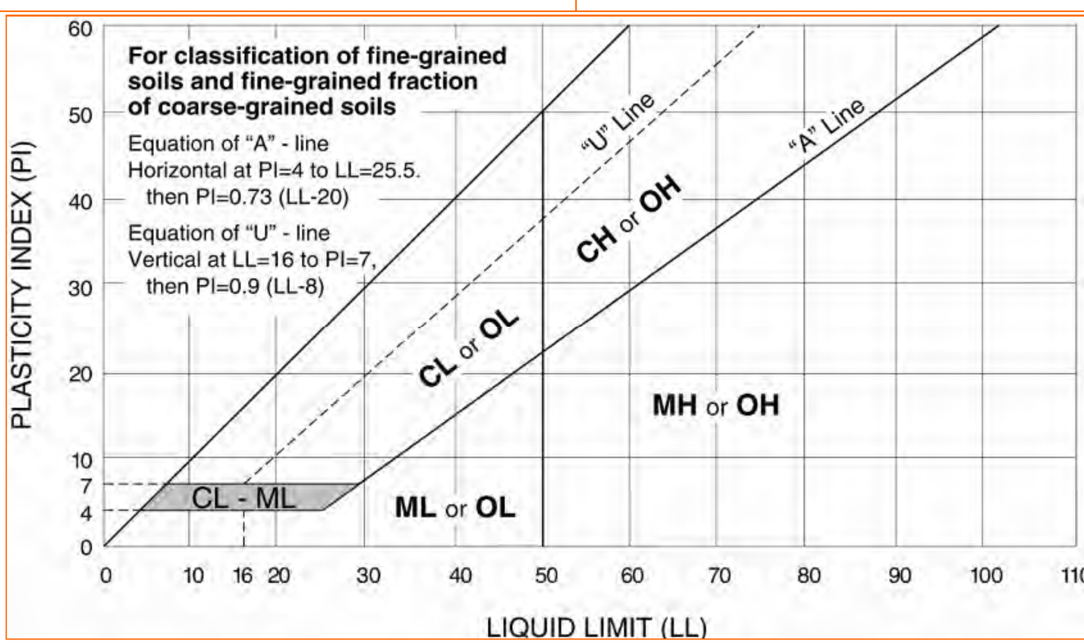
[M] If soil contains ³ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ³ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.



DESCRIPTION OF ROCK PROPERTIES

Terracon GeoReport

WEATHERING	
Fresh	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
Very Slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately Severe	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very Severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil". Rock "fabric" no discernible or discernible only in small, scattered locations. Quartz may be present as dikes or stringers.

HARDNESS (for engineering description of rock – not to be confused with Moh's scale for minerals)	
Very Hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately Hard	Can be scratched with knife or pick. Gouges or grooves to ¼ in. deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
Medium	Can be grooved or gouged 1/16 in. deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1-in. maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
Very Soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

Joint, Bedding, and Foliation Spacing in Rock [1]

Spacing	Joints	Bedding/Foliation
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

1. Spacing refers to the distance normal to the planes, of the described feature, which are parallel to each other or nearly so.

Rock Quality Designator (RQD) [1]

RQD, as a percentage	Diagnostic description
Exceeding 90	Excellent
90 – 75	Good
75 – 50	Fair
50 – 25	Poor
Less than 25	Very poor

1. RQD (given as a percentage) = length of core in pieces 4 inches and longer / length of run

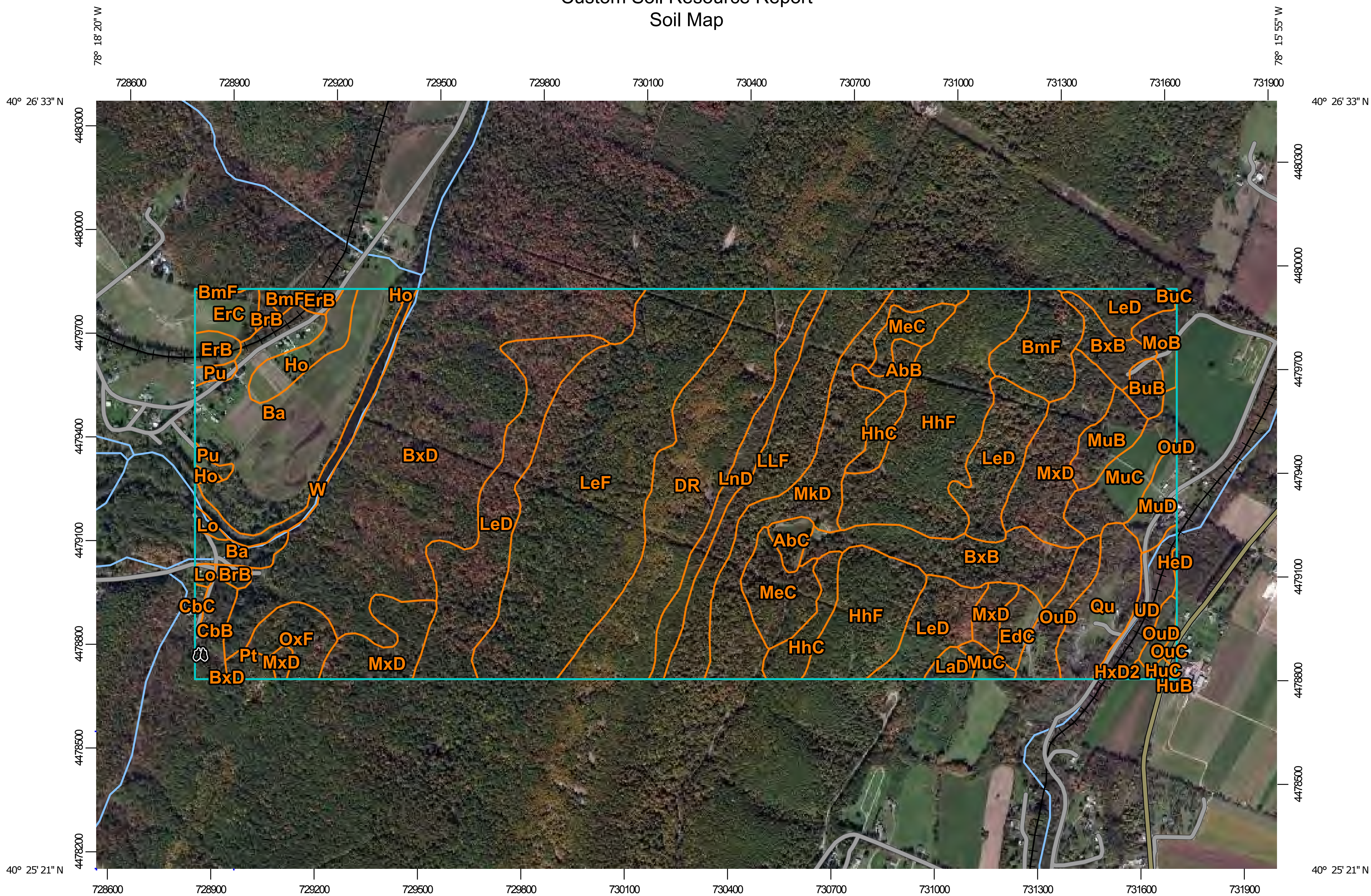
Joint Openness Descriptors

Openness	Descriptor
No Visible Separation	Tight
Less than 1/32 in.	Slightly Open
1/32 to 1/8 in.	Moderately Open
1/8 to 3/8 in.	Open
3/8 in. to 0.1 ft.	Moderately Wide
Greater than 0.1 ft.	Wide

References: American Society of Civil Engineers. Manuals and Reports on Engineering Practice - No. 56. Subsurface Investigation for Design and Construction of Foundations of Buildings. New York: American Society of Civil Engineers, 1976. U.S. Department of the Interior, Bureau of Reclamation, Engineering Geology Field Manual.

ATTACHMENT 2
SOIL RESOURCES MAP AND PROFILE DESCRIPTIONS

Soil Map



Map Scale: 1:15,700 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 200, 400, 800, 1200

Feet: 0, 500, 1000, 2000, 3000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

