HORIZONTAL DIRECTIONAL DRILL ANALYSIS
SLITTING MILL ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E23-524
PA-DE-0008.0000-RD
(SPLP HDD No. S3-0560)

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This reevaluation of the horizontal directional drill (HDD) installation of a 20-inch diameter pipeline under Slitting Mill Road has been completed in accordance with Condition No. 3 of the Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L (Order). Condition No. 3 stipulates for HDDs initiated after the temporary injunction issued by the Pennsylvania Department of Environmental Protection (PADEP) Environmental Hearing Board (July 25, 2017), a reevaluation must be performed on HDDs for which an inadvertent return (IR) occurs during the installation of one pipe (20-inch or 16-inch diameter) where a second pipe will thereafter be installed in the same right-of-way (ROW).

The installation of the 16-inch diameter pipeline at HDD S3-0560 was initiated after the temporary injunction issued by the PADEP Environmental Hearing Board on July 25, 2017. The 16-inch pipeline HDD had three (3) upland inadvertent returns (IRs), and therefore, installation of the second pipeline (20-inch diameter) requires reevaluation. The IRs for the 16-inch pipeline were easily remediated, and the HDD was completed when the pipe was pulled on 12/15/17.

The 20-inch pipeline HDD is referred to herein as HDD S3-0560.

PIPE INFORMATION

20-Inch: 0.456 wall thickness; X-65

Pipe stress allowances are an integral part of the design calculations performed for each HDD. For steel pipe the “pipe stress allowance” is the amount of curvature that a piece or length of pipeline can bend without resulting in damages such as a “kink” or “crimp” in the wall of the pipe. The innate curvature ability of pipe is termed the “free stress radius”. The stress allowance of the pipe is determined by the ductility of the steel, wall thickness, and the diameter of the pipe. An HDD design is limited by the horizontal distance between the points of entry and exit and the free stress radius of the pipe.

Ductility of the steel used for pipelines is determined by the percentage of carbon within the steel. Generally, steel pipe is categorized as either “low carbon” having less than 0.3% carbon content within the steel, or “high carbon” having greater than 3% carbon within the steel. As the carbon content within the steel used to make the pipe increases, the flexibility (ductility) of the pipe is decreased. The X65 20-inch pipe utilized on the Mariner project is a low carbon (high ductility) steel pipe.

The design of an HDD profile accounts for the free stress radius of the pipeline segment to be pulled into the drilled entry, through the entry radius of curvature at maximum horizontal depth, out the exit radius leaving maximum depth, and out the drilled exit; therefore, each HDD has a minimum of four (4) points of pipeline curvature to assess for pipeline stress. Additionally, a horizontally drilled profile is not a “perfect” pathway, especially when drilled through rock formations. The pilot tool cutting into the rock face has a larger cutting face than the drill stem pushing the tool forward, which results in flexibility of the tooling within the pilot hole, and as a result the pilot tool will drift in orientation as proceeding forward because the cutting tool will proceed easier into softer material while cutting due to natural variances in hardness of the materials being cut, whether they are soils or rock. Steering of the pilot tool is used to correct drifting as it occurs. As a result of this natural drifting during completion of the pilot hole, the entire length of the drilled pilot hole is assessed for stress allowances at three (3) joint intervals before reaming of the annulus is permitted. If errors during pilot drilling or reaming occur and a mid-point is identified that would breach the pipe stress allowance, then the use of an over-reamed annulus is assessed for breach of the stress allowance. In cases where an over-reamed annulus will not correct the stress problem, the HDD has to be re-drilled.

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Specifics for the original permitted 20-inch HDD plan and profile are discussed in the original permitted HDD design summary below. Specifics for the revised 20-Inch HDD plan and profile are discussed in the Redesigned Horizontal Directional Drill Design Summary at the end of this report.

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 1,378 foot (ft)
- Entry/Exit angle: 10 degrees
- Maximum Depth of cover: 61 ft
- Pipe design radius: 2,000 ft

The original profile design factors are below the pipeline stress allowances for all points of analysis.

ROOT CAUSE ANALYSIS FOR THE 16-INCH PIPE INSTALLATION INADVERTENT RETURNS

Three (3) IRs occurred during construction of the 16-inch line at HDD S3-0560. All three occurred within 220 feet of the southeast entry/exit where there was 40 feet or less of soil or weathered, or fractured, bedrock above the profile. IR-1 (50 gallons) occurred during the initial pilot hole drilling. IR-2 (15 gallons) occurred while an intercept pilot hole was being advanced from the southeast entry/exit before abandonment of the first pilot attempt due to an inability to complete an intercept of the pilot hole drilled from both ends. IR-3 (150 to 200 gallons) occurred during reaming. Between IR-1 on 10/13/17 and IR-3 on 12/12/17 a few small upland IRs (0.5 to 4 gallons each) occurred in the same general area as IR-1, IR-2 and IR-3.

The three upland IRs that occurred on the east side of Slitting Mill Road were the result of shallow overburden comprised of highly weathered and fractured bedrock. IRs No. 1 and No. 3, occurred as the drilling bits were approaching exit at the southeast entry/exit. IR No. 2 occurred while tools were being tripped out of the intercept pilot bore and was probably the result of drilling fluid finding a preferred flow path in the overburden and road base of Slitting Mill Road established by IR No. 1. A pathway created by abandoning the initial pilot hole and pilot intercept possibly contributed to IR-3.

GEOLOGIC ANALYSIS

Blackmer (2005) mapped the bedrock at HDD S3-0560 as the undifferentiated amphibolite facies gneiss unit of the Baltimore Gneiss and describes the unit as a heterogeneous felsic, intermediate and mafic amphibolite facies gneiss. The predominant lithology is described as intermediate plagioclase-hornblende-quartz-biotite gneiss with local orthopyroxene, clinopyroxene, potassium feldspar, and garnet. Banding is reported to poorly developed and massive.

Fracture trace analysis identified one west-east trending fracture trace intersects the northwest part of the alignment at approximately station 0+90 (proposed profile) and a second east-southeast trending fracture trace that intersects the southeast entry/exit location (proposed profile).

Seismic refraction and multichannel analysis of seismic waves (MASW) surveys were performed to identify potential fracture zones and the approximate depth of competent bedrock along the proposed profile. Data could not be collected between approximately Stations 6+70 to 7+30 because the HDD alignment crosses a driveway and a landscaped structure. Refraction data was unable to reach the elevation of the deeper portions of the proposed 20-inch HDD profile due to encountering bedrock at a higher elevation than the profile, however the MASW data extended to a depth that covered most of the proposed 20-inch profile, to

within approximately 10 feet of the central, deepest portion of the profile. The overall conclusion of geophysical survey was that the data indicate a lack of significant fractures and faulting at HDD S3-0560. The top of relatively competent bedrock as indicated by both survey types ranged from approximately 14 to 51 ft bgs. The MASW survey identified low velocity zones indicating potential fracture or fault zones at approximately stations 6+50 and 12+87. In general, these two locations do not directly correlate with the two mapped fracture traces that cross the alignment. One of the mapped fracture traces passes through the southeast entry/exit on the proposed plan and profile, approximately 180 feet southeast from the low velocity zone located at Station 12+87. Two of the three IRs that occurred during construction of the 16-inch line were due north of the alignment at Stations 12+63 and 13+02 where the overburden was relatively shallow at 39 and 33 feet, respectively. These two IRs are in the same general location as the low velocity zone identified at Station 12+87. The geophysical survey data may not reflect reality over the entirety of the revised HDD profile depth, since as shown within the geophysics report provided within Attachment 1 of this report, data was not obtained to the profile depth, and fractures typically reduce in number and aperture as depth below ground increases.

There is no known or mapped karst geology, or sinkholes in the area of this HDD.

The soil/weathered rock overburden on the redesigned profile ranges down to a depth of 32-65 ft below ground surface (bgs). Based on the vertical geotechnical core boring data acquired in September of 2017, the HDD will proceed through soil and highly weathered/fractured bedrock rock to depths between 38 and 65 ft bgs. RQD values indicate the top of a zone of more competent, stronger, bedrock will be encountered at approximately 65 bgs, below which RQD values mostly ranged from 72 to 100 percent, except for one low RQD value for a five-foot interval in each boring. For both borings, bedrock cored at the approximate elevation of the deepest, horizontal, section of the proposed profile is within a zone of 100 percent RQD.

Attachment 1 provides a discussion on the geology and results of the geotechnical and geophysical investigation performed at this location.

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

Groundwater in the metamorphic rocks of Delaware County is typically stored and moves within pore space in the saprolite comprised of highly weathered and fractured bedrock and within open discontinuities of more competent bedrock at depth. Some saturated zones within the saprolite may be under perched conditions.

A PAGWIS search of domestic wells within one mile of the HDD S3-0560 alignment produced water level measurements for 41 wells ranging from 4 to 70 ft bgs with an average of 28 ft bgs. The wells were completed between 36 and 525 ft bgs and all were drilled within the Baltimore Gneiss. The search listed well yields for 36 domestic wells ranging from 2 to 100 gallons per minuture (gpm), and with an average yield of 20 gpm.

Groundwater levels were variable among the geotechnical borings advanced in the area of HDD S3-0560. One of the two shallow borings advanced by Tetra Tech encountered water at 16 ft bgs, the other one was dry. Terracon borings B6-15W and B6-15E were drilled to depths of 113 and 100 feet, respectively, but both boring logs indicated groundwater was not encountered. Estimates of water levels were reported by well owners for 3 of the 22 wells sampled in SPLP's source water sampling program. These ranged from 15 to over 100 ft bgs. The landowner estimate of depth to water for the well closest to the HDD alignment (within 29 feet) was greater than 100 ft bgs.

Attachment 1 provides a discussion on the hydrogeology at this location.

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ADJACENT FEATURES ANALYSIS

This HDD is located 1.2 miles south of the Town of Willistown in Delaware County, Pennsylvania. The pipeline alignment crosses under Slitting Mill Road, and is set within light commercial and urban residential developments for the majority of its length. The HDD profile does not cross under any Waters of the Commonwealth, and the HDD alignment follows an existing SPLP pipeline easement for the majority of its length.

SPLP identified thirty-one (31) landowners within 450 ft of the HDD alignment. SPLP sent each of these landowners a notice letter via both certified and first-class mail that included an offer to sample the landowner's private water source (well or spring) in accordance with the terms of the Order and the Water Supply Assessment, Preparedness, Prevention and Contingency Plan. The letter also requested that each landowner contact the Right-of-Way agent for the local area and provide SPLP with information regarding: (1) whether the landowner has a water source; (2) where that water source is located, and its depth and size if known; and (3) whether the landowner would like to have the water source sampled. In accordance with paragraph 10 of the Order, copies of the certified mail receipts for the letters sent to landowners have been provided to Karyn Yordy, Executive Assistant, Office of Programs at PADEP's Central Office.

To date, SPLP has received thirty-one (31) responses from individual landowners. Of these, eighteen (18) landowners have confirmed the use of one or more private water sources on their parcel, and the remaining landowner responses verified the use of public water supply or no water use on the parcel. In all, twenty-two (22) private water sources on eighteen (18) parcels have been located and were tested. Fourteen of these water sources occur within 450 ft of the HDD alignment and four are within 100 feet of the HDD alignment at approximate distances of 10, 29, 63 and 84 feet from the HDD alignment. However, no water supply complaints were received during drilling for the 16-inch HDD, and none have been received since completion of the 16-inch pipeline installation.

In accordance with the requirements of the Stipulated Order, SPLP will transmit a copy of this HDD analysis to all landowners having a property line within 450 ft of any direction of this HDD location.

ALTERNATIVES ANALYSIS

As required by the Order, the reanalysis of HDD S3-0560 includes an evaluation of construction alternatives and a re-route analysis. As part of the PADEP Chapter 105 permit process for the Mariner II East Project, SPLP developed and submitted for review a project-wide Alternatives Analysis. During the development and siting of the Project, SPLP considered several different routings, locations, and designs to determine whether there was a practicable alternative to the proposed impact. SPLP performed this determination through a sequential review of routes and design techniques, which concluded with an alternative that has the least environmental impacts, taking into consideration cost, existing technology, and logistics. The baseline route provided for the pipeline construction was to cross every wetland and stream on the project by open cut construction procedures. The Alternatives Analysis submitted to PADEP conceptually analyzed the potential feasibility of any alternative to baseline route trenched resource crossings (e.g., reroute, conventional bore, HDD). The decision-making processes for selection of the HDD instead of an open cut crossing methodology is discussed thoroughly in the submitted alternatives analysis and was an important part of the overall PADEP approval of HDD plans as currently permitted. As described below, the construction methods and re-route analyses have confirmed the conclusions reached in the previously submitted Alternatives Analysis.