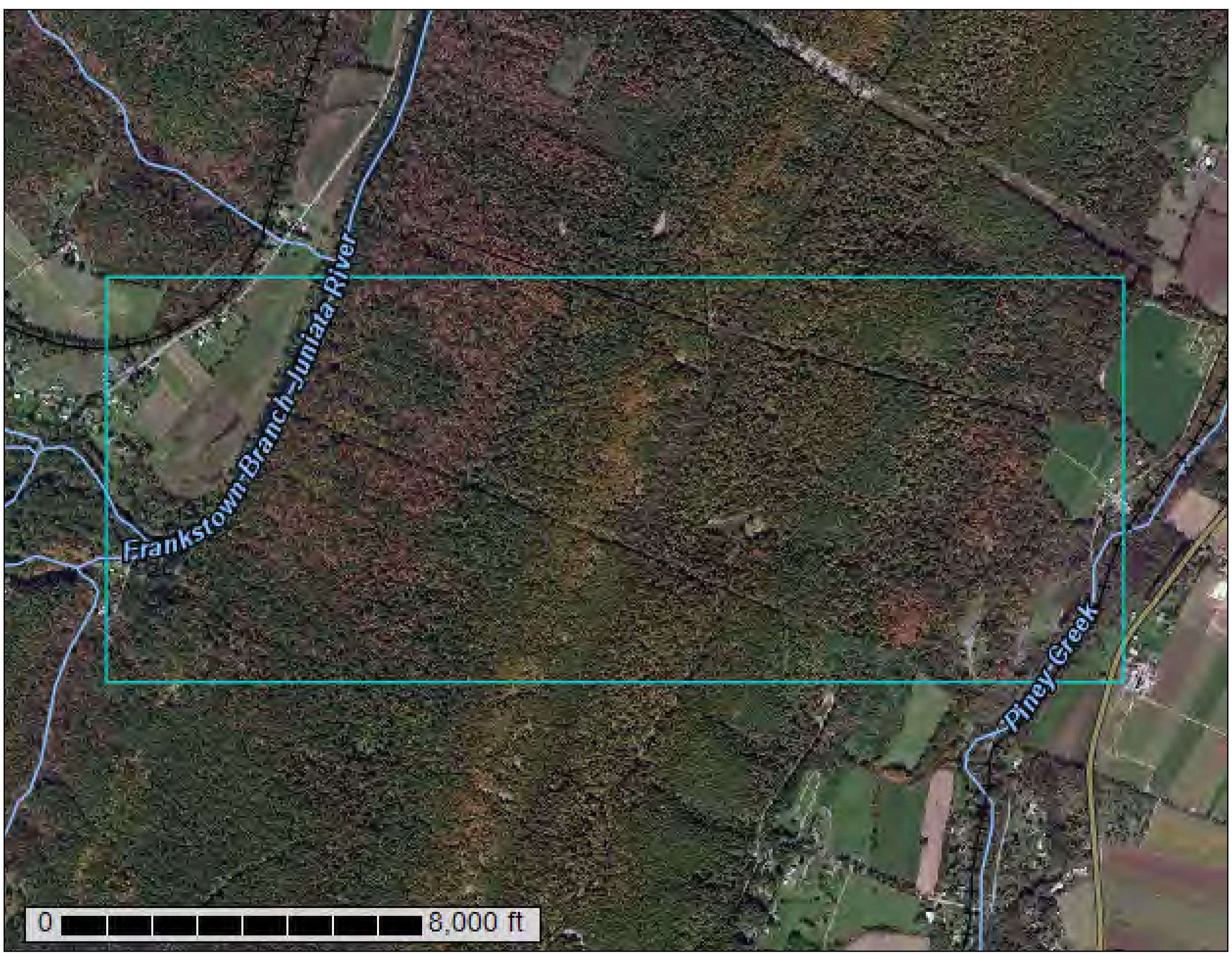
United States Department of Agriculture

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Blair County, Pennsylvania



October 2, 2017

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Unit Polygons

Soil Map Unit Lines

Soil Map Unit Points

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Blair County, Pennsylvania
Survey Area Data: Version 10, Sep 19, 2016

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 6, 2011—Oct 17, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

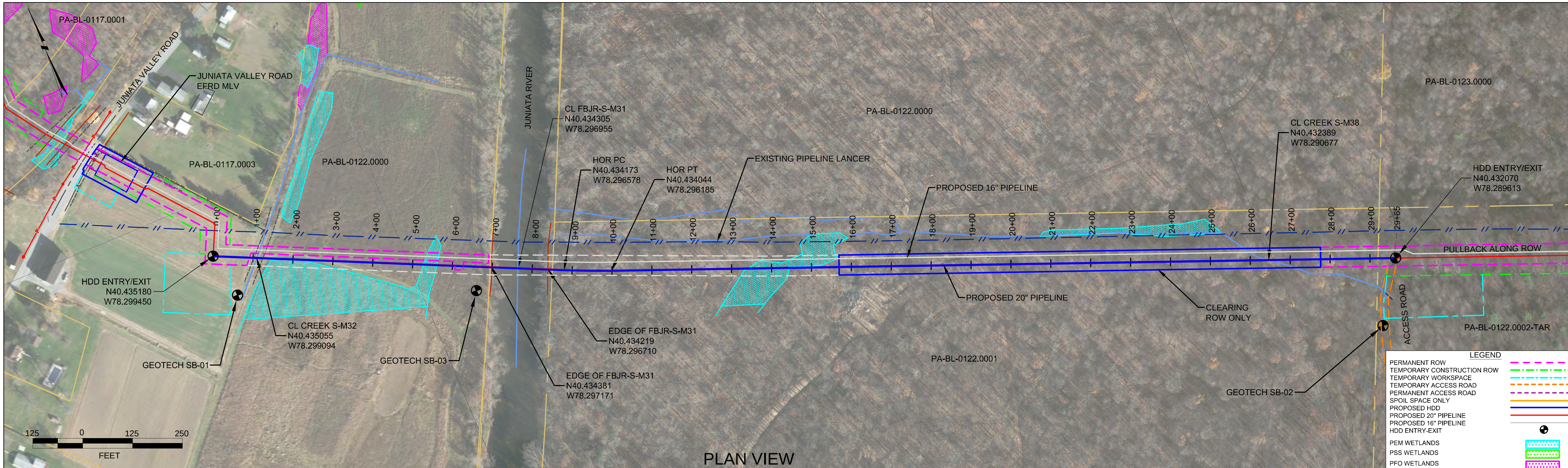
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
AbB	Albrights gravelly silt loam, 3 to 8 percent slopes	3.7	0.5%
AbC	Albrights gravelly silt loam, 8 to 15 percent slopes	3.2	0.4%
Ba	Basher soils	57.8	7.2%
BmF	Berks-Weikert channery silt loams, 25 to 70 percent slopes	15.9	2.0%
BrB	Brinkerton silt loam, 3 to 8 percent slopes	2.6	0.3%
BuB	Buchanan gravelly silt loam, 3 to 8 percent slopes	3.5	0.4%
BuC	Buchanan gravelly silt loam, 8 to 15 percent slopes	0.1	0.0%
BxB	Buchanan extremely stony silt loam, 3 to 8 percent slopes	28.0	3.5%
BxD	Buchanan extremely stony silt loam, 8 to 25 percent slopes	118.3	14.8%
CbB	Clarksburg silt loam, 3 to 8 percent slopes	6.0	0.7%
CbC	Clarksburg silt loam, 8 to 15 percent slopes	0.8	0.1%
DR	Dystrochrepts-Rubble land complex	55.7	7.0%
EdC	Edom silty clay loam, 8 to 15 percent slopes	4.6	0.6%
ErB	Ernest silt loam, 3 to 8 percent slopes	4.6	0.6%
ErC	Ernest silt loam, 8 to 15 percent slopes	5.5	0.7%
HeD	Hagerstown-Rock outcrop complex, 8 to 25 percent slopes	0.3	0.0%
HhC	Hazleton very stony sandy loam, 8 to 15 percent slopes	11.5	1.4%
HhF	Hazleton channery sandy loam, 25 to 70 percent slopes, extremely stony	66.4	8.3%
Ho	Holly silt loam	8.7	1.1%
HuB	Hublersburg cherty silt loam, 3 to 8 percent slopes	0.1	0.0%
HuC	Hublersburg cherty silt loam, 8 to 15 percent slopes	0.7	0.1%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
HxD2	Hublersburg cherty silty clay loam, 15 to 25 percent slopes, eroded	0.7	0.1%
LaD	Laidig channery loam, 15 to 25 percent slopes	2.4	0.3%
LeD	Laidig extremely stony loam, 8 to 25 percent slopes	71.0	8.9%
LeF	Laidig extremely stony loam, 25 to 45 percent slopes	96.3	12.1%
LLF	Leck kill channery silt loam, very steep	32.3	4.0%
LnD	Lehew very stony loam, 8 to 25 percent slopes	14.6	1.8%
Lo	Linden soils	1.9	0.2%
MeC	Meckesville gravelly silt loam, 8 to 15 percent slopes	17.3	2.2%
MkD	Meckesville very stony silt loam, 8 to 25 percent slopes	34.8	4.4%
MoB	Monongahela silt loam, 3 to 8 percent slopes	4.3	0.5%
MuB	Murrill gravelly silt loam, 3 to 8 percent slopes	7.8	1.0%
MuC	Murrill gravelly silt loam, 8 to 15 percent slopes	15.6	2.0%
MuD	Murrill gravelly silt loam, 15 to 25 percent slopes	6.2	0.8%
MxD	Murrill extremely stony silt loam, 8 to 25 percent slopes	37.0	4.6%
OuC	Opequon silty clay loam, 8 to 15 percent slopes	0.8	0.1%
OuD	Opequon silty clay loam, 15 to 25 percent slopes	11.6	1.4%
OxF	Opequon-Hagerstown-Rock outcrop complex, 25 to 50 percent slopes	8.8	1.1%
Pt	Pits-Dumps complex	2.5	0.3%
Pu	Purdy silt loam	2.4	0.3%
Qu	Quarries-Dumps complex	15.7	2.0%
UD	Udifluvents-Dystrochrepts complex	9.1	1.1%
W	Water	8.0	1.0%
Totals for Area of Interest		**798.8**	**100.0%**

FRANKSTOWN BRANCH JUNIATA RIVER CROSSING
PADEP SECTION 105 PERMIT NO.: E67-920
PA-BL-0122.0000-WX & PA-BL-0122.0000-WX -16
(SPLP HDD No. S2-0140)

ATTACHMENT 2

ORIGINAL AND REVISED HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



BLAIR COUNTY, PENNSYLVANIA - FRANKSTOWN TOWNSHIP
S2-0140

PROFILE VIEW

GEOTECH SB-01

- NG EL. 894'
- TOPSOIL (0' - 0.3')
- ML (0.3' - 6.5')
- GROUNDWATER (16.0')
- SM (6.5' - 30.0')
- COMPLETION DEPTH EL. 864'

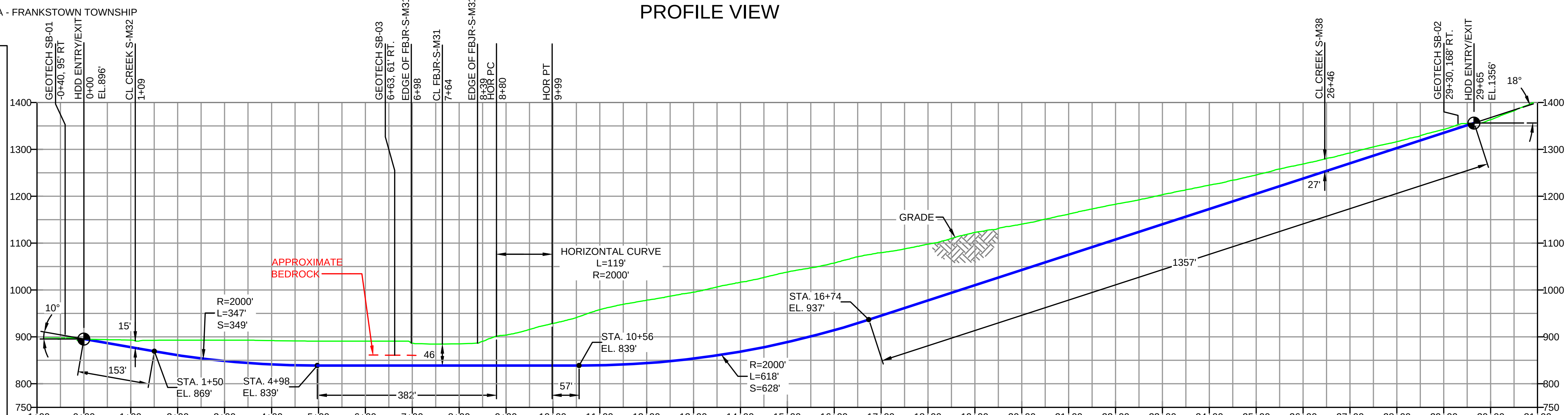
GEOTECH SB-02

- NG EL. 1359'
- ML (0.3' - 6.5')
- SM (6.5' - 18.5')
- GROUNDWATER (16.5')
- ML/CL (16.5' - 30.0')
- COMPLETION DEPTH EL. 1329'