Open-cut Analysis

The HDD profile passes through and under parts of three (3) light industry properties; four (4) residential properties, and three (3) buried utilities owned by other companies. An open cut/conventional auger bore

construction plan to replace the proposed HDD is feasible. To implement an open cut/auger bore construction plan would require cooperation or condemnation of four (4) private landowners to accept a revised permanent easement, or second permanent easement. The easement revision or addition is required to account for the final pipeline location and temporary workspace needed to implement the open cut/bore construction plan to avoid structures encroaching onto and into the existing SPLP easement. This plan would require passing under the two existing SPLP pipeline three times.

Sunoco Pipeline, L.P. (SPLP) specifications require a minimum of 48-inches of cover over the installed pipelines. The Pennsylvania Department of Transportation (PADOT) cover requirements under public roadways is 60-inches of cover. The HDD as planned avoids a conventional auger bore, or open cut of Slitting Mill Road; however, with an approved Road Closure Permit from Edgmont Township, and a reorientation of the new pipeline alignment, Slitting Mill Road could be crossed by conventional auger bore or an open cut if a permitted road closure was approved by Edgmont Township.

Although technically feasible, this plan was proposed during the original assessment and permitting of the Pennsylvania Pipeline Project, and was rejected by the landowners. Comparing the direct effects of this open cut/auger bore construction to the occurrence of three upland IRs during drilling for installation of the 16-inch pipeline which were readily contained and cleaned up, to implementation of legal action to take an easement for implementation of this plan results in SPLP's opinion that an HDD crossing of this area is still the preferred methodology.

Use of Conventional Auger Bore

Planning for a conventional bore must account for the extent or width of the feature (road, stream, etc.) being bored under, as well as the length and width of the setup-entry pit for setting the boring equipment within while operating, and the receiving pit through which the product pipeline is pulled back through after the boring machinery exits.

Based on experience gained during construction of the Mariner II Pipeline project, conventional auger bores should be limited to approximately 200 linear ft at a time, or less, varying by the underlying substrate. Conventional auger bores for the 16-inch pipeline, attempted at longer distances, have at times had alignment drift and elevation deflections occur which have complicated installation.

A conventional auger bore could be used in combination with open cut construction, as discussed above, to install the 20-inch pipe under Slitting Mill Road near the southeast entry/exit as well as subset footages within the length of the permitted HDD. This would require landowner agreements as discussed above, and comparing the direct effects of this open cut/auger bore construction to the occurrence of three upland IRs which were readily contained and cleaned up, to implementation of legal action to take an easement for implementation of this plan results in SPLP's opinion that an HDD crossing of this area is still the preferred methodology.

FlexBor Analysis

SPLP contractors attempted three (3) FlexBors and partially completed two of these to replace HDDs on the Mariner Project. One FlexBor failed in the pilot phase and was replaced with a conventional bore under a highway and open cut construction. The two partially successful FlexBors completed the pilot phases, but both had difficulties completing the reaming phase. SPLP's analysis is that this technology is not perfected for larger diameter bore attempts.

Direct Pipe Bore Analysis

The direct pipe bore method is also known as "microtunneling". This method of pipeline installation is a remote-controlled, continuously supported pipe jacking method. During the direct pipe installation,

operations are managed by an operator in an above-ground control room alongside of the installation pit. Rock and soil cutting and removal occurs by drilling fluid injection through the cutting tool during rotation at the face of the bore, and the cuttings are forced into inlet holes in the crushing cone at the tool face for circulation to a recycling plant through a closed system. The entire operating system for this method of pipeline installation, including the cutting tool drive hydraulics, fluid injection, fluid return, and operating controls are enclosed inside the outside diameter bore pipe (or casing pipe) being installed. At the launching point/entry pit, the bore pipe is attached to a "jacking block" that hammers the bore pipe while the tool is cutting through the substrate or geology. The cutting tool face is marginally larger in diameter than the pipe it is attached to. As a result, there is minimal annulus space, which minimizes the potential for drilling fluid returns or the production of groundwater returning back to the point of entry. Unlike an HDD, this technology has no steering capability. Changes in direction are made by adjusting the cutting angle of the tool face which results in a maximum of 4 degrees radius between the point of entry and exit.

SPLP's construction contractors have successfully completed one (1) Direct Pipe Bore approximately 925 ft on the Pennsylvania Pipeline Project (PPP) at the crossing of the Frankston Branch of the Juniata River in Blair County. This Direct Pipe Bore was setup within a relatively flat area immediately outside the river floodplain and bored under the floodplain, wetlands, and river, exiting at the toe of a mountain slope.

The Direct Pipe Bore method requires substantially more surface workspace than required for an HDD for the setup and operation of the entry pit due to the space requirements for the hydraulic jacking press and supporting equipment which approximates the equipment assembly for operating an HDD, plus layout room for the casing pipe string to be jacked into place.

Although feasible, implementation of one or more Direct Pipe bores in combination with open cut installation segments would require landowner agreements for the workspace for setup of the equipment and re-alignment of the pipeline installation as discussed above, and comparing the direct effects of this construction to the occurrence of three upland IRs, which were readily contained and cleaned up to legal action to take a revised easement and the workspace for implementation of this plan results in SPLP's opinion that an HDD crossing of this area is still the preferred methodology.

Re-Route Analysis

The general route of the Mariner II project in this area of Pennsylvania is from northwest to the southeast. The pipeline route as currently permitted follows an existing SPLP easement through light commercial and residential development and bypasses or directly avoids impacting three commercial buildings, Slitting Mill Road, and three (3) private driveways.

Southwest of the existing SPLP easements, there are no apparent existing utility corridors for consideration for use to co-locate the PPP project. Residential developments occupy most of the grounds outside of stream corridors; therefore no probable alternative for rerouting of the PPP exists to the southwest.

An existing pipeline corridor with two (2) existing pipeline lies approximately 1.0 miles northeast of the SPLP easement. This utility corridor never bi-sects the SPLP utility easement either northeast of, or southeast of the SPLP easement; therefore use of this existing easement requires establishment of a new greenfield to leave the SPLP route, intersect this corridor; establish a new parallel easement, plus workspace, and then leaving this alternate route to return to the route of the PPP to achieve the endpoint.

In summary, due to the settings surrounding the overall route of the Mariner II pipelines in this area, there is no alternative route that could avoid conflicts with existing developments. Since SPLP possesses no prior rights for multiple utility lines in any nearby existing corridor, nor any new corridor that could be developed, SPLP anticipates significant legal action to acquire a new easement.

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This re-route analysis conducted for the Slitting Road HDD confirms the conclusions reached in the previously submitted alternatives analysis.

HORIZONTAL DIRECTIONAL DRILL REDESIGN

SPLP has considered all geologic data and the events during installation of the 16-inch pipeline and has redesigned the 20-inch HDD profile. A summary of the redesign factors is provided below. The original and redesigned HDD plan and profile for the 20-inch pipeline are provided in Attachment 2.

Revised Horizontal Directional Drill Design Summary: 20-inch

- Horizontal length: 1,465 feet (ft)
- Entry/Exit angles: 15 - 16 degrees
- Maximum depth of cover: 98 ft
- Pipe design radius: 2,400 ft

The redesigned HDD profile increases the angle of entry and exit to reduce the potential for IRs as occurred during installation of the 16-inch pipeline. This design nearly maximizes the profile potential and leaves 124 ft of horizontal run for any required corrections before proceeding into the exit radius. The remaining design factors are below the pipeline stress allowances for all points of analysis.

CONCLUSION

Based on the original and revised profile for the 20-inch HDD, the revised HDD profile increases the depth in bedrock for a majority of the HDD profile; therefore, adjustments to the plan of construction for the 20-inch pipeline represent a reduced risk of IRs that would impact uplands over the profile. The HDD does not pass beneath any Waters of the Commonwealth. Although no water supply impacts occurred during installation of the 16-inch pipe, four (4) private water supplies are within 100 feet of the alignment, representing a heightened risk for a water supply impact. This risk will be managed by SPLP, as it does for all private water supplies within 450-feet of HDD alignments, by offering pre-drilling water quality sampling, and temporary water supplies during the time of HDD installation. Upland and punch out IRs are common on entry and exit of the drilling tool and other measures are required to minimize IR potential. In particular, upon the start of this HDD, SPLP will employ the following HDD best management practices:

- SPLP will provide the drilling crew and company inspectors the location(s) data on potential zones of higher risk for fluid loss and IRs, including the area related to previous IRs, and potential zones of fracture concentration identified by fracture trace analysis, so that monitoring can be enhanced when drilling through these locations;

- SPLP will mandate annular pressure monitoring during the drilling of the pilot hole, which assists in immediate identification of pressure changes indicative of loss of return flows or over pressurization of the annulus, managing development 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;

- SPLP will implement short-tripping of the reaming tools as indicated by monitoring of return flows, 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;

- The drilling manager and SPLP drilling inspectors will monitor the tool face pressure while advancing towards exit to determine when mud pressures can be reduced to lower IR potential while completing the final footage for exiting of the pilot tool. During the reaming phase, the driller can implement both push and pull reaming to minimize IR potential at this HDDs southeast end to lower IR potential; and

- During all drilling phases, the use of Loss Control Materials (LCMs) will be implemented upon detection of a LOC or indications of a potential IR are noted or an IR is observed. The use of LCMs, however, is less effective 70 ft-bgs. Accordingly, the preferred corrective action needed to address the presence of fractures or LOC at greater depths below ground will require grouting of the HDD annulus. Two types of grouting may be utilized for corrective actions to seal fractures. These are: 1) grouting using “neat cement”; and 2) grouting using a sand/cement mix. Neat cement grout is a slurry of Portland cement and water which is highly reactive to bentonite and induces solidification. The sand/cement grout mix is a slurry of mostly sand with a small percentage of Portland cement and activators that result in a material having the competency of a friable sandstone or mortar, after setup. Both grouting actions require tripping out the drilling tool, and then tripping in with an open-ended drill stem to apply or inject the grout mixes. Either of these grouting actions may be implemented upon the first detection of an LOC, with the selection of the treatment based upon the circumstances of the LOC, being small or large in magnitude. The monitoring PGs and Drilling Specialists will assess the LOCs and make a determination as to which LOCS will require remediation and the method employed.

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FEASIBILITY DETERMINATION

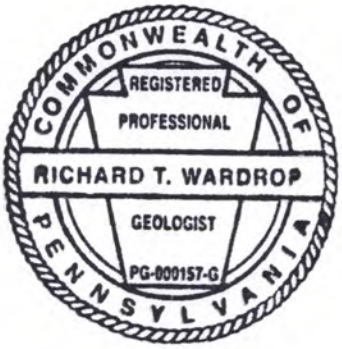
Based on the information reviewed by the Geotechnical Evaluation Leader, Professional Geologists, Professional Engineers, and HDD specialists, the HDD Reevaluation Team's opinion is that the proposed HDD design and implementation of the management measures contained within this re-evaluation report will minimize the risk of IRs

Pertaining to Horizontal Directional Drilling Practices and Procedures; Conventional Construction Alternatives; and Environmental Effects

10/10/2019
Date:

Larry J. Gremminger, CWB
Vice President – Environmental
Geotechnical Evaluation Leader
Mariner East 2 Pipeline Project

Pertaining to the practice of geology



10/10/19
Date:

Richard T. Wardrop, P.G.
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Lead Hydrogeologist

Pertaining to the pipeline stress and HDD geometry

10/10/19
Date:

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ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

HDD HYDROGEOLOGIC REEVALUATION REPORT

Mariner East II
Spread 6
S3-0560
Slitting Mill Road
Edgmont and Thornbury Townships, Delaware County, Pennsylvania

Prepared for:

Sunoco Pipeline, L.P.

Prepared by:

Groundwater & Environmental Services, Inc.
440 Creamery Way, Suite 500
Exton, Pennsylvania 19341

October 2019

HDD HYDROGEOLOGIC REEVALUTION REPORT

Mariner East II
Spread 6
S3-0560
Slitting Mill Road
Edgmont and Thornbury Townships, Delaware County, Pennsylvania

October 2019

Prepared for:

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Prepared by:

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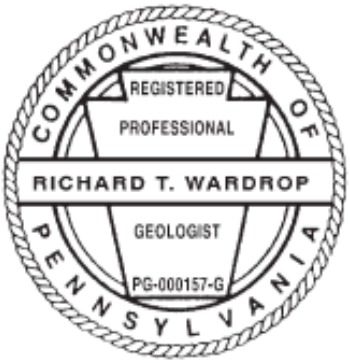
By affixing my seal to this document, I am certifying that the geologic and hydrogeologic information is true and correct. I further certify I am licensed to practice geology in the Commonwealth of Pennsylvania and that it is within my professional expertise to verify the correctness of the information.



Richard T. Wardrop, P. G.
License No. PG000157G

10/10/2019
date

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FIGURES

ATTACHMENTS

1.0 INTRODUCTION

Sunoco Pipeline, L.P., (SPLP) retained Groundwater & Environmental Services, Inc. (GES) to prepare HDD Hydrogeologic Reevaluation Reports (HRRs) for horizontal directional drills (HDDs) that meet Exhibit 3 criteria as per the Stipulated Order EHB Docket No. 2017-009-L signed August 10, 2017. These include pending second pipe HDD installations for which one or more inadvertent returns (IRs) occurred during installation of the first pipe. This report represents the HRR for the 20-inch line at HDD S3-0560. The 16-inch line was completed in December 2017 and experienced three upland IRs. The alignment for HDD S3-0560 is located between Middletown Road (State Route 0352) and Slitting Mill Road in Edgmont and Thornbury Townships, Delaware County, Pennsylvania. The discussion presented in this report is based on plan and profiles (P&Ps) developed by Tetra Tech/Rooney, revised on 9/30/2016 (permitted profile) and a proposed profile revised on 3/14/2019 (both provided in **Attachment A**). The proposed profile was developed to increase the depth of the borehole by slightly extending the east and west entry/exit points (total of approximately 87 feet), increasing the entrance angles and increasing the radii of curvature at the ends of the profile. The purpose for deepening the profile is to minimize the risk of IRs by advancing the pipes deeper into more competent bedrock. For the purpose of this assessment, GES utilized the permitted and proposed P&Ps, and the as-built profile for the 16-inch line to evaluate the hydrogeologic conditions at HDD S3-0560.

A map depicting the location of the HDD with topographic information for the surrounding area is presented as **Figure 1**.

Figure 1. Site Location Map (mod. from PaGEODE).

This report presents the following information:

- Geologic and hydrogeologic characteristics in the area of HDD S3-0560;
- Summaries of studies performed pertinent to reevaluation, including fracture trace analysis, geotechnical borings, and a geophysical survey;
- A site conceptual model; and
- A reevaluation summary with conclusions.

The content of this report was developed from interpretation of published information, field observations, IR reports and related field studies. Site geotechnical boring programs were conducted by Tetra Tech in July 2015 and by Terracon Consultants, Inc. (Terracon) in September 2017. Please note that GES did not oversee or direct either geotechnical drilling program, including, but not limited to, the selection of number and location of borings, determination of surface elevations, target depths, observations of rock cores during drilling operations, or preparation of boring logs; nor was GES involved in the planning and conducting of the geophysical surveys. GES relied on the reports of these studies and incorporated their data into the general geologic and hydrogeologic framework for this hydrogeologic reevaluation report.

As described in the Stipulated Order (pages 3 and 4), the HRRs will provide information to eliminate, reduce, or control the release or IR of HDD drilling fluids to the surface of the ground or impact to water supplies at the location during HDD operations. The HRRs are not intended to evaluate potential adverse effects of nearby man-made structures from HDD operations.

2.0 HDD GEOLOGY / HYDROGEOLOGY

2.1 Physiography

HDD S3-0560 is located within the Piedmont Upland Section of the Piedmont Physiographic Province of southeastern Pennsylvania, which consists of broad rounded to flat-topped hills and shallow valleys.

2.1.1 Topography

As shown on **Figure 1**, HDD S3-0560 is located on the southwest edge of a relatively flat hilltop that trends west to east. The surrounding area is comprised of residential and light industrial property uses.

The permitted profile for the 20-inch line is a concave bore on the northwestern and southeastern ends with a straight run along the lowest, central portion of the profile. The surface elevation at the northwest entry/exit is 433 feet above mean sea level (ft. amsl) and there is a very gradual decline in surface elevation to the southeastern entry/exit, which is at 422 ft. amsl. The overall horizontal distance covered for the permitted 20-inch profile is 1,378 feet.

The proposed profile for HDD S3-0560 is similar to the permitted profile. The northwestern entry/exit is located approximately 33 feet northwest of that position on the permitted profile and the southeastern entry/exit is located approximately 54 feet southeast of that position on the permitted profile; therefore, the proposed profile is 87 feet longer in horizontal distance. By increasing the entry/exit angles from 10 degrees to 15 and 16 degrees, and by increasing the radii of curvature on the two end segments from 2,000 feet to 2,400 feet, the lowest, middle, section of the drill is approximately 39 feet deeper than the permitted profile and 30 feet deeper than the as-built profile for the installed 16-inch line (see **Attachment A**).

2.1.2 Hydrology

HDD S3-0560 is located in the headwaters of Chester Creek. The nearest surface water body to HDD S3-0560 is an unnamed tributary to Chester Creek to the west. The unnamed tributary begins approximately 2,000 feet west of the northwest entry/exit and enters Chester Creek approximately 1.1 miles southwest of the alignment.

2.2 Geology

2.2.1 Soils

Based on information obtained from the National Resource Conservation Service Web Soil Survey database (NRCS WSS), soils along the path of HDD S3-0560 can range from 4 to 8.5 feet thick. Most of the alignment (approximately 80 percent) falls within the Glenelg channery loam on 3 to 8 percent slopes (GeB). GeB soils grade from loam and channery loam to a very channery loam for the 22 inches of soil above weathered gneissic bedrock and are well drained. Sections of the northwest end of the alignment (20 percent) fall within the Glenelg channery silt loam on 8 to 15 percent slopes (GeC). Similarly, GeC soils grade from channery silt loam to very channery loam with depth and are well drained.

2.2.2 Bedrock Lithology

Figure 2 is a map depicting bedrock geology for the area surrounding HDD S3-0560 (PaGEODE). All bedrock underlying the area of HDD S3-0560 is mapped as the pre-Cambrian age felsic and intermediate facies of the Baltimore Gneiss. The felsic and intermediate gneiss is described as light buff to light pink and fine to medium grained; with most mineral grains about 1 mm in diameter. The primary minerals are

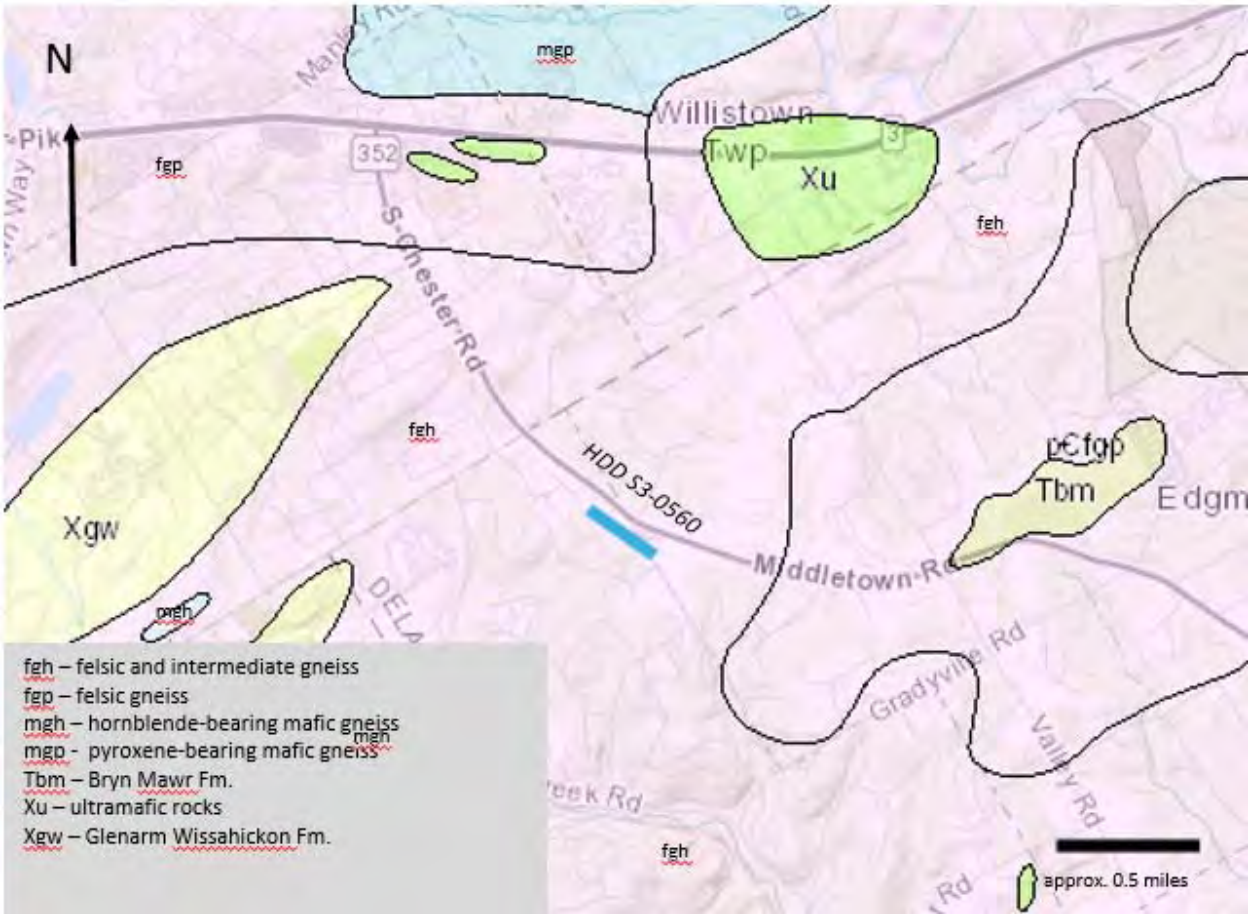

Figure 2. Site Geology Map (mod. from PaGEODE).

quartz, microcline, hornblende, and some biotite; and banding is poorly developed and massive.

Blackmer (2005) mapped the bedrock at HDD S3-0560 as the undifferentiated amphibolite facies gneiss unit of the Baltimore Gneiss and described the unit as a heterogeneous felsic, intermediate and mafic amphibolite facies gneiss. The predominant lithology is described as intermediate plagioclase-hornblende-quartz-biotite gneiss with local orthopyroxene, clinopyroxene, potassium feldspar, and garnet.

2.2.3 Structure

Structurally, the HDD S3-0560 drill path is located between the West Chester Massif to the north and the Avondale Anticline to the south. The Street Road Fault, a thrust fault, trends northeast through the region, dips south, and is located approximately 0.4 miles northwest of the northwest entry/exit (Blackmer, 2005).

Discontinuities in the form of joints and faults are imprinted in the broadly folded bedrock in the region. These forms of fracturing can act as conduits for groundwater movement and can represent areas of weakness in the rock.

2.2.4 Fracture Trace Analysis

Fracture trace analysis using high altitude aerial photography was performed for the area of interest to identify potential zones of bedrock weakness along drill paths. Fracture traces (one mile in length or less) and lineaments (greater than one mile in length) can be the surficial expressions on natural landscapes of vertical to near vertical zones of bedrock fracture concentration. Fracture trace analysis is partly subjective;

therefore, every mapped fracture trace does not necessarily represent a zone of bedrock fracture concentration.

The fracture trace map shown on **Figure 3** was prepared for this HRR. Traces intersecting the S3-0560 alignment are shown on the proposed P&P in **Attachment A,** as well. This mapping was performed using aerial stereographic pairs flown in the September 1937. At that time, much of the land surface appears undeveloped and therefore fracture traces are more easily seen. One west-east trending fracture trace intersects the northwest part of the alignment and a second east-southeast trending fracture trace runs proximal to the southeast entry/exit location.