GEOTECH SB-03

- NG EL. 892'
- NO INFO (0.0' - 14.5')
- FRACTURED GRAY LIMESTONE (14.5' - 34.5')
- COMPLETION DEPTH EL. 857'

NOTE: REFER TO TEST BORING LOG S2-0140 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 2965'
   HDD PIPE LENGTH (S=): 3045'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
4	REVISED PROFILE WITH 2017 LIDAR	MRS	03/21/17	RMB	03/21/17	CAG	03/21/17
3	REVISED PER ENGINEERING COMMENTS	DLM	08/26/16	RMB	08/26/16	AAW	08/26/16
2	MLV NAME UPDATED	DLM	04/07/16	RMB	04/07/16	AAW	04/07/16
1	ADDED "CLEARING ROW ONLY" ANNOTATION	MRS	03/28/16	RMB	03/28/16	AAW	03/28/16
0	ISSUED FOR CONSTRUCTION	MRS	12/22/15	RMB	12/22/15	AAW	12/22/15

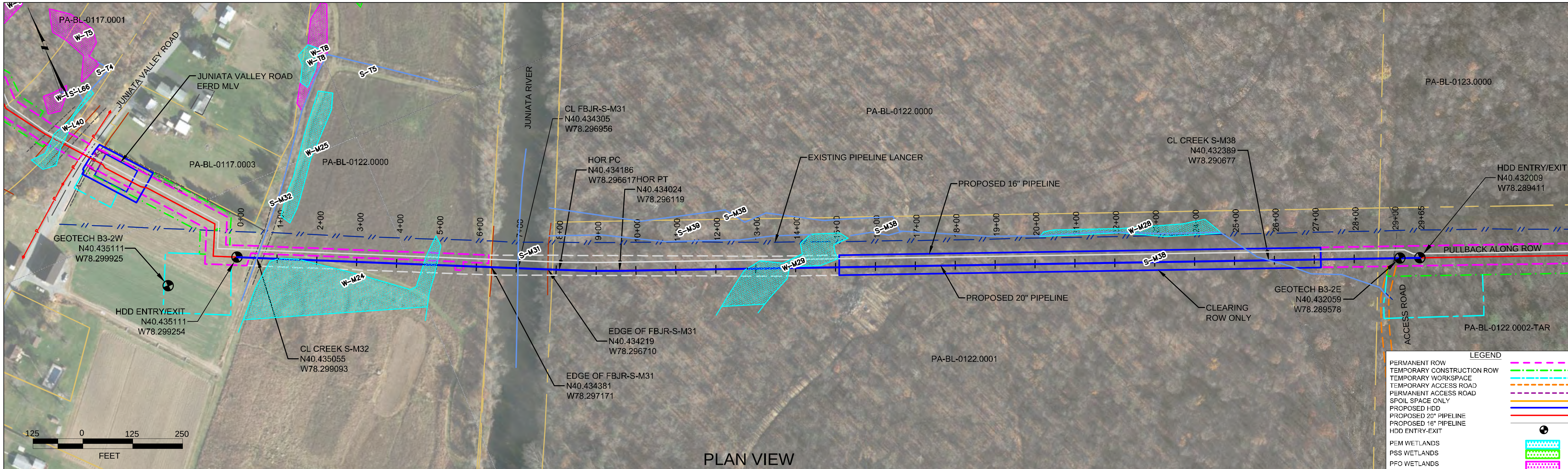
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
JUNIATA RIVER
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'
DWG. NUMBER: PA-BL-0122.0000-WX



PLAN VIEW

PROFILE VIEW

BLAIR COUNTY, PENNSYLVANIA - FRANKSTOWN TOWNSHIP
S2-0140

GEOTECH B3-2E

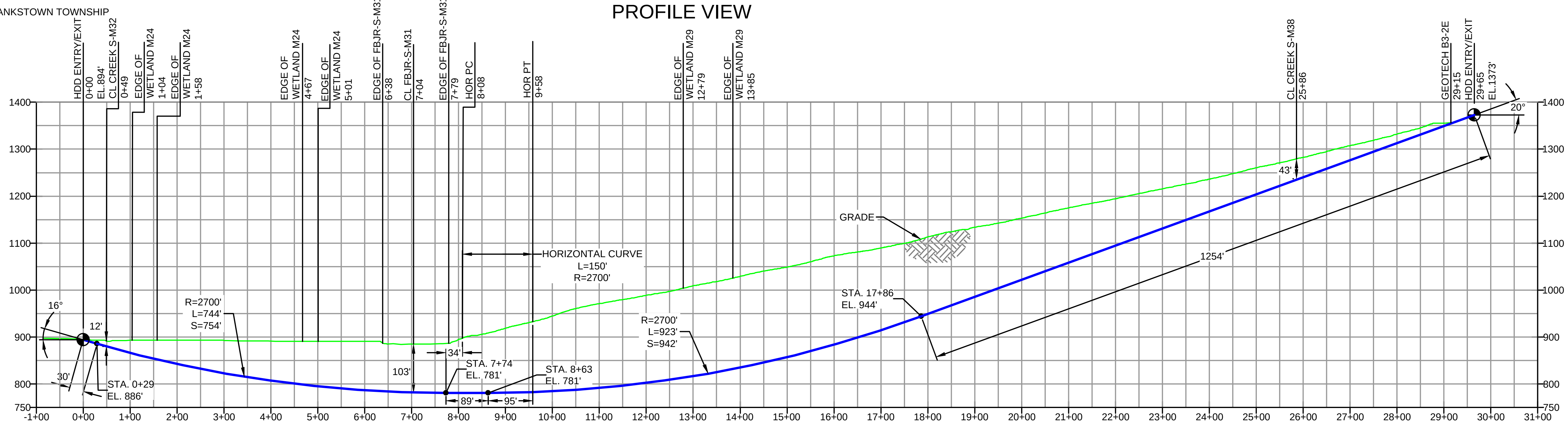
- NG EL. 1356'
- GRAVEL (0.0' - 0.7')
- GROUNDWATER (12.0')
- LEAN CLAY W/ SAND CL (0.7' - 13.5')
- GC (13.5' - 23.5')
- WEATHERED ROCK LIMESTONE (23.5' - 586.8')
- BORING TERMINATED EL.769'

NOTE: REFER TO TEST BORING LOG B3-2E TERRACON INC. PROJECT # J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B3-2W

- NG EL. 898'
- GROUNDWATER (6.0')
- LEAN CLAY CL (0.0' - 8.0')
- MUDSTONE (8.0' - 120.0')
- BORING TERMINATED EL.778'

NOTE: REFER TO TEST BORING LOG B3-2W TERRACON INC. PROJECT # J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 2965'
   HDD PIPE LENGTH (S=): 3067'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.
14. CONTRACTOR IS REQUIRED TO USE DRILLING FLUID / MUD WITH A UNIT WEIGHT OF 9.5 PPG OR LESS.

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
2. STATIONING IS BASED ON HORIZONTAL DISTANCES.
3. ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP ARE NOT RESPONSIBLE FOR LOCATION OF FOREIGN UTILITIES SHOWN IN PLOT PLAN OR PROFILE. THE INFORMATION SHOWN HEREON IS FURNISHED WITHOUT LIABILITY ON THE PART OF ROONEY ENGINEERING, INC. AND SUNOCO PIPELINE, LP, FOR ANY DAMAGES RESULTING FROM ERRORS OR OMISSIONS THEREIN.
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-3.51	TO	ES-3.53	EROSION & SEDIMENT PLAN
SHEET 33	TO	SHEET 34	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	INCREASED VERTICAL CURVE RADIUS - DESIGN CHANGE PER MICHELS	MRS	10/19/17	RMB	10/19/17	CAG	10/19/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ADDED GEOTECH INFO	MRS	09/04/15	RMB	09/04/15	AAW	09/04/15
B	ISSUED FOR BID	JAM	07/31/15	RMB	07/31/15	AAW	07/31/15

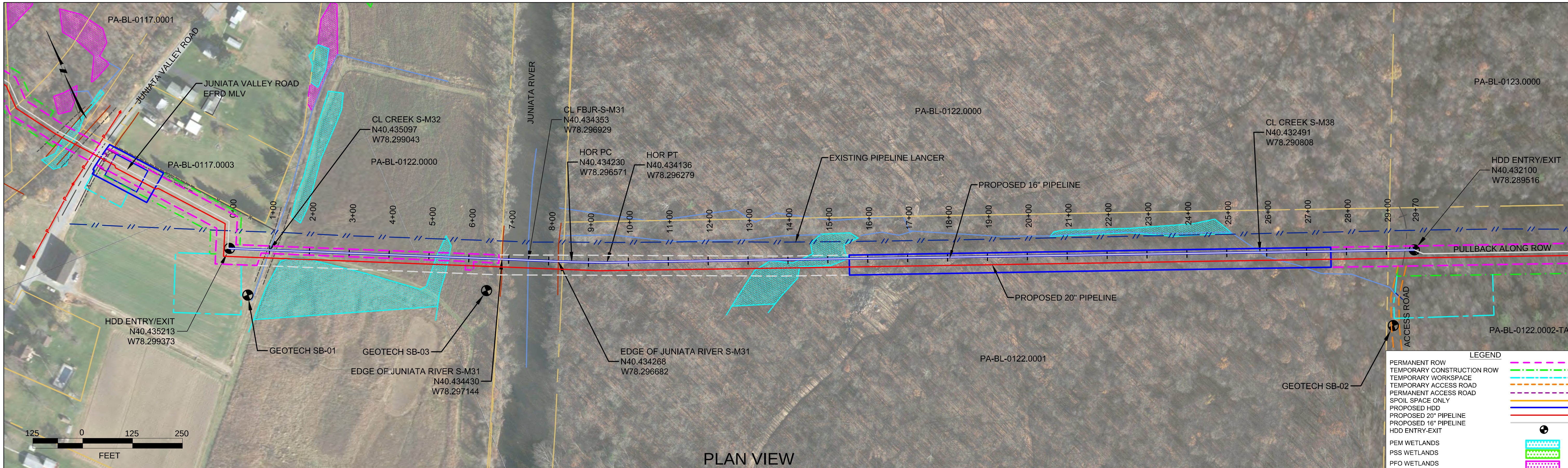
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
JUNIATA RIVER
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' | DWG. NUMBER: PA-BL-0122.0000-WX



PLAN VIEW

BLAIR COUNTY, PENNSYLVANIA - FRANKSTOWN TOWNSHIP
S2-0140-16

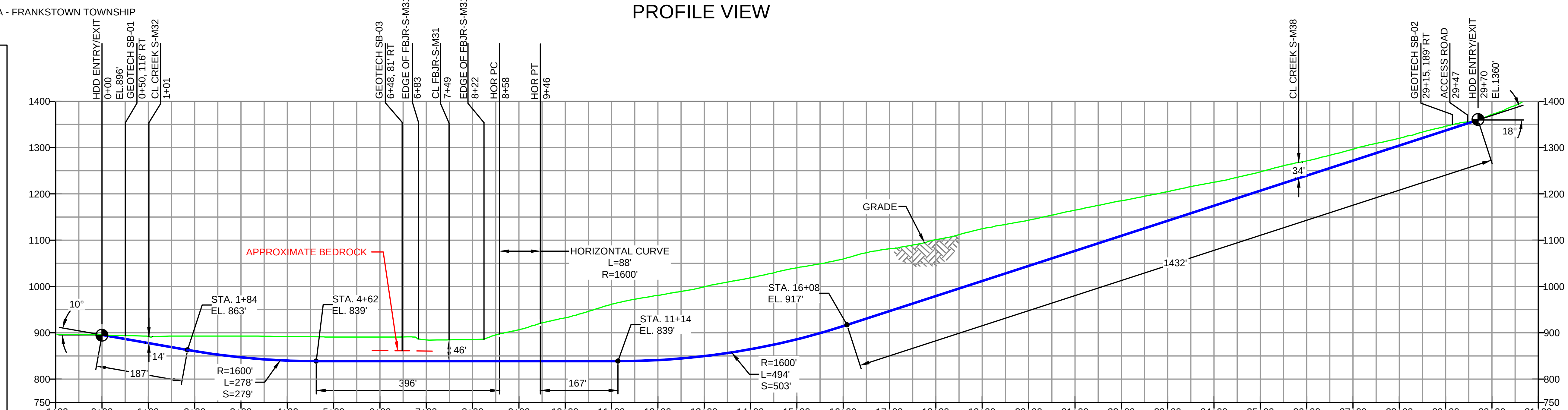
PROFILE VIEW

GEOTECH SB-01
- NG EL. 894'
- TOPSOIL (0' - 0.3')
- ML (0.3' - 6.5')
- GROUNDWATER (16.0')
- SM (6.5' - 30.0')
- COMPLETION DEPTH EL. 864'

GEOTECH SB-02
- NG EL. 1359'
- ML (0.3' - 6.5')
- SM (6.5' - 18.5')
- GROUNDWATER (16.5')
- ML/CL (16.5' - 30.0')
- COMPLETION DEPTH EL. 1329'

GEOTECH SB-03
- NG EL. 892'
- NO INFO (0.0' - 14.5')
- FRACTURED GRAY LIMESTONE (14.5' - 34.5')
- COMPLETION DEPTH EL. 857'

NOTE: REFER TO TEST BORING LOG S2-0140 FOR COMPLETE SOIL MATERIAL DESCRIPTION



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4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 2970'
   HDD PIPE LENGTH (S=): 3052'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
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REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
4	REVISED PROFILE WITH 2017 LIDAR	MRS	03/21/17	RMB	03/21/17	CAG	03/21/17
3	REVISED PER ENGINEERING COMMENTS	MRS	08/26/16	RMB	08/26/16	AAW	08/26/16
2	MLV NAME UPDATE	DLM	04/07/16	RMB	04/07/16	AAW	04/07/16
1	ADDED "CLEARING ROW ONLY" ANNOTATION	MRS	03/28/16	RMB	03/28/16	AAW	03/28/16
0	ISSUED FOR CONSTRUCTION	MRS	12/22/15	RMB	12/22/15	AAW	12/22/15

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
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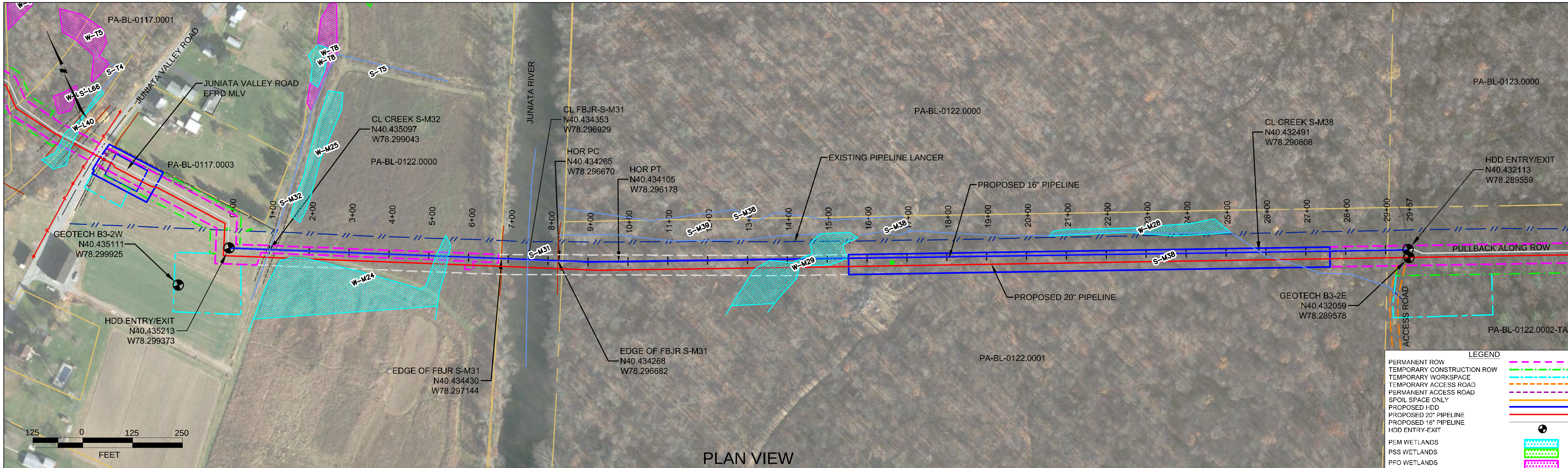
SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
JUNIATA RIVER
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'
DWG. NO: PA-BL-0122.0000-WX-16



BLAIR COUNTY, PENNSYLVANIA - FRANKSTOWN TOWNSHIP
S2-0140-16

PROFILE VIEW

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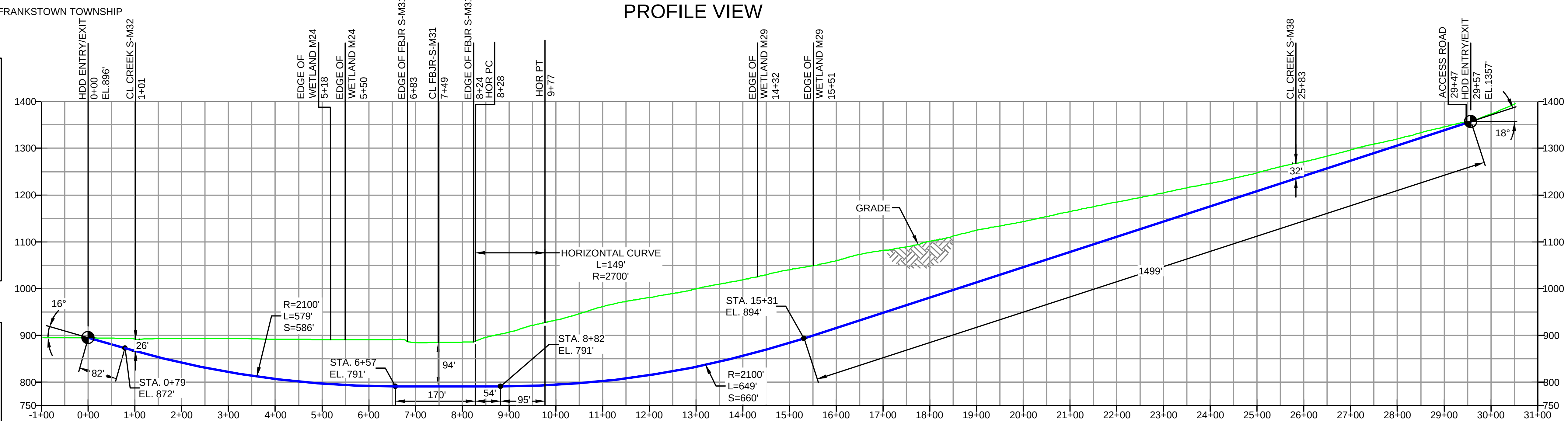

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SHEET 33	TO	SHEET 34	AERIAL SITE PLAN

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B	ADDED GEOTECH INFO	MRS	09/04/15	RMB	09/04/15	AAW	09/04/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	08/31/15

Sunoco Logistics Partners L.P.