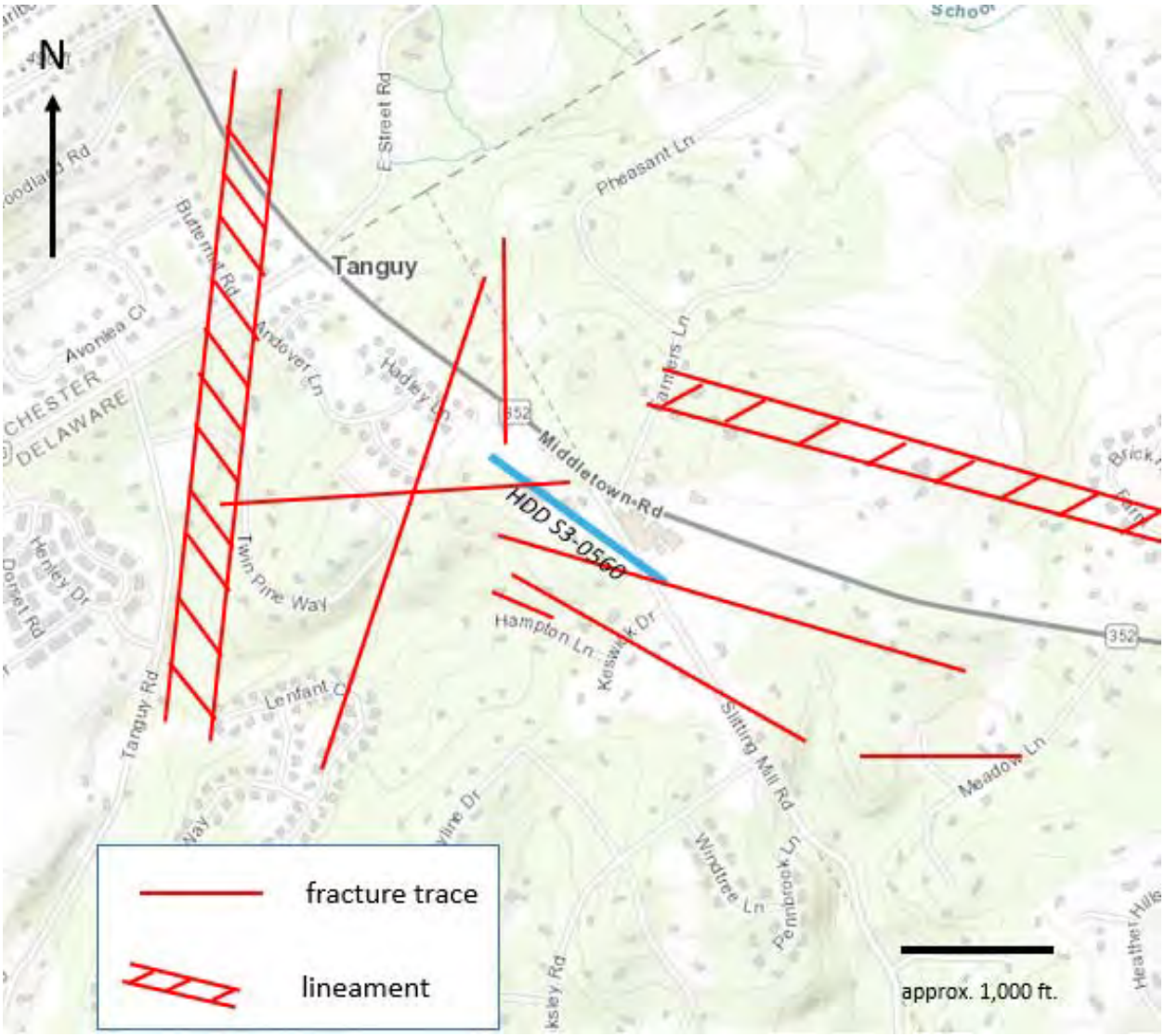

Figure 3. Fracture Trace Map (mod. from PaGEODE).

2.2.5 Karst

Based on published geologic data, no carbonate rock or karst features are anticipated in the area of HDD S3-0560.

2.2.6 Mining

Based on published geologic data, no mining has been completed within the area of HDD S3-0560. One of the largest quarries in the region is located due east of the town of Glen Mill, approximately two miles south-southeast of the HDD site. This crushed and broken aggregate quarry began operations in 1884 and is currently operated by Hanson Aggregates Pa, LLC. The quarry is 300 feet deep, well below the bed of nearby Chester Creek; however, seepage into the mine is minimal (Mindat.org).

2.2.7 Rock Engineering Properties

Geyer and Wilshusen (1982) refer to the felsic and intermediate gneiss as the undifferentiated amphibolite and granulite gneiss facies Baltimore Gneiss and describe the bedrocks engineering properties, as follow:

- Banding is poorly developed and massive.
- Generally, joints have an irregular pattern, moderately to poorly formed, moderately abundant, widely to moderately spaced, irregular and steeply dipping to vertical, open.
- Joints provide very low secondary porosity with low permeability.
- Median groundwater yield 20 gallons per minute (gpm) to >35 gpm.
- Highly resistant to weathering.
- Slow drilling rate.

2.2.8 Results of Geotechnical Borings

Two geotechnical borings, SB-01 and SB-02, were installed by Tetra Tech in July 2015 in support of the permitted HDD design. These borings were advanced to a depth of 30.0 ft bgs. Two additional, deeper, geotechnical borings, B6-15W and B6-15E, were installed by Terracon in September 2017 and were advanced to depths of 113 and 100 feet, respectively. The boring locations are shown on the P&Ps in **Attachment A** and the boring logs are provided in **Attachment B**.

Tetra Tech Borings

Boring SB-01 was located near the northwest entry/exit, 31 feet northeast of Station 0+37 on the permitted P&P with a surface elevation of approximately 431 ft amsl. Boring SB-02 was located near the southeast entry/exit, 58 feet northeast of Station 14+36 with a surface elevation of approximately 421 ft amsl.

Unconsolidated materials logged in SB-01 were comprised of 0.1 feet of topsoil underlain by 29 feet of fine micaceous sand with varying percentages of secondary silt. The materials logged in SB-02 included 0.3 feet of topsoil, underlain by up to approximately 7.5 feet of micaceous clay, turning to micaceous fine sand and silt to total depth. The unconsolidated materials in both borings were derived from highly weathered gneissic bedrock.

Groundwater was not detected in SB-01, but was measured at a level of 16.0 ft bgs in SB-02.

Terracon Borings

B6-15W

Boring B6-15W was advanced adjacent to the northwest entry/exit point. The surface elevation is listed on the log as approximately 434 ft amsl and the boring was installed to a depth of 113 feet or approximate elevation 321 ft. amsl. The lowest elevation for the proposed profile is 332 ft amsl. Unconsolidated overburden observed at B6-15W was comprised of weathered rock with gravel and clay (decreasing in gravel content with depth) before roller bit refusal occurred at 23 ft bgs and bedrock coring started at 25 ft

bgs. Bedrock cores for B6-15W contained gneiss characteristic of the Baltimore Gneiss. Core recovery percentage was generally high with a value of 100 percent from 33 to 108 ft bgs (see **Figure 4**). Lower core recoveries was recorded for the second core run (67 percent from 28 to 33 ft bgs) and for the deepest 5-foot run (53 percent from 108 to 113 ft bgs). Regarding Rock Quality Determinations (RQDs), values ranged from 6 to 100 percent. Higher RQD values occurred from 63 to 103 ft bgs, ranging from 86 to 100 percent, except for the run from 78 to 83 ft bgs at 72 percent. RQD for the last, deepest, 5-foot run was 53 percent. The approximate elevation of the deepest, horizontal part of the proposed profile occurs at the bottom of the high strength zone in the run from 98 to 103 ft bgs where RQD was 100 percent. The boring log for B6-15W indicated that groundwater was not encountered.

Geotechnical Core Log Summary
HDD S3-0560
Slitting Mill Road

Boring B6-15W

Depth (ft)	Recovery (%)	RQD (%)
25 - 28	89	13
28 - 33	67	6
33 - 38	100	25
38 - 43	100	27
43 - 48	100	30
48 -53	100	60
53 -58	100	52
58 -63	100	70
63 -68	100	92
68 -73	100	92
73 - 78	100	88
78 - 83	100	72
83 - 88	100	86
88 - 93	100	100
93 - 98	100	86
98 - 103	100	100
103-108	100	72
108-113	53	40

Boring B6-15E

Depth (ft)	Recovery (%)	RQD (%)
32-37	30	0
37-42	17	0
	Split Spoon Sampling	
50-55	90	0
55-60	95	16
60-65	100	36
65-70	100	78
70-75	95	36
75-80	100	86
80-85	100	86
85-90	100	100
90-95	100	72
95-100	100	100

Recovery	
<60%	
60-80%	
>80%	

RQD	
0-25% Very Poor	
26-50 Poor	
51-75 Fair	
76-90 Good	
>90% Excellent	

Figure 4. Recovery and RQD with Depth for Borings B6-15W and B6-15E

B6-15E
Boring B6-15E was advanced adjacent to the southeast entry/exit point. The surface elevation is listed on the log as approximately 421 ft amsl and the boring was installed to a depth of 100 feet or approximate elevation 321 ft. amsl. Unconsolidated overburden observed at B6-15E was comprised of silty clay and clay to 15 ft bgs and silty sand with gravel to a depth of 32 ft bgs before split spoon refusal and the start of coring. The initial ten feet of coring showed very low recoveries and no RQD in highly weathered gneissic material and the driller returned to split spoon sampling from 42 to 50 ft bgs. Bedrock coring began again at 50 ft bgs and continued to the total depth of 100 feet.

The bedrock cores contained gneiss characteristic of the Baltimore Gneiss. Recoveries from 50 to 100 ft bgs (total depth) ranged from 90 to 100 percent with most at 100 percent (see **Figure 4**). Regarding RQD values, very poor to poor RQD was logged from 32 to 75 ft bgs. RQD was good to excellent from 75 to 100 ft bgs except for the five foot run from 90 to 95 ft bgs for which the recorded RQD value was slightly lower at 72 percent. The elevation of the lowest, horizontal, section of the proposed profile occurs in the run between 85 and 90 ft bgs in the approximate middle of the higher RQD zone. The boring log for B6-15E also indicated that groundwater was not encountered.

2.3 Hydrogeology

In general, groundwater flow proximal to HDD S3-0560 moves along gradients established by a water table surface that is a subdued reflection of the local topography. The alignment of S3-0560 HDD passes northwest to southeast along the southwest edge of a relatively flat hilltop trending west to east. The headwaters of an unnamed tributary to Chester Creek originate southwest and downslope of the alignment (see **Figure 1**). In this setting it is anticipated that the area of HDD S3-0560 is a local groundwater recharge zone and the groundwater flow gradient is southwest toward the unnamed tributary of Chester Creek.

2.3.1 Occurrence of Groundwater

Groundwater in the metamorphic rocks of Delaware County is typically stored and moves within pore space in the saprolite comprised of highly weathered and fractured bedrock and a within open discontinuities of more competent bedrock at depth. This secondary porosity is created by fractures, bedding plane partings, and faults. Note groundwater was only detected in one of the four geotechnical borings (SB-02) near the southeast entry/exit, at a depth of approximately 16 feet, in unconsolidated materials. Given this is a groundwater recharge zone, the water table is expected to be deeper and the water level depth recorded for SB-02 was probably perched groundwater. One of the residential wells shown on **Figure 5** is located approximately 29 feet from the alignment and had a reported depth to water of greater than 100 ft bgs. No groundwater discharge was noted in any of the daily PG logs for the 16-inch installation at HDD S3-0560.

2.3.2 Water Level

A query of the Pennsylvania Groundwater Information System (PaGWIS) of domestic wells within one mile of the HDD S3-0560 alignment produced water level measurements for 41 wells ranging from 4 to 70 ft bgs with an average of 28 ft bgs. The wells were completed between 36 and 525 ft bgs and all were drilled within the Baltimore Gneiss.

Local water level measurements of private wells adjacent to the HDD S3-0560 bore path were recorded during ME II water source sampling events performed by GES. Of 19 private wells sampled, measurements could be taken in three wells and these ranged from 15 to greater than 100 ft bgs. Two of the wells were located over 250 feet from the alignment, off the topographic high to the south, and had water levels ranging from 15 to 40 ft bgs. The one well located close to the alignment (29 feet) had the reported depth to water of greater than 100 feet.

2.3.3 Ground Elevation between HDD entry/exits

The surface elevation at the southeast entry/exit on the permitted profile for the 20-inch line is 422 ft amsl and the elevation of the northwest exit/entry is 433 ft amsl. The permitted profile has a bottom elevation of approximately 371 ft amsl. The geometry of the proposed profile is similar except the bottom elevation is 332 ft amsl. Given the geometry of each profile and the information concerning groundwater levels, there is a very small risk of a groundwater discharge from completing the pilot bore.

2.3.4 Well Yields

Water supply well yields published in Geyer and Wilshusen (1982) is variable for the Baltimore Gneiss. The median yield is listed at 20 gpm; however, yields of more than 35 gpm may be obtained in properly sited and constructed wells. The aforementioned PaGWIS database search provided well yield information that was similar. The PaGWIS search produced well yields for 36 domestic wells, drilled into the Baltimore Gneiss and within a mile of HDD S3-0560, ranging from 2 to 100 gpm, and with an average yield of 20 gpm.

2.3.5 Local Water Supply Wells

SPLP has identified all landowners with property located within 450 ft of the HDD alignment. There are 31 individual landowners with properties located within 450 ft of the HDD alignment. SPLP sent each of these landowners a notice letter via both certified and first-class mail on October 30, 2017. To date, SPLP has received responses from all 31 individual landowners. Of these, 18 have confirmed the use of a private water source and the remaining landowner responses verified the use of public water supply, or that the parcel did not contain a water source. Twenty-two private water sources were identified on the 18 parcels with multiple water sources on a few parcels. All 22 of the private water sources (21 wells and 1 spring) have been located and tested (see **Figure 5**). Note 14 of the private water sources (13 wells and 1 spring) are located inside the 450-foot line and four of these locations are within 100 feet of the HDD alignment at approximate distances of 10, 29, 63 and 84 feet from the HDD alignment.