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SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
JUNIATA RIVER
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'

DWG. NO. PA-BL-0122.0000-WX-16

FRANKSTOWN BRANCH JUNIATA RIVER CROSSING
PADEP SECTION 105 PERMIT NO.: E67-920
PA-BL-0122.0000-WX & PA-BL-0122.0000-WX -16
(SPLP HDD No. S2-0140)

ATTACHMENT 3

ANNULAR PRESSURE AND FRACTURE PRESSURE CALCULATIONS

HORIZONTAL DIRECTIONAL CONCEPTUAL DRILL DESIGN

PROJECT: Sunoco Pipeline, L.P.
Mariner East Pipeline
Blair County, Pennsylvania

CROSSING: **JUNIATA RIVER HDD**
20-INCH STEEL PIPE

ISSUE: **APC/FPC DESIGN**

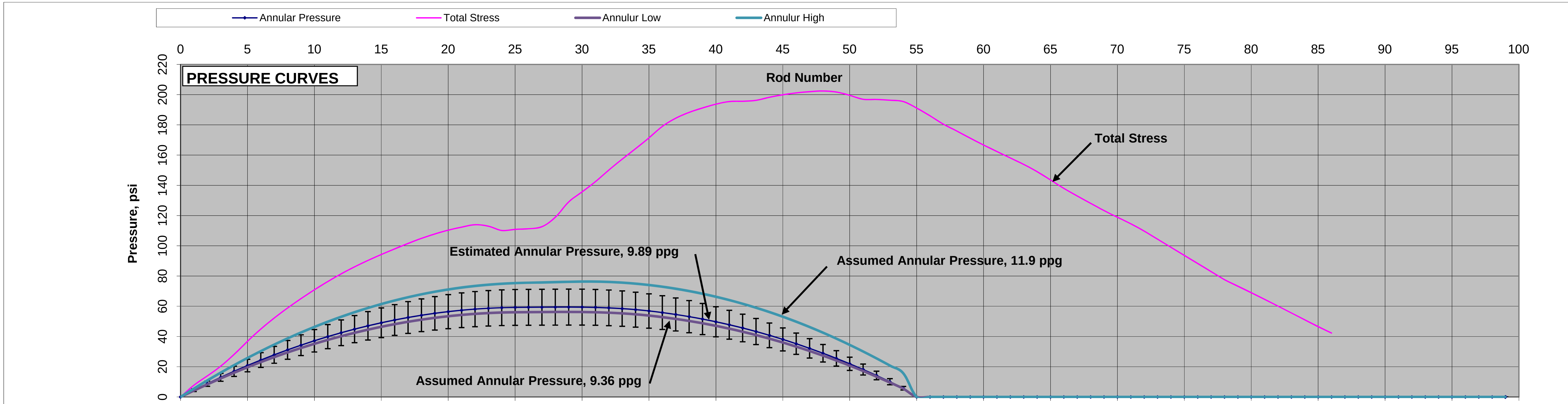
Contents:

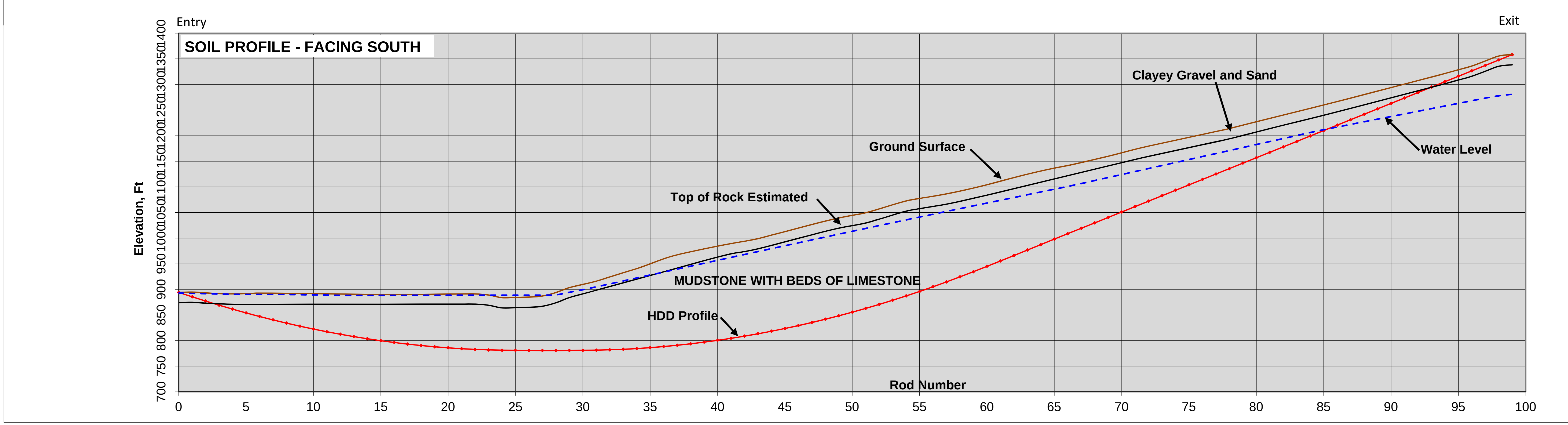
Prepared For: Sunoco Logistics Partners L.P.
525 Fritztown Road
Sinking Spring, PA 19608
855-430-4491

Prepared By: Directional Project Support
33311 Lois Lane, Suite A
Magnolia, Texas 77354
281.259.7819 (O) 617.510.8090 (C)
B. Dorwart

Project No: 0
Print Date: 5-Oct-2017

Revision	ID	DESCRIPTION	BY
10/5/2017	0	APC/FPC Design	BCD





Notes:
1. Geology is interpreted from project data
2. Rod length: 31 feet
3. The error bars are at 20 %
4. Ground surface data obtained from project survey data
5. Subsurface data from Geotechnical Report, Properties are interpreted from field and laboratory data as presented in Table 3.

ISSUED: APC/FPC DESIGN

Basis of annulur pressure calculations

12.31 in	Pilot Hole Diameter
74.0 pcf	Unit Weight Drill Fluid
300 gal/min	Pump Rate
6.63 in	Drill Rod Diameter
31	Ft per rod
20%	for APC curve

Print Date ; 10/5/2017 17:31

33311 Lois Lane, Suite A
Magnolia, Texas 77354
59.7819 (O) 617.510.80

Sunoco Pipeline, L.P.
Mariner East Pipeline
Blair County, Pennsylvania

ANNULAR PRESSURE AND FORMATION PRESSURE CURVES JUNIATA RIVER HDD

Revision 0

FIGURE 1

PATH DESIGN CALCULATIONS

Entry Station	0+00.00	FT
Exit Station	29+65.47	FT

Entry and Exit Design Coordinates & Elevations (Ft) (Note 2)

	East	North	Elevation
Entry	1815553.1404	401864.4720	894.00 ft
Horizontal Curve PI	1816391.3314	401473.2105	896.00 ft
Exit	1818285.4442	400714.2943	1,358.33 ft
Depth to Mudline	14.00 ft	Clearance Depth =	99.25 ft
Measured Plan Length at ties =	2965.4689 ft		
Coordinate Length =	2965.4689 ft		
	OK-HORIZONTAL CURVE		

Water Surface Elev.	887.00 ft
Mudline Elev.	880.00 ft
Lowest centerline Elev.	780.75 ft

SUMMARY HORIZONTAL CURVE CALCULATIONS

	Start			End						
	Station	Easting	Northing	Station	Easting	Northing	Azimuth	Length	Radius	Angle
Tangent	0+00.00	1815553.1404	401864.4720	8+49.87	1816323.2428	401504.9938	E 334.97717 N	849.87		
Curve	8+49.87	1816323.2428	401504.9938	10+00.12	1816461.0824	401445.2633	E 338.16545 N	150.24	2700.00	3.188 deg.
Tangent	10+00.12	1816461.0824	401445.2633	29+65.47	1818285.4442	400714.2943	E 338.16545 N	1965.35		

HORIZONTAL PLAN CALCULATIONS (FT)

Entry Tangent Segment		*Horizontal Curve Segment*		*Exit Tangent Segment*		
Plan Length, ft.	849.87	Input Radius, ft.	2700.00	Plan Length, ft.	1965.35	
Entry Azimuth, deg.[5]	E 334.97717 N	Curve, deg	3.188 deg.	Exit Azimuth, deg.[5]	E 338.16545 N	
Entry Azimuth, rad.[5]	5.84645	Curve, rad	0.05565	Exit Azimuth, rad.[5]	5.90210	
		Calculate PTH		**Calculate Exit**		
Calculate PCH		Chord Length, ft.	150.22	Easting	1818285.4442	**Check**
PCH Easting	1816323.2428	Arc Length, ft.	150.24	Northing	400714.2943	**Delta**
PCH Northing	401504.9938	Chord Azimuth, deg	336.5713			**0.0000**
		PI Easting =	1816391.3314			**0.0000**
		PI Northing =	401473.2105			**OK CALC**
		PTH Easting =	1816461.0824			
		PTH Northing =	401445.2633			**Exit Station**
						29+65.47
Cum Plan Length	849.87	Cum Plan Length	1000.12	Cum Plan Length	2965.468906	**OK STA**

Pull Geometry

Pipe Entry	EXIT	Enter the pipe entry location into the hole: Entry/Exit					
	Elevations		Vertical Angle, (-) = Clockwise			Path	Curve
Segment	**Start**	**End**	**Start**	**End**	**Δ Angle**	**Length**	**Radius**
Entry Tangent	1358.33 ft	943.58 ft	20.00 deg	20.00 deg	0.00 deg	1212.65 ft	0.00 ft
Entry Curve	943.58 ft	780.75 ft	20.00 deg	0.00 deg	-20.00 deg	942.48 ft	2700.00 ft
Bottom Tangent	780.75 ft	780.75 ft	0.00 deg	0.00 deg	0.00 deg	128.10 ft	0.00 ft
Exit Curve	780.75 ft	885.34 ft	0.00 deg	-16.00 deg	-16.00 deg	753.98 ft	2700.00 ft
Exit Tangent	885.34 ft	894.00 ft	-16.00 deg	-16.00 deg	0.00 deg	31.39 ft	0.00 ft
					Total Check =	3068.60 ft	OK

Compound Curve Assessment

	Vert. Plan	Horiz. Plan	
Entry	774.40	849.87	No, Horiz > Entry V(Tan+Curve)
Exit	2062.97	1965.35	Yes, Horiz < Exit V(Tan+Curve

VERTICLE PATH DESIGN CALCULATIONS (FT)

Entry Tangent Segment 1		*Entry Vert. Curve Segment 2*		*Middle Tangent Segment 3*		*Exit Vert. Curve Segment 4*		*Exit Tangent Segment 5*	
Entry Angle	-16.000 deg.	Vertical Radius	2700.00	Rod Length	128.09857	Radius	2700.00	Exit Elevation	1358.33
Entry Angle, rad.	-0.2793 rad	Vert. Curve, deg.	16.000 deg.	Inclined Bottom Tan	NO	Design Exit Angle	20.000 deg.		
Rod/Path Length	31.39	Vert. Curve, rad.	0.2793 rad			Vert. Curve, rad.	0.3491 rad		
Calculate Vertical PCV		**Calculate Vertical PTV**		**Calculate Vertical PCV**		**Calculate Vertical PTV**		**Calculate Exit**	
Plan Length	30.18	Plan Length	744.22	Plan Length	128.0985726	Vert. Curve, deg	20.000 deg.	Plan Length	1139.52
Path Length	31.39	Arc Path Length	753.98	Path Length	128.10	Vert. Curve, rad.	0.34906585	Path Length	1212.65
Tangent Depth	-8.65	Curve Vert Depth	-104.59	End Elevation	780.75	Plan Length	923.45	Elevation	1358.33
End Elevation	885.34	End Elevation	780.75	Rise/drop	0.00	Path Arc Length	942.48	Rise/drop	414.75
		Lowest Elevation	780.75			Lowest Elevation	780.75		
		End Vert Angle	0.000 deg.	End Vert Angle	0.000 deg.	Elevation	943.58		
		End Vert Angle, rad	0.0000 rad	End Vert Angle, rad	0.0000 rad	Curve Vert Depth	162.83	***Prop. Plan Length***	***2965.468906***