2.4 Summary of Geophysical Study

Tetra Tech performed a geophysical survey for the HDD S3-0560 alignment in January 2019. A detailed description of the work appears in **Attachment C**. Both seismic refraction and multichannel analysis of seismic waves (MASW) surveys were performed along six spreads coincident to the alignment. Data could not be collected between approximately Stations 6+70 to 7+30 (proposed P&P) because the HDD alignment crosses a driveway and a landscaped structure. Refraction data was unable to reach the elevation of the deeper portions of the proposed 20-inch HDD profile due to encountering bedrock at a higher elevation than the profile, but the mappable segments were included in the images. The MASW data extended to a depth that covered most of the proposed 20-inch profile, to within approximately 10 feet of the central, deepest portion of the profile. Due to the limits of geophysical survey methods, data could not be obtained to maximum profile depth; however, data was collected at depths associated with the descent of the profile to maximum depth after entry and at depths associated with ascent of the profile prior to exit. As such, the geophysical data is very useful for assessing variations in bedrock conditions along those sections of the profile where the IRs occurred during installation of the 16-inch line and where IRs would most likely occur along the proposed 20-inch profile.

Tetra Tech interpreted the survey data to identify “low velocity zones” and zones where the depth to bedrock was relatively deep. The overall conclusion of Tetra Tech’s report is that the geophysical survey data indicate a lack of significant fractures and faulting at HDD S3-0560. Top of relatively competent bedrock as indicated by both survey types ranged from approximately 14 to 51 ft bgs. The MASW survey

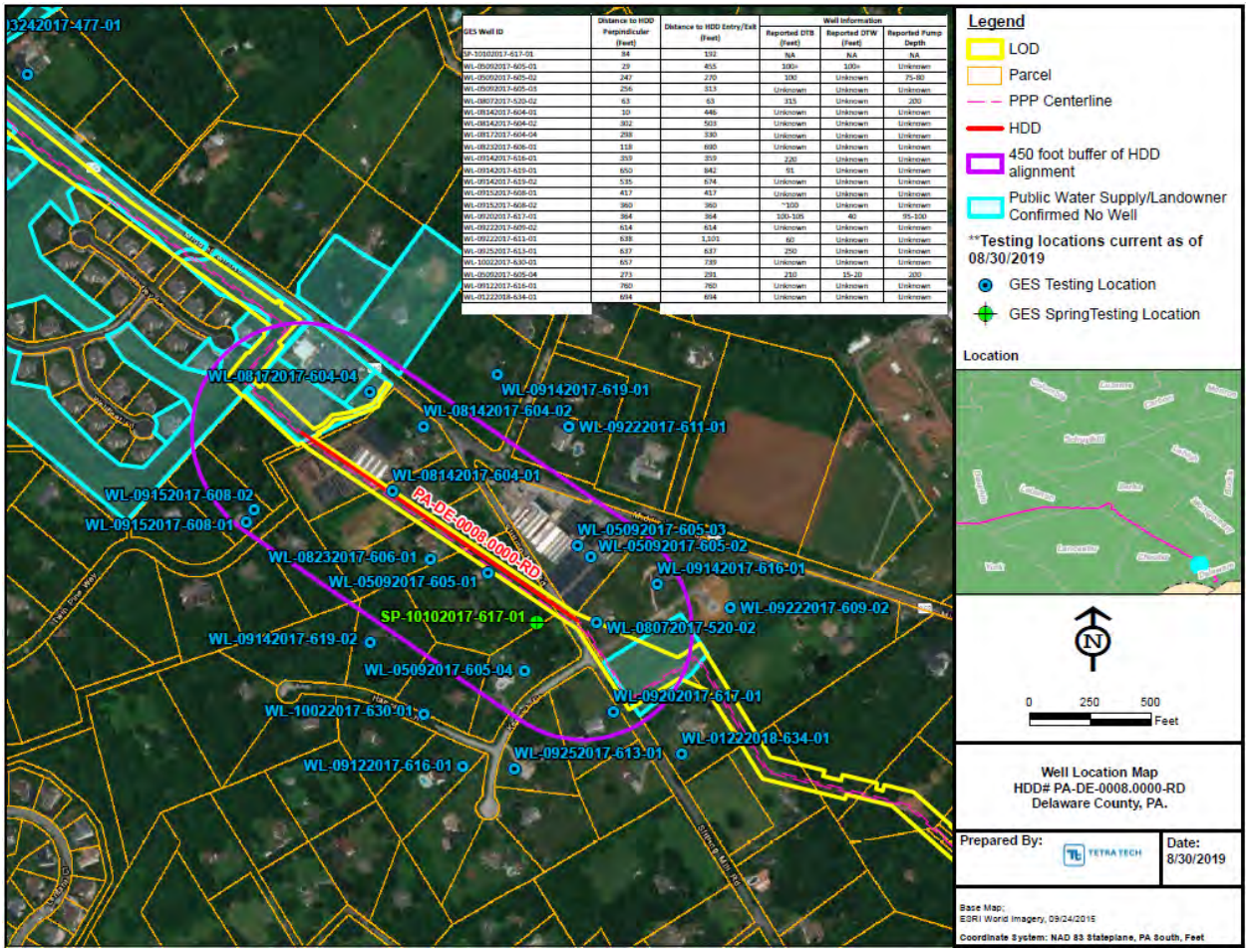

Figure 5. 450-foot Water Supply Survey Map.

identified low velocity zones indicating potential fracture or fault zones at approximately Stations 6+50 and 12+87. In general, these two locations do not directly correlate with the two mapped fracture traces that cross the alignment. One of the mapped fracture traces passes through the southeast entry/exit on the proposed P&P, approximately 180 feet southeast from the low velocity zone located at Station 12+87. Two of the three IRs that occurred during construction of the 16-inch line were due north of the alignment at Stations 12+63 and 13+02 where the overburden was relatively shallow at 39 and 33 feet, respectively. These two IRs are in the same general location as the low velocity zone identified at Station 12+87.

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3.0 OBSERVATIONS TO DATE

3.1 On This HDD Alignment

The pilot bore for HDD S3-0560 20-inch line spudded in on 10/2/2017. Drilling proceeded from the northwest entry/exit point to the southeast on a 1,475-foot HDD (horizontal distance). A loss of circulation (LOC) of approximately 500 gallons of drilling fluid occurred on 10/9/2017 when the drill bit was at station 9+53 with approximately 70 feet of overburden (see proposed P&P in **Attachment A**); however, no associated IR occurred. Drilling proceeded until 10/13/17 when a 50-gallon upland IR (IR No. 1) was found approximately 25 feet east of Slitting Mill Road near Station 12+63 where there was approximately 39 feet of overburden. At this point, the pilot bore was approximately 86 percent complete. After the IR and cleanup, drilling was suspended and a second rig was placed at the southeast entry/exit to drill an intercept pilot bore from southeast to northwest, a horizontal distance of approximately 215 feet to connect to the initial pilot bore.

The intercept spudded in on 10/17/17. By 10/25/17, the intercept bore had overlapped the primary pilot bore approximately 30 feet without connecting and a 15-gallon upland IR (IR No. 2) occurred while the drilling contractor was tripping tooling out of the bore. At that time, the intercept bore had been drilled approximately 245 feet northwest from the southeast entry/exit point. This IR also occurred on the east side of Slitting Mill Road near Station 13+02, approximately 39 feet southeast of the first IR. At this location, the overburden over the as-built profile for the 16-inch line (see proposed P&P in **Attachment A**) was 33 feet thick. After the second IR was cleaned up, drilling continued until 11/7/17 when hydraulic communication was established between the original pilot and the intercept bore. At that point, the intercept bore had been advanced to approximately Station 11+13 or 360 feet (horizontal distance) from entry.

The original pilot drill was advanced an approximate horizontal distance of 1,258 feet from northwest to southeast. Subsequently, the intercept bore was advanced approximately 360 feet from southeast to northwest. Due to alignment issues, both bores were abandoned and beginning on 11/7/17, a new continuous and complete pilot was drilled the full length of the planned HDD. By this time, SPLP had decided to complete the 16-inch line through the far southeast end of the project and the S3-0560 20-inch install was converted to a 16-inch install. On 11/20/17, the pilot exited at the southeast entry/exit and reaming was initiated (northwest to southeast). Reaming proceeded without incident until 12/12/17 when, during a 24-inch ream pass, a 150 to 200 gallon punch-out, upland IR (IR No. 3) occurred east of Slitting Mill Road between Slitting Mill Road and the southeast entry/exit pit near Station 14+35. This punch out IR was cleaned up and the last approximate 50 feet of reaming was completed by pushing and rotating the tooling to the southeast entry/exit without pumping drilling fluid. On 12/15/17, the 16-inch pipe was pulled into place.

Between IR-1 on 10/13/17 and IR-3 on 12/12/17 a few small upland IRs (0.5 to 4 gallons each) occurred in the same general area as IR-1, IR-2 and IR-3.

The three upland IRs that occurred on the east side of Slitting Mill Road were the result of shallow overburden comprised of highly weathered and fractured bedrock. IRs No. 1 and No. 3 occurred as the drilling bits were approaching exit at the southeast entry/exit. IR No. 2 occurred while tools were being tripped out of the intercept pilot bore and was probably the result of drilling fluid finding a preferred flow path in the overburden and road base of Slitting Mill Road established by IR No. 1. A pathway created by abandoning the initial pilot hole and pilot intercept may have contributed to IR-3.

3.2 On Other HDD Alignments in Similar Hydrogeologic Settings.

IRs have occurred during the drilling of other ME II HDDs in the metamorphic rocks of Chester and Delaware County. Factors that contributed to the cause of these IRs include an overburden comprised of thick, highly weathered and fractured, saprolite capping more competent bedrock, thinning of the overburden as the pilot drill rose along the profile towards exit, and an increase in annular pressure towards the end of pilot bores to maintain drilling fluid circulation back to the entry. In some cases, IRs occur into water resources where overburden thickness is reduced as the profile passes under a resource occupying a section of the alignment with the lowest surface elevation along the profile. Additionally, fracture traces and fracturing identified by geophysical surveys sometime correlate with the occurrence of IRs.

4.0 SUMMARY AND CONCLUSIONS

4.1 HDD Site Conceptual Model

HDD S3-0560 is located within the Piedmont Upland Section of the Piedmont Physiographic Province of southeastern Pennsylvania, which consists of broad rounded to flat top hills and shallow valleys. HDD S3-0560 is located in the headwaters of Chester Creek. The nearest surface water body to HDD S3-0560 is an unnamed tributary to Chester Creek that originates approximately 2,000 feet west of the northwest entry/exit and enters Chester Creek approximately 1.1 miles southwest of the alignment. The surrounding area characterized by residential and light industrial land use (see **Figure 1**).

The area surrounding HDD S3-0560 is relatively flat, in an upland, and represents a groundwater recharge zone where the water table is expected to be relatively deep compared to surrounding lowlands. Given local water level information and the geometry of the proposed profiles, there is a very low risk of a groundwater discharge created by completion of the pilot drill. The profile does not cross beneath any streams or wetland complexes.

The profile for HDD S3-0560 occurs within the felsic and intermediate gneiss unit of the Baltimore Gneiss. Geotechnical boring logs indicate highly weathered and fractured bedrock occurs to a depth of approximately 58 to 65 feet before more competent, fractured bedrock occurs at depth. The central, deepest portion of the proposed profile run at elevation 332 ft amsl and is generally within a zone of good to excellent RQD bedrock as indicated on the logs for two geotechnical borings drilled near each of the entry/exit locations.

Fracture traces cross the proposed profile at approximately Stations 0+90 and at the southeast entry/exit, which may contribute to the fracturing and weathering of rock that occurs there. A geophysical survey of the HDD S3-0560 alignment (see **Attachment C**) concluded that top of relatively competent bedrock ranged from approximately 14 to 51 ft bgs across the profile. Low velocity zones indicating a potential fracture zone or fault were identified at approximately Stations 6+50 and 12+87. In general, these two locations do not correlate with the two fracture traces that cross the alignment. The three IRs that occurred during construction of the 16-inch line were due north of the alignment from Stations 12+63 and 13+02, in the same general location of the low velocity zone identified at Station 12+87.

The central deepest portion of the proposed profile for the 20-inch line is 39 feet deeper than the permitted profile and 30 feet deeper than the as-built 16-inch line profile. Using a deeper profile at this location reduces the risk LOCs and IRs by placing the profile into more competent bedrock and increasing the overburden thickness. However, upland IRs that occurred during installation of the 16-inch line occurred at the southeast end of the profile as the profile rose to meet land surface, where overburden ranged from 8 to 39 ft bgs. The three upland IRs that occurred during the installation of the 16-inch line were the result of shallow overburden comprised of highly weathered and fractured bedrock. IRs No. 1 and No. 3 occurred at the end of an initial pilot hole and during a 24-inch ream. Respectively, as weak overburden was thinning during ascent of the drill bit to the land surface, and annular pressures may have been increasing to maintain circulation back to the northwest entry/exit. IR No. 2 occurred during advance of an intercept bore from the southeast entry/exit to the northwest, and was probably the result of drilling fluid finding a preferred flow path that was established in the overburden and coarse road base of Slitting Mill Road, when IR No. 1 occurred. Assuming the proposed profile and a depth of highly weathered and fractured bedrock of 65 ft bgs, the first approximate 270 feet (horizontal distance) at the northwest end of the profile and the first approximate 285 feet at the southeast end of the profile will be within weaker overburden materials, similar to conditions associated with the IRs that occurred during installation of the 16-inch pipe.

The original pilot drill was advanced an approximate horizontal distance of 1,258 feet from northwest to southeast. Subsequently, an intercept drill was advanced approximately 360 feet from southeast to northwest. Although there was evidence of hydraulic connection, both bores were abandoned due to inability to intercept and a new continuous and complete pilot drill was eventually completed the full distance from northwest to southeast, which was reamed and used for installation of the 16-inch pipe. Although some borehole collapse is anticipated where overburden is 65 feet thick or less, sections of the abandoned pilot holes could remain open and become pathways for drilling fluid migration during installation of the 20-inch line. Where the proposed profile is within more competent bedrock (between stations 2+60 and 12+40, assuming 65 feet of weaker overburden) the separation between the abandoned pilot holes and the deepest part of the proposed profile should range from approximately 12 to 30 feet, decreasing the chances of an LOC. An LOC into a section of abandoned pilot hole within competent bedrock would be apparent to site workers and quickly addressed, reducing the risk of an IR. Therefore, the greatest risk of LOCs and IRs from the abandoned pilot holes would be those sections of proposed profile near entry and exit where overburden is weaker and thinner, but where subsurface materials have not collapsed to the extent of sealing the hole.

SPLP's 450-foot water supply survey identified 21 wells and 1 spring on properties within 450-feet of the HDD alignment and four of the water sources were within 100 feet of the alignment. Given regional and local water level data and the depth of the proposed profile it is likely that HDD S3-0560 will transect water-producing zones that supply these wells. Note however, no claims of a water supply impact were filed with DEP during installation of the 16-inch pipe.

4.2 Conclusions and Recommendations

As with many HDDs, the greatest risk of LOCs and IRs for the 20-inch installation at HDD S3-0560 will be at the ends of the drill where the profile rises to meet the surface and the overburden is thinning. The thickness of highly weathered and fractured bedrock at this site has been measured at approximately 65 feet, and could be deeper, based on information collected at other HDD sites in the metamorphic rocks of Chester and Delaware Counties. At this location, the risk at the ends of the drill is increased by potential communication between the 20-inch pilot hole and abandoned sections of 16-inch pilot hole. Separation of the bore holes and collapse of weaker materials into the abandoned pilot hole serves to reduce this risk. The risk of LOCs and IRs is increased at the exit end of the pilot hole when annular pressure is increasing in order to maintain circulation back to the drill rig and mud plant. Pre-drill planning between the drilling contractor and SPLP should address these conditions for HDD S3-560. Due to space requirements for pullback of the pipeline into the prepared hole, this HDD will be drilled from northwest to southeast. One means of controlling the factors contributing to IR risk would be to monitor the annular pressure, tool face pressure and rate of advancement. When the face pressure reduces and rate of advancement indicates leaving competent rock, the driller can reduce fluid pressures and flows while advancing the pilot tool to the exit point.

The HDD S3-0560 alignment does not cross any surface water resources and the IRs that occurred during installation of the 16-inch line were all upland IRS; therefore, there is a low risk of a water resource impact from implementation of the proposed P&P.

Although no water supply impacts occurred during installation of the 16-inch pipe, a few private water supplies are within 100 feet of the alignment and these supplies could be at risk during drilling for the 20-inch line. This risk should be managed by SPLP, as it has at other ME II HDD sites, by offering pre-, during, and post-installation water quality sampling, and temporary water supplies for owners of private supplies within 450 feet of the HDD S3-0560 alignment.

Based on information provided by, and the expertise of, the HDD team, as well as our experience with the relevant hydrogeology and geology, GES believes that implementation of the profile on the proposed P&P for the 20-inch line at S3-0560 and best management practices inherent to the ME II construction project, including station specific references to areas of concern identified in this HRR, will minimize the risk of IRs and LOCs, and minimize the likelihood of an impact to the environment. Furthermore, based on such information, expertise and experience, GES believes that implementation of the profile on the proposed P&P for S3-0560 (20-inch line), in conjunction with the SPLP's temporary water supply offer to private well owners within 450 feet of the HDD alignment, will minimize the risk of any impact to an active private water supply. In the event of an impact to a private water supply, SPLP will implement the procedures of the IR PPC Plan.

5.0 REFERENCES

Geyer, A. R. and J. P. Wilshusen, (rev. 1982) *Engineering Characteristics of the Rocks of Pennsylvania.* PaDER, ORM, Pa Geol. Surv., 4th ser., EGR-1.

Blackmer, G. C., (2005) Preliminary Bedrock Geologic Map of a Portion of the Wilmington 30- by 60-Minute Quadrangle, Southeastern Pennsylvania, Open-File Report OFBM-05-01.0, Pa. Geol. Surv., 4th Ser.

PaGEODE, Pennsylvania Department of Conservation and Natural Resources, http://www.gis.dcnr.state.pa.us/geology/ .

PAGWIS, Pennsylvania Groundwater Information System, https://www.dcnr.pa.gov/Conservation/Water/Groundwater/PAGroundwaterInformationSystem/Pages/default.aspx .

NRCS-WSS, United States Department of Agriculture, Natural Resources Conservation Service – Web Soil Survey, https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx .

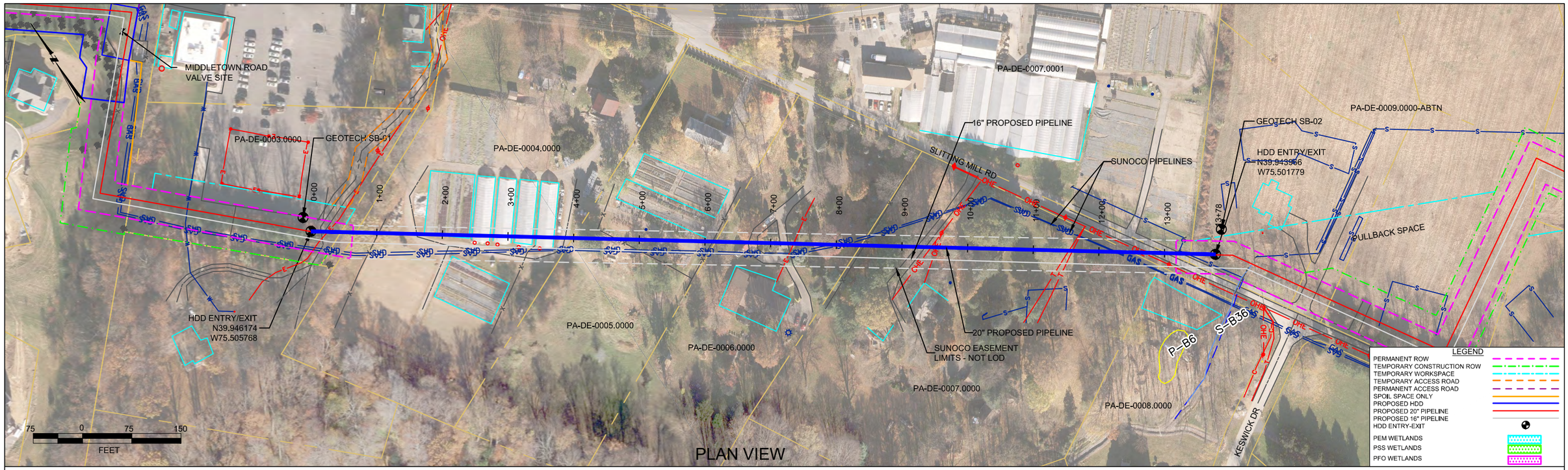
mindat.org, Primary outreach project of the Hudson Institute of Mineralogy, "world's leading authority on minerals and their localities, deposits, and mines", https://www.mindat.org/loc-105649.html .

Attachment A

Plan and Profiles

Permitted HDD S3-0560 Plan and Profile (rev. 9/30/16)

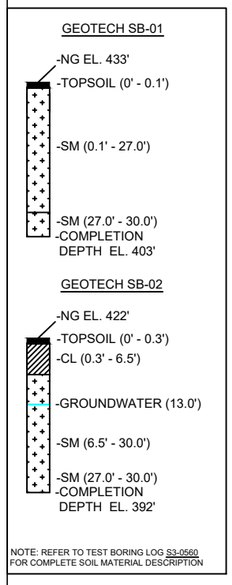
Proposed HDD S3-0560 Plan and Profile (rev. 3/14/19), showing IRs and geology



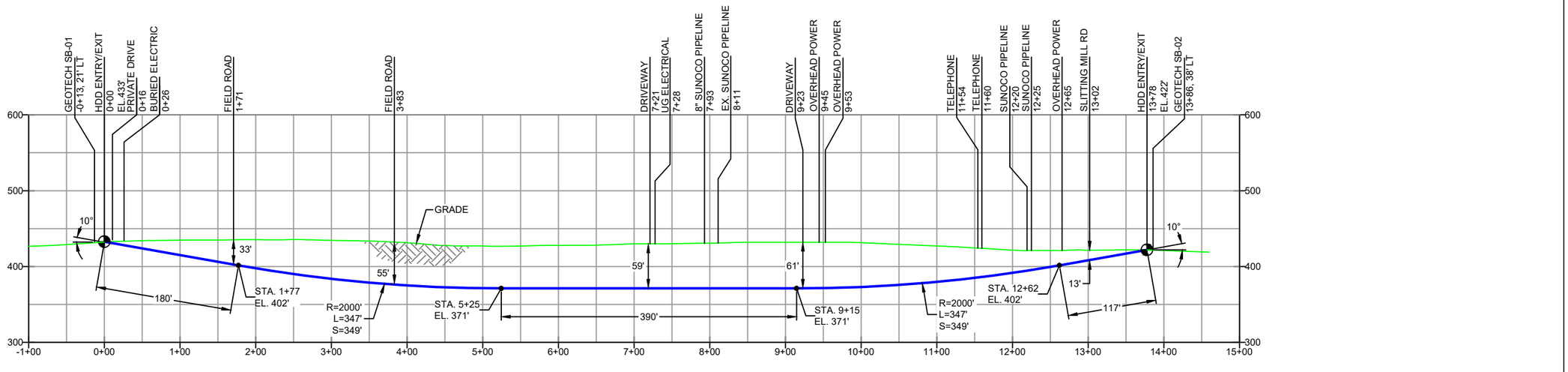
PLAN VIEW

PROFILE VIEW

DELAWARE COUNTY, PA - EDGMONT AND THORNBURY TOWNSHIPS
S3-560



NOTE: REFER TO TEST BORING LOG S3-0560
FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING 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=):1378'
   HDD PIPE LENGTH (S=):1385'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
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.

REF. DRAWING

ES-6.02	TO	ES-6.03	EROSION & SEDIMENT PLAN	
SHEET 1	TO	SHEET 2	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
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	05/20/16	RMB	05/20/16	AAW	05/20/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ISSUED FOR BID/DESIGN CHANGE	DLM	08/21/15	RMB	08/21/15	AAW	08/21/15
B	ISSUED FOR BID	DLM	07/31/15	RMB	07/31/15	AAW	07/31/15
A	ISSUED FOR REVIEW	KB	03/30/15	RMB	03/30/15	AWW	03/30/15

Sunoco Logistics Partners L.P.