SUMMARY VERTICLE CURVE CALCULATIONS

Start Station	0+00.00	Start Station	0+30.18	Start Station	7+74.40	Start Station	9+02.50	Start Station	18+25.95
PVC Station	0+30.18	PTV Station	7+74.40	PCV Station	9+02.50	PTV Station	18+25.95	Exit Station	29+65.469
Cum Plan Length	30.18	Cum Plan Length	774.40	Cum Plan Length	902.50 ft	Cum Plan Length	1825.95	Cum Plan Length	2965.468906
Cum Path Length	31.39	Cum Path Length	785.38	Cum Path Length	913.48 ft	Cum Path Length	1855.95	Cum Path Length	3068.601501
Cum Depth	-8.65	Cum Depth	-113.25	Cum Depth	-113.25 ft	Cum Depth	49.58	Cum Depth	464.33

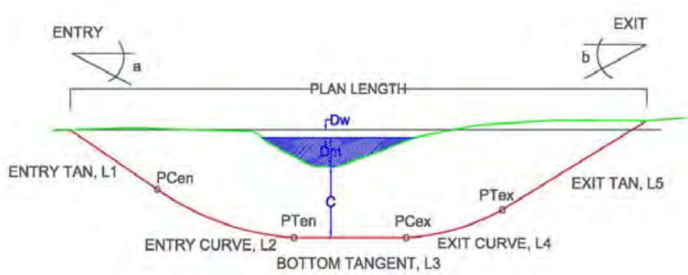
Summary of Drill Calculations

Entry to Exit Elevation Change =	**464.33 ft**
Minimum Design Elevation =	**780.75 ft**
Invert Depth below exit =	**577.58 ft**
Invert Depth below entry =	**113.25 ft**
Path Length =	**3,068.60 ft**
Plan Length =	**2,965.47 ft**
Minimum Plan Length (No Tangent) =	**2,837.37 ft**
Entry Angle =	**-16.00 deg**
Exit Angle =	**20.00 deg**
Compound Curve at Entry =	**NO**
Compound Curve at Exit =	**1,909 ft**

Stationing Check
OK STATIONING

Plan Length Check
OK CALCULATION

NOTES:
1. Sign convention for angles - positive (+) angles are counterclockwise.
   Due East is defined as 0 degrees.
2. Coordinates are in feet and reference NAD 83 Pennsylvania South State Plane
3. Elevations are in feet and reference NAVD 88.
4. All calculation locations represent the center of the drill hole.



Indicates inputs
Indicates status on internal design checks

ISSUE: **APC/FPC DESIGN**

Sunoco Pipeline, L.P.
Mariner East Pipeline
Blair County, Pennsylvania

TABLE 2
DESIGN DRILL PATH CALCULATION
JUNIATA RIVER HDD
20-INCH STEEL PIPE

Directional Project Support
33311 Lois Lane, Suite A
Magnolia, Texas 77354

Revision 0 10/5/2017

TABLE 3
ESTIMATED ANNULAR PRESSURE CURVE (APC) EXAMPLE CALCULATION
Sunoco Pipeline, L.P.
Mariner East Pipeline
Blair County, Pennsylvania

JUNIATA RIVER HDD
20-INCH STEEL PIPE
INPUT

1. Drill path data

	Measured Distance	Elevations	Angles	Lengths	Angle Change	
Drill Entry	0.000 ft	893.997	-16	Entry to PC	31.395 ft	
PC	31.395 ft			PC to PT	753.982 ft	-0.021 deg/ft
PT	785.377 ft			Invert Tangent	128.099 ft	
PC	913.476 ft			PC to PT	942.478 ft	0.021 deg/ft
PT	1855.953 ft			PT to Exit	1212.648 ft	
Drill Exit	**3068.602 ft**	1358.33 ft	20		**3068.602 ft**	
					Length Ck	**OK**

2. Drill Fluid Hydraulic Assumptions

	Assumed		**Low**		**High**	
Density, γ_f =	74	9.89 lb/gal	70	9.36 lb/gal	89	11.90 lb/gal
Dynamic annulus pressure P_d =	0.0014 psi/ft		0.0013 psi/ft		0.0068 psi/ft	
Drill fluid viscosity, μ_p =	2 cp		6 cp		13 cp	
Yield point of drill fluid, YP =	41		19		5	

3. Drill Data Assumptions

Assumed Drill Size:	**DD660**		
Avg Rod length =	31.0 feet	Max Rig Pump =	1200 gpm
Diameter of hole, D_h =	12.31125	Number of drill rods =	99
Drill Rod Tube Diameter, D_r =	6.625 in	Estimated annular pilot uphole drill fluid velocity, V_{ha} =	68.29 ft/min
Drilling Pump rate, gpm =	300 gal/min		

4. Calculate Annular Pressure, P

Method A - (API RP) 13D

$P_A = [\gamma_f\,(Y_{entry} - Y)/144] + (P_d)(MD)$

Method B - HDD Good Practices Cavity Expansion Annular Pressure

$P_B = [\gamma_f * (Y_{entry} - Y)/144] + MD*[\mu_p*(V_{ha}/60)/(1000*(D_h-D_r)^2) + YP/[200*(D_h-D_r)]$

Start Station	0+00.00	1

Drill Path			**Assumed Return Density**		**Low Return Density**		**High Return Density**	
			Density, γ_{fE} =	**74**	**Density, γ_{fL} =**	**70**	**Density, γ_{fH} =**	**89**
Rod Measured Distance MD	**Station X**	**Elevation Y**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**
ft	**ft**	**ft**	**psi**	**psi**	**psi**	**psi**	**psi**	**psi**
0.00	0+00.00	894.00	0.00	0.00	0.00	0.00	0.00	0.00
31.00	0+29.80	885.45	4.43	5.51	4.19	4.68	5.49	5.43
62.00	0+59.65	877.08	8.78	10.93	8.30	9.27	10.88	10.76
93.00	0+89.59	869.04	12.95	16.18	12.25	13.70	16.06	15.88
124.00	1+19.62	861.35	16.94	21.26	16.03	17.97	21.03	20.78
155.00	1+49.74	854.01	20.76	26.15	19.64	22.06	25.78	25.47
186.00	1+79.93	847.01	24.40	30.87	23.08	25.99	30.32	29.95
217.00	2+10.21	840.36	27.86	35.40	26.35	29.74	34.64	34.21
248.00	2+40.56	834.05	31.14	39.76	29.46	33.33	38.75	38.25
279.00	2+70.99	828.10	34.24	43.94	32.39	36.75	42.64	42.08
310.00	3+01.48	822.49	37.16	47.94	35.16	40.00	46.32	45.70
341.00	3+32.03	817.24	39.91	51.76	37.75	43.08	49.78	49.10

TABLE 4
ESTIMATED FORMATION PRESSURE CURVE (FPC) EXAMPLE CALCULATION
Sunoco Pipeline, L.P.
Mariner East Pipeline
Blair County, Pennsylvania

JUNIATA RIVER HDD
20-INCH STEEL PIPE
INPUT

1. Drill path data from vertical path calculations

	Measured Distance	Elevations	Angles	Lengths	Angle Change	
Entry	0.000 ft	893.997	-16	Entry to PC	31.395 ft	
PC	31.395 ft			PC to PT	753.982 ft	-0.021 deg/ft
PT	785.377 ft		0	Invert Tangent	128.099 ft	
PC	913.476 ft			PC to PT	942.478 ft	0.021 deg/ft
PT	1855.953 ft			PT to Exit	1212.648 ft	
Exit	**3068.602 ft**	1358.33 ft	20		**3068.602 ft**	**Length Ck OK**

2. Drill Fluid Hydraulic Data for Estimated Drill Fluid

Dynamic annulus pressure =	0.00135 psi/LF	
Uphole Drill Fluid Density =	74	9.9 lb/gal
Drill fluid viscosity, cp =	2 cp	
Up hole drill fluid velocity, ft/sec =	68.29 ft/sec	
Pump rate, gpm =	300 gal/min	
Diameter of hole D_H, in =	12.31125	
Diameter of Drill Rod D_R, in =	6.625	
Yield point of drill fluid, lb/100 ft^2 =	41.00 Lb/100FT^2	

Radius

R_H =	6.156 in
R_R =	3.313 in

3. Soil Profile Data
Technical approach to generate data as no testing available

Material Layer	Dry Density γ (pcf)	Moisture Content %	Insitu Saturated Density (pcf)	Effective UW (pcf)	Phi, Φ	Undrained Cohesion c, psf	Poisson Ratio μ	Slow Shear Modulus, G psf	OCR Cohessive (Use 0 if non-cohessive)	Model Material Layer Description	Cohesive
1	110	15.0%	126.5	47.60 pcf	10	2000	0.3	67,613	1	Clay	Y
2	150	5.0%	157.5	87.60 pcf	75	0.01	0.3	526,858	1	Mudstone	N
3								0			
4								0			
5								0			
6								0			
7								0			
8								0			
9								0			
10								0			
Water	62.4			62.40 pcf							

Dynamic Shear Velocity, $V_s = 61.4*N_{60}^{1/2}$ Based on Seed and Idris approximation

Dynamic Shear Modulus, $G_{max} = (\gamma/g)*Vs^2$

Extended Strain Shear Modulus G is typically between 5% and 20% of G_{max}

g = acceleration of gravity =	32.2	ft/s^2
Select Reduction Factor, RF =	15%	Ref 1

4 Select Controlling Location and list properties (Based on inspection of Figure 1 plot

Joint = 9 | Away Distance from Entry = 270.99 ft | Depth of Cover = 63.90 ft

Layers	*Surface 1-2*	*Surface 2-3*	*Surface 3-4*	*Surface 4-5*	*Surface 5-6*	*Surface 6-7*	*Surface 7-8*	*Surface 8-9*	*Surface 9-10*	TOTAL	Total CK
Soil Type in Layer =	1	2	2								
Dry Density in Layer, γ_d =	110.00 pcf	150.00 pcf	150.00 pcf								
Insitu Density in Layer, γ_s =	126.50 pcf	157.50 pcf	157.50 pcf								
Effective Weight in Layer, γ'_e =	47.60 pcf	87.60 pcf	87.60 pcf								
Total Layer Thickness over drill, h_s =	21.08 ft	42.82 ft	0.00 ft							63.90 ft	63.90 ft
Saturated Thickness over drill, h_{sat} =	18.74 ft	42.82 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	61.56 ft	
Dry Thickness over drill, h_{dry} =	2.34 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	2.34 ft	
Contribution Effective Stress, σ' =	1,458.74 psf	4,071.97 psf	0.00 psf								
Contribution Total Stress, $\sigma = h_s*\gamma_s$	2,628.02 psf	6,743.79 psf	0.00 psf								
Shear Modulus, G =	67,613 psf	526,858 psf	526,858 psf								

Height of Water above Soil Surface, h_w = 0.00 ft

Total soil and water height above drill path, H_T = 63.90 ft

Total water height above drill path, H_W = 61.56 ft

Properties At Drill Depth for Selected Joint

R_H =	0.51 ft	Radius of drill hole
$R_{max} = h_s/FS_D$ =	42.60 ft	Maximum allowable radius of plastic zone = Height of soil above Drill Path (h_s) divided by Delft & Queens Equation FS_D
	2	Soil Layer At Drill Depth
G_w =	526,858 psf	Large Strain Shear Modulus at drill depth
$S_u = c = q_u/2$	0 psf	Cohessive material: cohession c = unconfined compressive strength (q_u) divided by 2
ϕ =	75 deg	1.3090 rad
H_W =	61.56 ft	Total water height above drill path
FS_D =	1.5	Factor of Safety for Delft & Queens Equation soil type: Use 1.5 for Sand and 2 for Clay at Drill Depth - Apply to R_{max} and P_{max}
μ =	0.3	Poisson ration (Granular Soil: Angle of internal friction of layer at drill path depth
OCR =	1	Over Consolidation Ratio
K_o =	0.429	Coefficient of lateral earth pressure at rest. For OCR = 1 use relation $K_o = \mu/(1-\mu)$; For OCR >1 use $K_o = (K_{o\,normally\ consolidated}) * OCR^{-1/2}$
σ_o =	9,372 psf	Total Stress at drill depth, $\sigma = \gamma_d$(above water)*hdry + γ_s(saturated)*h_{sat}
u =	3,841 psf	Water pressure at drill depth, $u = \gamma_W * H_W$
σ' =	5,531 psf	Effective Stress at drill depth, $\sigma' = \sigma - u$

5. Method A - Total Stress Method (Conservative)

Calculate Allowable Controlling Formation Pressure Capacity

$P_{max} = \sigma_o = \Sigma (h_s*\gamma_s) + h_w*\gamma_w$

P_{maxA} = 9,372 psf | 65.08 psi

65.08 psi | Check Calculation

6. Method B - Total Stress Method + Local Formation Strength

Calculate Allowable Controlling Formation Pressure Capacity

$P_{max} = \Sigma (h_s*\gamma_s) + h_w*\gamma_w + S$

P_{maxB} 30,013 psf | 208.42 psi

208.42 psi | Check Calculation

Based on Mohr-Coulomb

Strength = c + σ' * tan(ϕ)

20,641 psf | 143.34 psi

7. Method C - Delft Equation for cavity expansion **(Assumes drained properties)**

$P_{max} = \mu + [p'_f + c * \cot\phi] * \{[R_o/R_{pmax}]^2 + [(\sigma_o' * \sin\phi + c * \cos\phi)/G]\}^{-\sin\phi/(1+\sin\phi)} - c*\cot(\phi)$

$\sin(\phi)$ =	0.96592583		A =	10872.96243	$A = p'_f + c * \cot\phi$	
$\cos(\phi)$ =	0.25881905		B =	0.000145007	$B = [R_o/R_{pmax}]^2$	
$\cot(\phi)$ =	0.26794919		C =	0.010139841	$C = (\sigma_o' * \sin\phi + c * \cos\phi)/G$	
μ =	3,841 psf	Initial Pore Pressure, $\mu = \gamma_w * H_w$	D =	-0.49133381	$D = -\sin\phi/(1+\sin\phi)$	
σ' =	5,531 psf	Effective Stress, $\sigma_o' = \Sigma [\gamma_d * h_d + \gamma' * h_s]$	E =	0.002679492	$E = c*\cot\phi$	
p'_f =	10,873 psf	p'_f =	σ' =	5,530.71	Check Calculation	

Checks
10872.96243
0.000145006
0.010139841
-0.49133381
0.002679492

P_{max} =	106,885 psf	742.26 psi	$P_{max} = \mu + A * (B + C)^D - E$	106,885 psf	Check Calculation
P_{allC} =	71,257 psf	494.84 psi	$P_{all} = P_{max}/FS$		

8. Method D - Queens Equation (Cohessive Soils Only) better for softer clay soils **(Assumes undrained properties)**

$K_o < 1$ $P_i = S_u + (1/2)*(3K_o - 1)*\sigma_o - S_u*\ln[(R_o/R_{pmax})^2 + (S_u/G)]$

$K_o > 1$ $P_i = S_u + (1/2)*(3 - K_o)*\sigma_o - S_u*\ln[(R_o/R_{pmax})^2 + S_u/G]$

To Determine if hydraulic fracturing or blowout occurs **(<2Su) indicates hydraulic fracturing; (>2Su) indicates blowout**

$K_o < 1$ $F_1(K_o, \sigma_o, S_u) = (3*K_o - 1)*\sigma_o$

$K_o > 1$ $F_1(K_o, \sigma_o, S_u) = (3 - K_o)*\sigma_o$

K_o =	0.429	P_i =	1,339 psf	9.30 psi	9.30 psi	Check Calculation
		F_1 =	Expect Blowout			

9. SUMMARY and Assessment of Estimated Drilling Annular Pressure and Formation Capacity

(See Annular Pressure Calculations for joint by joint calculations)

Method A - (API RP) 13D

Method B - HDD Good Practices Cavity Expansion Annular Pressure

$P_{annularA}$ =	34.24 psi	$P_A = [\gamma_f (Y_{entry} - Y)/144] + (P_d)(MD)$		
$P_{annularB}$ =	43.94 psi	$P_B = [\gamma_f * (Y_{entry} - Y)/144] + MD*[\mu_p * V_{ha}/(1000*(Dh-Dr)^2)] + YP/[200*(D_h - D_r)]$		
Method A	65.08 psi	FS =	1	Total Stress
Method B	208.42 psi	FS =	1	Total Stress + Strength
Method C	494.84 psi	At FS_D =	1.5	Delft Equation
Method D	9.30 psi	At FS_D =	1.5	Queens Equation

Comparitive Factor of Safety against Drill Fluid Loss at Critical Joint

Critical Joint =	9	Depth of Cover =	63.9 ft	
Confining Pressure Calculation Method	Method A	Method B	Method C	Method D
Method (X)/$P_{annularA}$	1.90	6.09	14.45	0.27
Method (X)/$P_{annularB}$	1.48	4.74	11.26	0.21

Acceptable if Factor of Safety >=1.0

Drill Path			Assumed Return Density		Low Return Density		High Return Density	
			Density, γ_{fE} =	74	Density, γ_{fL} =	70	Density, γ_{fH} =	89
Rod Measured Distance MD	**Station X**	**Elevation Y**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**
ft	**ft**	**ft**	**psi**	**psi**	**psi**	**psi**	**psi**	**psi**
372.00	3+62.64	812.33	42.47	55.40	40.17	45.99	53.02	52.28
403.00	3+93.30	807.78	44.85	58.86	42.43	48.72	56.05	55.24
434.00	4+24.02	803.58	47.05	62.14	44.51	51.29	58.85	57.99
465.00	4+54.78	799.74	49.07	65.24	46.42	53.68	61.44	60.52
496.00	4+85.58	796.24	50.90	68.15	48.16	55.90	63.81	62.82
527.00	5+16.42	793.10	52.56	70.88	49.72	57.96	65.97	64.92
558.00	5+47.29	790.32	54.03	73.43	51.11	59.83	67.90	66.79
589.00	5+78.20	787.89	55.32	75.80	52.34	61.54	69.61	68.44
620.00	6+09.13	785.81	56.43	77.99	53.38	63.07	71.11	69.87
651.00	6+40.08	784.09	57.36	79.99	54.26	64.43	72.38	71.09
682.00	6+71.05	782.73	58.10	81.81	54.96	65.62	73.44	72.08
713.00	7+02.04	781.72	58.66	83.45	55.49	66.63	74.28	72.85
744.00	7+33.03	781.07	59.04	84.91	55.85	67.47	74.89	73.41
775.00	7+64.03	780.77	59.23	86.18	56.03	68.14	75.29	73.74
806.00	7+95.03	780.71	59.30	87.33	56.10	68.70	75.54	73.93
837.00	8+26.03	780.71	59.35	88.45	56.14	69.22	75.75	74.08
868.00	8+57.03	780.71	59.39	89.57	56.18	69.74	75.96	74.23
899.00	8+88.03	780.71	59.43	90.69	56.22	70.27	76.17	74.38
930.00	9+19.03	780.81	59.42	91.76	56.22	70.75	76.33	74.47
961.00	9+50.02	781.17	59.28	92.69	56.08	71.09	76.31	74.40
992.00	9+81.02	781.90	58.95	93.44	55.77	71.26	76.08	74.10
1023.00	10+12.00	782.98	58.43	94.00	55.28	71.26	75.62	73.58
1054.00	10+42.96	784.41	57.74	94.39	54.62	71.09	74.95	72.85
1085.00	10+73.91	786.20	56.86	94.59	53.79	70.74	74.05	71.89
1116.00	11+04.84	788.35	55.80	94.60	52.79	70.23	72.94	70.71
1147.00	11+35.74	790.85	54.56	94.44	51.61	69.53	71.61	69.32
1178.00	11+66.61	793.70	53.13	94.09	50.26	68.67	70.05	67.70
1209.00	11+97.44	796.91	51.52	93.56	48.74	67.63	68.28	65.87
1240.00	12+28.23	800.48	49.73	92.85	47.05	66.43	66.29	63.82
1271.00	12+58.98	804.39	47.76	91.96	45.19	65.05	64.09	61.55
1302.00	12+89.69	808.66	45.61	90.88	43.15	63.50	61.66	59.06
1333.00	13+20.34	813.28	43.28	89.63	40.95	61.77	59.02	56.36
1364.00	13+50.94	818.26	40.76	88.19	38.57	59.88	56.15	53.43
1395.00	13+81.48	823.58	38.07	86.58	36.02	57.82	53.08	50.29
1426.00	14+11.96	829.26	35.20	84.78	33.30	55.58	49.78	46.94
1457.00	14+42.37	835.28	32.14	82.80	30.41	53.18	46.27	43.36
1488.00	14+72.70	841.65	28.91	80.65	27.35	50.60	42.54	39.58
1519.00	15+02.97	848.37	25.50	78.32	24.13	47.86	38.60	35.57
1550.00	15+33.15	855.44	21.91	75.80	20.73	44.95	34.45	31.35
1581.00	15+63.25	862.85	18.14	73.11	17.17	41.87	30.08	26.92
1612.00	15+93.26	870.61	14.19	70.25	13.44	38.62	25.49	22.28
1643.00	16+23.19	878.72	10.07	67.20	9.54	35.21	20.70	17.42
1674.00	16+53.01	887.16	5.77	63.98	5.47	31.63	15.69	12.35
1705.00	16+82.74	895.95	0.00	0.00	0.00	0.00	0.00	0.00
1736.00	17+12.37	905.08	0.00	0.00	0.00	0.00	0.00	0.00
1767.00	17+41.89	914.55	0.00	0.00	0.00	0.00	0.00	0.00
1798.00	17+71.29	924.35	0.00	0.00	0.00	0.00	0.00	0.00
1829.00	18+00.59	934.49	0.00	0.00	0.00	0.00	0.00	0.00
1860.00	18+29.77	944.95	0.00	0.00	0.00	0.00	0.00	0.00
1891.00	18+58.90	955.55	0.00	0.00	0.00	0.00	0.00	0.00
1922.00	18+88.03	966.16	0.00	0.00	0.00	0.00	0.00	0.00
1953.00	19+17.16	976.76	0.00	0.00	0.00	0.00	0.00	0.00
1984.00	19+46.29	987.36	0.00	0.00	0.00	0.00	0.00	0.00
2015.00	19+75.42	997.97	0.00	0.00	0.00	0.00	0.00	0.00
2046.00	20+04.55	1,008.57	0.00	0.00	0.00	0.00	0.00	0.00