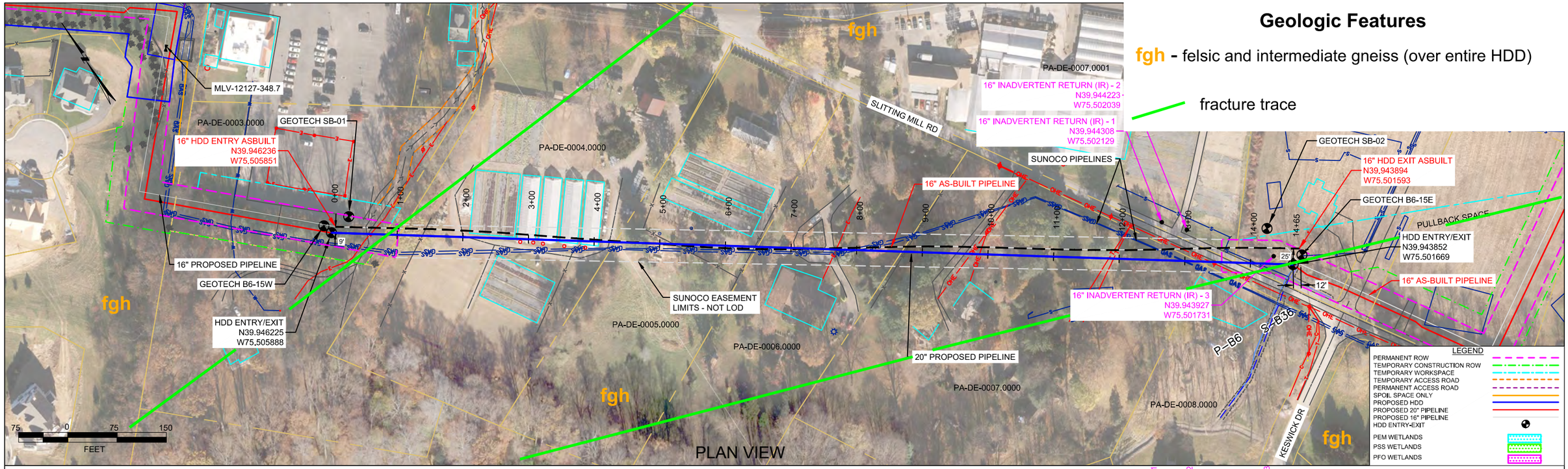
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

20-INCH HORIZONTAL DIRECTIONAL DRILL
SLITTING MILL RD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'

DWG. NO: PA-DE-0008.0000-RD



PLAN VIEW

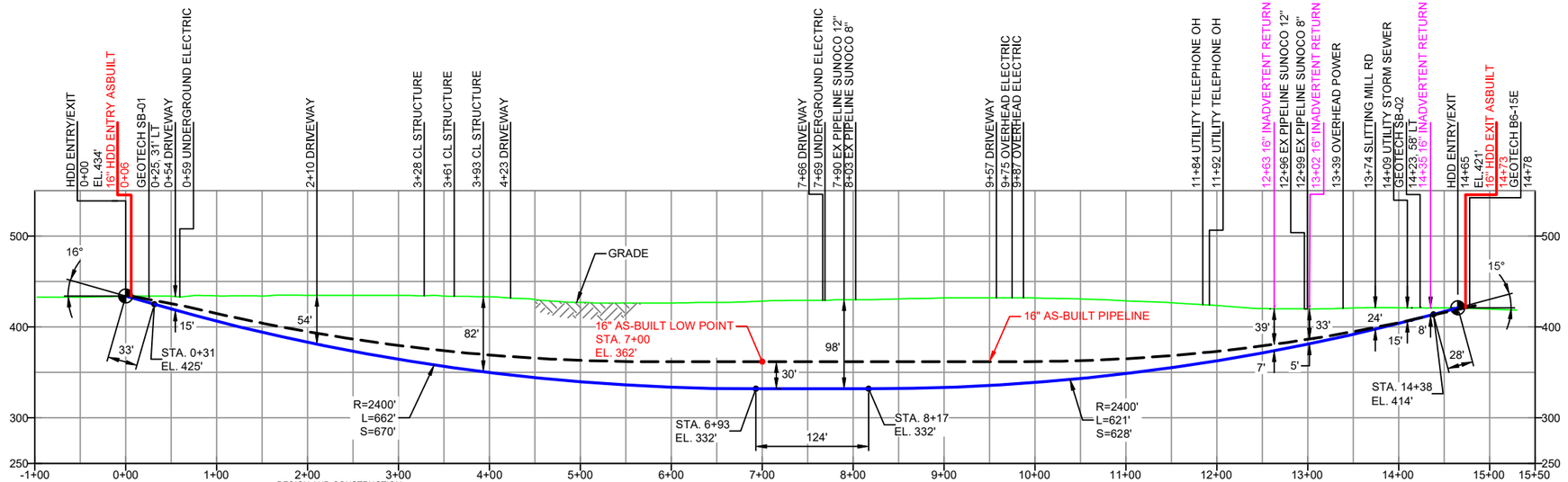
Geologic Features

fgh - felsic and intermediate gneiss (over entire HDD)

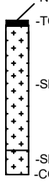
fracture trace

PROFILE VIEW

DELAWARE COUNTY, PA - EDGMONT AND THORNBURY TOWNSHIPS
S3-0560



GEOTECH SB-01



GEOTECH SB-02

NOTE: REFER TO TEST BORING LOG S3-0560 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B6-15W

NOTE: REFER TO TEST BORING LOG B6-15W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B6-15E

NOTE: REFER TO TEST BORING LOG B6-15E TERRACON 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=): 1465'
   HDD PIPE LENGTH (S=): 1483'
   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.

NOTES

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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

ES-6.02	TO	ES-6.03	EROSION & SEDIMENT PLAN
SHEET 1	TO	SHEET 2	AERIAL SITE PLAN

DWG NO		DWG NO	DESCRIPTION

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	SWITCHED 20" CENTERLINE LOCATION, INCREASED DEPTH OF DRILL AND ADDED GEOTECH INFORMATION	MRS	03/14/19	RMB	03/14/19	AMC	03/14/19
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	05/20/16	RMB	05/20/16	AAW	05/20/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ISSUED FOR BID/DESIGN CHANGE	DLM	08/21/15	RMB	08/21/15	AAW	08/21/15
B	ISSUED FOR BID	DLM	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
SLITTING MILL RD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'

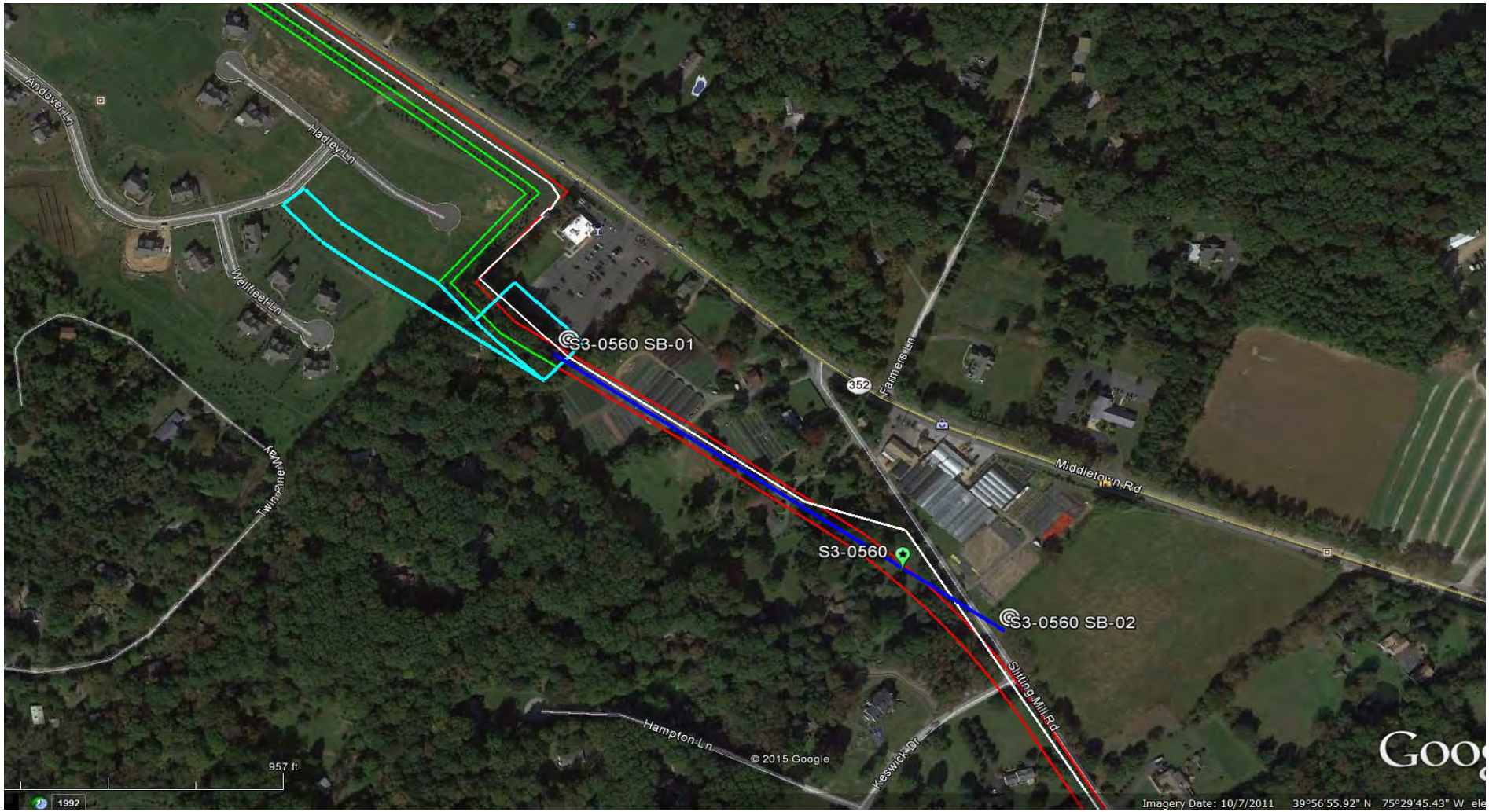
DWG. NO: PA-DE-0008.0000-RD

Attachment B

Geotechnical Boring Reports

Tetra Tech, July 2015

Terracon, September 2017



LEGEND:

Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S3-0461
DELAWARE COUNTY, THORNBURY/EDGMONT TWPS, 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:	192 MIDDLETOWN ROAD, DUFFERS TAVERN, GLEN MILLS, PA		Page 1 of 1
HDD No.:	S3-0560	Dates(s) Drilled: 07-07-15	Inspector: E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 30.0
Boring Location Coordinates:		39° 56' 46.464" N	75° 30' 20.742" 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	0.1			TOPSOIL (NONE, GRAVEL SURFACE)					
1	3.0	5.0	0.1		21		DR, VARIEGATED BROWN, ORANGE BROWN AND LIGHT BROWN	2	7	4	6	**11**
							MICACEOUS F-M SAND, SOME SILT, TRACE FINE ROCK FRAGS.					
2	8.0	10.0			24		DR, VARIEGATED BROWN,ORANGE BROWN, WHITE FINE TO MEDIUM	3	13	8	11	**21**
							SAND, SOME SILT, TRACE FINE ROCK FRAGS.					
3	13.0	15.0			24		DR, VARIEGATED LIGHT GRAY, WHITE, LIGHT BROWN FINE TO MEDIUM	3	8	12	15	**20**
						SM	SAND, SOME SILT, TRACE FINE ROCK FRAGS.					
4	18.0	19.9			20		DR, VARIEGATED LIGHT BROWN AND GRAY FINE MICACEOUS SAND	2	5	5	8	**10**
							AND SILT (USCS: SM).					
5	23.0	25.0			19		DR, VARIEGATED LIGHT BROWN AND GRAY FINE MICACEOUS SAND	3	7	6	10	**13**
				27.0			WITH SOME SILT.					
6	28.0	28.5	27.0		5	SM	DR, LIGHT BROWN AND ORANGE BROWN FINE SAND AND SILT,	50/6"				**>50**
				30.0			A LITTLE MICACEOUS.					
							AUGERED TO 30'.					
							CAVED AND DRY AT 27.5'.					

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:	1861SLITLING MILL ROAD, GLEN MILLS, PA		Page 1 of 1
HDD No.:	S3-0560	Dates(s) Drilled: 07-07-15	Inspector: E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 13.0	Total Depth (ft): 30.0
Boring Location Coordinates:		39° 56' 38.540" N	75° 30' 6.033" 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	CL	MOTTLED BROWN AND GRAY MICACEOUS SILTY CLAY, TRACE	1	4	7	8	**11**
				6.5			FINE SAND. (USCS: CL).					
2	8.0	10.0	6.5		24		DR, VARIEGATED BROWN,LIGHT BROWN, ORANGE BROWN FINE SAND	1	1	2	3	**3**
							AND SILT, MICACEOUS.					
3	13.0	15.0			24		DR, VARIEGATED LIGHT BROWN AND GRAY FINE MICACEOUS SAND	1	4	5	7	**9**
							AND SILT, TRACE FINE ROCK FRAGS.					
4	18.0	19.9			24		DR, VARIEGATED BROWN, WHITE, ORANGE BROWN FINE TO MEDIUM	1	3	6	7	**9**
						SM	MICACEOUS SAND AND SILT. (USCS: SM).					
5	23.0	25.0			16		DR, ALTERNATING BANDS OF BROWN, GRAY AND ORANGE BROWN	1	1	2	6	**3**
							MICACEOUS FINE TO MEDIUM SAND AND SILT.					
6	28.0	28.5			18		DR, ALTERNATING BANDS OF BROWN, GRAY, ORANGE BROWN AND	2	3	6	9	**9**
				30.0			WHITE MICACEOUS FINE TO MEDIUM SAND AND SILT.					
							WET ON SPOON AT 13'.					
							WATER LEVEL THROUGH AUGERS AT 16'.					
							CAVED AT 13', WET.					