Drill Path			Assumed Return Density		Low Return Density		High Return Density	
			Density, γ_{fE} = 74		Density, γ_{fL} = 70		Density, γ_{fH} = 89	
Rod Measured Distance MD	**Station X**	**Elevation Y**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**	**Annular Fluid Pressure P_A**	**Annular Fluid Pressure P_B**
ft	**ft**	**ft**	**psi**	**psi**	**psi**	**psi**	**psi**	**psi**
2077.00	20+33.68	1,019.17	0.00	0.00	0.00	0.00	0.00	0.00
2108.00	20+62.82	1,029.77	0.00	0.00	0.00	0.00	0.00	0.00
2139.00	20+91.95	1,040.38	0.00	0.00	0.00	0.00	0.00	0.00
2170.00	21+21.08	1,050.98	0.00	0.00	0.00	0.00	0.00	0.00
2201.00	21+50.21	1,061.58	0.00	0.00	0.00	0.00	0.00	0.00
2232.00	21+79.34	1,072.18	0.00	0.00	0.00	0.00	0.00	0.00
2263.00	22+08.47	1,082.79	0.00	0.00	0.00	0.00	0.00	0.00
2294.00	22+37.60	1,093.39	0.00	0.00	0.00	0.00	0.00	0.00
2325.00	22+66.73	1,103.99	0.00	0.00	0.00	0.00	0.00	0.00
2356.00	22+95.86	1,114.59	0.00	0.00	0.00	0.00	0.00	0.00
2387.00	23+24.99	1,125.20	0.00	0.00	0.00	0.00	0.00	0.00
2418.00	23+54.12	1,135.80	0.00	0.00	0.00	0.00	0.00	0.00
2449.00	23+83.25	1,146.40	0.00	0.00	0.00	0.00	0.00	0.00
2480.00	24+12.38	1,157.00	0.00	0.00	0.00	0.00	0.00	0.00
2511.00	24+41.51	1,167.61	0.00	0.00	0.00	0.00	0.00	0.00
2542.00	24+70.64	1,178.21	0.00	0.00	0.00	0.00	0.00	0.00
2573.00	24+99.77	1,188.81	0.00	0.00	0.00	0.00	0.00	0.00
2604.00	25+28.90	1,199.42	0.00	0.00	0.00	0.00	0.00	0.00
2635.00	25+58.03	1,210.02	0.00	0.00	0.00	0.00	0.00	0.00
2666.00	25+87.16	1,220.62	0.00	0.00	0.00	0.00	0.00	0.00
2697.00	26+16.29	1,231.22	0.00	0.00	0.00	0.00	0.00	0.00
2728.00	26+45.42	1,241.83	0.00	0.00	0.00	0.00	0.00	0.00
2759.00	26+74.56	1,252.43	0.00	0.00	0.00	0.00	0.00	0.00
2790.00	27+03.69	1,263.03	0.00	0.00	0.00	0.00	0.00	0.00
2821.00	27+32.82	1,273.63	0.00	0.00	0.00	0.00	0.00	0.00
2852.00	27+61.95	1,284.24	0.00	0.00	0.00	0.00	0.00	0.00
2883.00	27+91.08	1,294.84	0.00	0.00	0.00	0.00	0.00	0.00
2914.00	28+20.21	1,305.44	0.00	0.00	0.00	0.00	0.00	0.00
2945.00	28+49.34	1,316.04	0.00	0.00	0.00	0.00	0.00	0.00
2976.00	28+78.47	1,326.65	0.00	0.00	0.00	0.00	0.00	0.00
3007.00	29+07.60	1,337.25	0.00	0.00	0.00	0.00	0.00	0.00
3038.00	29+36.73	1,347.85	0.00	0.00	0.00	0.00	0.00	0.00
3068.60	29+65.49	1,358.32	0.00	0.00	0.00	0.00	0.00	0.00

Item	Comment/Exception/Assumption
3	CALCULATION OF ANNULAR PRESSURE: Drill fluids are Non-Newtonian fluids and must be modeled with specific fluid properties. Annular Pressure is based on assumptions for drill fluid rheological properties that may be expected in the field. As the field data, and the properties of various bentonitic products can vary significantly, error bars have been assigned to the estimated results to represent these unknowns between assumptions and the actual products and blends provided by the contractor. These assumptions should be confirmed in the field during construction as the changes will also change the Annular Pressure curve. Field values of drill fluid should be expected to change as different subsurface materials may require different drill fluid properties. Annular pressure has been calculated by two independent methods: METHOD A is based on the API-13D method using a Power Law to model the Dynamic pressure of a visco-plastic fluid; METHOD B uses a hydraulic model for modeling the Dynamic Pressure as a viscous flow in an annulus and is described in the HDD Good Practices Guidelines; a book available through the NASTT. Both methods are accepted in the industry. The annular pressure curves shown in Figure 1 plot the API-13D data by drill rod along the drill path. Three annular pressure curves are shown on Figure 1 representing three different drill fluid densities that range the possible field conditions that may occur: Assumed estimate of reasonable drill fluid properties, Highest reasonable drill fluid properties, Lowest reasonable drill fluid properties. The "Assumed estimate" data include a 20% error bar on each point representing the accuracy of the data with regard to the ability to predict the actual pressures. The 20% error bar is based on experience with field measurements of annular pressure vs predictions. This assessment does not offer a risk of fluid loss by leakage through natural or manmade preferred pathways such as rock joints, adjacent utility installations, and adjacent foundation systems.
4	CALCULATION OF FORMATION PRESSURE: The Formation Pressure capacity may be approximated by using one or more of four alternative calculation methods: Total Stress (used for Rock and conservatively for dense soils, Cavity Expansion (Delft Equation) (used for medium dense granular and soft to stiff cohesive soils), Total Stress plus Strength (used for Cohesive materials), and the Queens Equation (which is used for very soft or loose cohesive or granular soils). The Total Stress Method is based strictly on the dead weight of the overlying material above the drill path thus excluding any potential strength that the formation material may have. This method is considered conservative but is considered a reasonable approximation for rock. Note that in areas of high topographic relief and where the drill path approaches within about 5 times the depth below the entry to a topographic surface, then the total stress must be adjusted for both magnitude and direction as the pressure vector is no longer vertical. The cavity expansion, Stress plus Strength, and Queens methods adds the strength of the formation material to the total stress. These methods are considered more realistic however these equations require significant assumptions regarding input parameters that are not often, if ever, substantiated by field data. These three relations are not generally appropriate for rock. The sensitivity of the input data assumptions for these three approaches have been shown to be significant to the results. Significant experience is often required in determination of these input values. Thus these methods may not be conservative and can lead to overly optimistic results leading to a false impression of an unreasonably high Formation Pressure Capacity.

Item	Comment/Exception/Assumption
5	TECHNICAL APPROACH DRILL FLUID MANAGEMENT: Table 2 provides the proposed drill path for the interpreted geologic profile assumed for the crossing. Table 3 provides the calculated Annular Pressure and Table 4 the calculated Formation Pressure Capacity. Calculations are provided for each drill rod along the design drill path. The results are summarized on Figure 1. Assessment is based on comparison of the Formation Pressure Capacity to the Annular Pressure. This relation provides a tool to assess the risk of hydraulic fracturing of a formation or hydraulic jacking along pathways within a formation caused by Annular Pressure exceeding the Formation Capacity Pressure. When the Annular Pressure is higher than the Formation Pressure Capacity, then the risk of drill fluid loss by jacking or hydrofracturing is considered high for the design drill path and drill direction. Mitigation considerations may include: reversing the drill direction, adjusting the depth of the drill path in problem areas, or reduction of drill fluid pressure by methods such as reduction of drill fluid weight, use of drill foam, reduction in the elevation head pressure which may be accomplished by pumping the drill fluid elevation in the hole down to a lower elevation.
6	**Limitations:** These calculations are for HDD planning purposes only. It should be expected that the drill process will generate new data that may require adjustments to the assumed conditions used for the basis of these calculations. Adjustments to the assumed subsurface conditions may require corresponding adjustments to the various HDD drill parameters or tools to optimize production. Typical parameters that are adjusted include: drill fluid pump rate, penetration rate, drill fluid properties, along with bit dimensions and types or other tooling.