Notes/Comments:

Pocket Pentrometer Testing
5': 3.0 TSF

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.

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0560

HDD No.	Test Boring No.	Sample No.	Depth of Sample (ft.)		Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318)			USCS Classif. (ASTM D2487)
			From	To			Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	
S3-0560	SB-01	2	8.0	10.0	11.1	24.5	-	-	-	-
		3	13.0	15.0	11.1	29.9	-	-	-	-
		4	18.0	19.9	16.1	42.8	30	24	6	SM
		5	23.0	25.0	15.1	33.5	-	-	-	-
		6	28.0	28.5	20.5	47.6	-	-	-	-
	SB-02	1	3.0	5.0	23.0	97.9	41	23	18	CL
		2	8.0	10.0	44.8	48.1	-	-	-	-
		3	13.0	15.0	28.5	44.1	-	-	-	-
		4	18.0	19.9	20.9	40.1	29	23	6	SM
		6	28.0	30.0	27.7	42.0	-	-	-	-

Notes:

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

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0560

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
S3-0560		SB-01	Felsic gneiss - Light, medium grained; includes rocks of probable sedimentary origin.	Generally level, slighly dipping to the north	Felsic gneiss (Precambrian age)	Felsic gneiss; Secondary - paragneiss	Unknown	Widely ranging from 4 to 95 ft bgs, Avg. 47 ft bgs (.25 mile radius)	
		SB-02		Generally level					

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.

October 19, 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 6 – Slitting Mill Road
Commonwealth of Pennsylvania
Drawing #PA-DE-0007.0000-RD
PO #20170831-4
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 Slitting Mill Road (Drawing #PA-DE-0007.0000-RD) 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 B6-15W and B6-15E, visual classification and photography of the rock core samples, and laboratory testing of representative rock samples.

Test borings B6-15W and B6-15E were drilled between September 11 and 14, 2017 to depths of 113 and 100 feet, respectively, as shown on the attached **Test Boring Location Plan**. Bedrock typically consisted of metamorphic rock comprised of gneiss. 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. As an exception to the planned 20-foot intervals, rock samples from B6-15W near 23 feet, as well as from B6-15E near 32, 40 and 50 feet, were not tested due to highly fractured or weathered conditions. 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

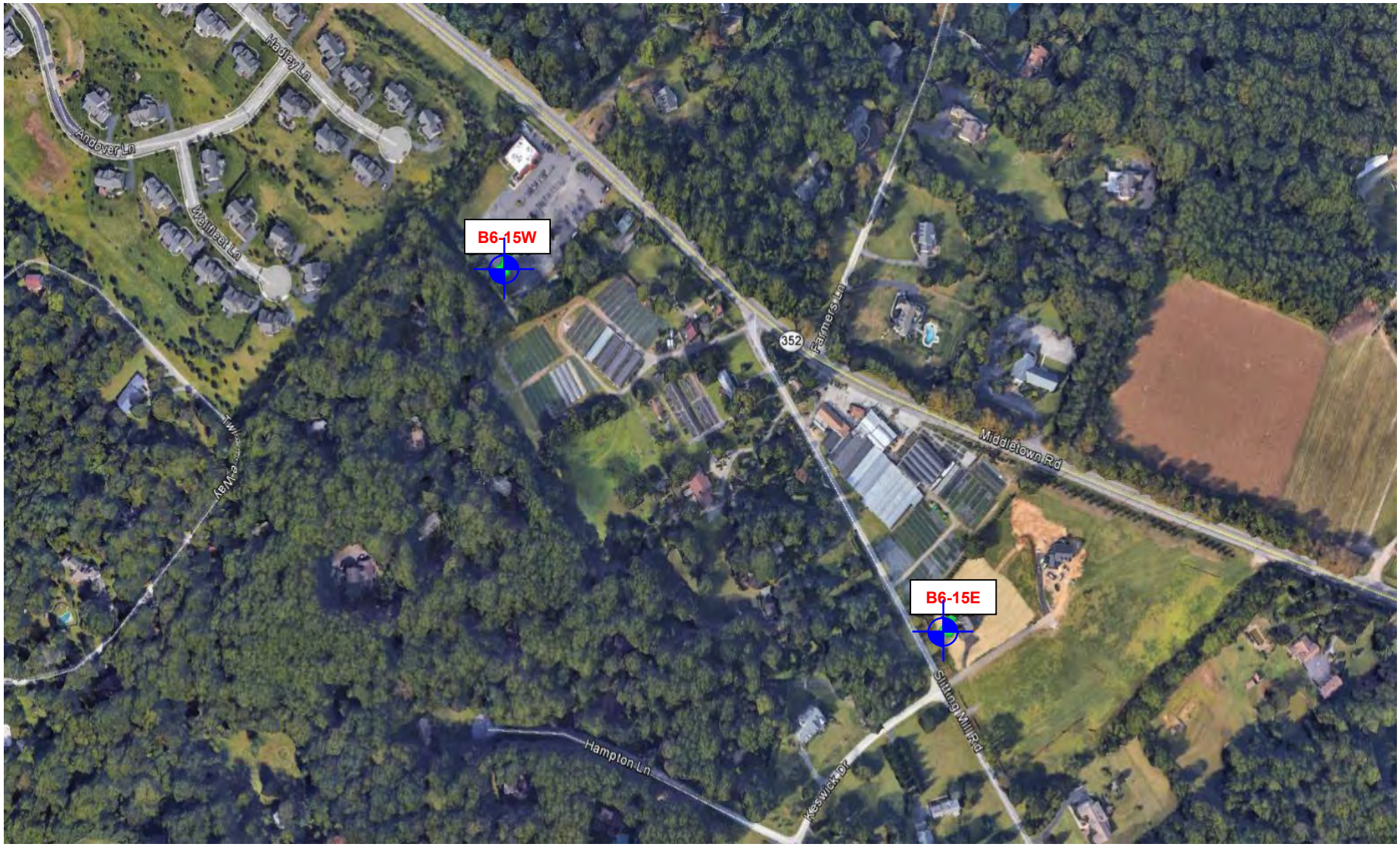
Lawrence J. Dwyer, P.E. (CT 15120)
Principal

Erich Christiansen, P.E. (NJ 42266)
Senior Associate

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

Slitting Mill Road HDD Core B6-15W and B6-15E
PA-DE-0007.0000-RD
Delaware County, Pennsylvania

Exhibit
A-2

EXPLORATION RESULTS

BORING LOG NO. B6-15W Slitting Mill Rd West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-DE-0007.0000-RD
20170831-4
Latitude: 39.946267° Longitude: -75.505901°
Approximate Surface Elev: 434 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)
FILL - , Asphalt, topsoil, weathered rock, reddish brown							
1.5	432.5+/-			9	10-15-21 N=36		
Weathered rock with gravel and clay, reddish brown, medium dense		5		11	6-9-11 N=20		
Completely weathered rock, with clay, reddish brown to brown, medium dense		10		14	11-12-11 N=23		
Weathered rock with clayey gravel, reddish brown, medium dense		15		13	6-8-17 N=25		
Weathered rock with clay, reddish brown, very dense		20		14	31-39-33 N=72		
Roller bit refusal at 23 feet, begin rock core at 25 feet							
25.0	409+/-	25					
Run 1, Hard, highly to completely weathered, yellowish gray to brown, fine-grained, GNEISS, very thin bedding, primary joints set, horizontal to low angle, very close to close spacing, rough, discolored to decomposed				32		13	1 1 2 2 1
28.0	406+/-						
Run 2, Similar, low angle to moderately dipping		30		40			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

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-11-2017 | Boring Completed: 09-12-2017

Drill Rig: Mobile B-57 | Driller: Terracon/S. Bray

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-15W Slitting Mill Rd West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-DE-0007.0000-RD
20170831-4
Latitude: 39.946267° Longitude: -75.505901°
Approximate Surface Elev: 434 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
		Run 2, Similar, low angle to moderately dipping *(continued)*				40		6	1 3 3 2	
33.0	401+/-									
		Run 3, Hard, moderately to slightly weathered, dark gray with white, fine-grained, GNEISS, moderately dipping, very close to close spacing, rough, discolored	35			60		25	5 4 6 7 7	
38.0	396+/-									
		Run 4, Similar, frequent quartz bands	40			60		27	5 6 6 3 5	
43.0	391+/-									
		Run 5, Hard, slightly weathered, dark gray, fine-grained, GNEISS, very thin bedding, primary joint set, horizontal to low angle, close spacing, rough, discolored to fresh	45			60		30	3 3 3 4 3	
48.0	386+/-									
		Run 6, Similar	50			60		60	5 3 4 4 4	
53.0	381+/-									
		Run 7, Similar, fine to medium-grained Quartz intrusion from 53.7 to 54.6 feet	55			60		52	2 2 2 2 2	
58.0	376+/-									
		Run 8, Similar, fine-grained, moderately close spacing	60			60			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

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-11-2017 | Boring Completed: 09-12-2017

Drill Rig: Mobile B-57 | Driller: Terracon/S. Bray

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-15W Slitting Mill Rd West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-DE-0007.0000-RD
20170831-4
Latitude: 39.946267° Longitude: -75.505901°
Approximate Surface Elev: 434 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
Run 8, Similar, fine-grained, moderately close spacing *(continued)*					
63.0	371+/-		60	70	2 3 3 3
Run 9, Similar, horizontal to moderately dipping		65			
68.0	366+/-		60	92	2 2 2 3 3
Run 10, Similar, moderately dipping, moderately close to wide spacing, increased number of quartz bands		70			
73.0	361+/-		60	92	3 4 2 4 4
Run 11, Similar, moderately dipping to high angle, close to moderately close spacing		75			
78.0	356+/-		60	88	5 7 6 8 8
Run 12, Similar, very hard		80			
83.0	351+/-		60	72	7 7 7 8 8
Run 13, Similar to 84.4 feet At 84.4 feet: Very hard, fresh, dark gray, aphanitic to fine-grained GNEISS, no visible foliation, primary joint set, moderately dipping, close to moderately close spacing, rough, fresh		85			
88.0	346+/-		60	86	12 12 10 9 9
Run 14, Similar, close to wide spacing		90			
			60		9

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

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-11-2017 | Boring Completed: 09-12-2017
Drill Rig: Mobile B-57 | Driller: Terracon/S. Bray
Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-15W Slitting Mill Rd West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-DE-0007.0000-RD
20170831-4
Latitude: 39.946267° Longitude: -75.505901°

Approximate Surface Elev: 434 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
Run 14, Similar, close to wide spacing *(continued)*					
93.0	341+/-		60	100	9 10 10 10
Run 15, Similar, horizontal to low angle, close to moderately close spacing		95			
98.0	336+/-		60	86	5 5 5 5 5
Run 16, Similar, moderately close spacing		100			
103.0	331+/-		60	100	7 6 6 7 7
Run 17, Similar, moderately dipping, close to moderately close spacing, increased number of quartz bands below 105 feet		105			
108.0	326+/-		60	72	6 6 6 6 6
Run 18, Similar, very close to close spacing Weathered at 111 feet followed by possible void		110			
113.0	321+/-		32	40	3 3 2 1 NR
Boring Terminated at 113 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

Notes:
NR - Not recorded

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-11-2017 | Boring Completed: 09-12-2017

Drill Rig: Mobile B-57 | Driller: Terracon/S. Bray

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-15E Slitting Mill Rd East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-DE-0007.0000-RD
20170831-4
Latitude: 39.943865° Longitude: -75.5016°
Approximate Surface Elev: 421 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS
		SILTY CLAY (CL-ML), with roots, reddish brown, stiff			11	4-5-6 N=11
		Similar, with weathered rock	5		12	3-3-4 N=7
10.0	411+/-	**SILT (ML)**, with gravel, reddish brown, very loose	10		14	1-1-2 N=3
15.0	406+/-	**SILTY SAND WITH GRAVEL (SM)**, reddish brown, loose to very dense	15		15	1-3-4 N=7
		Similar, visible bedding	20		18	3-3-4 N=7
			25		13	3-7-5 N=12
			30			

GRAPHIC LOG | WATER LEVEL OBSERVATIONS | RQD (%) | Core rate (min/ft) | Penetrometer Test (tsf)

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

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-13-2017 | Boring Completed: 09-14-2017

Drill Rig: CME-850X | Driller: Terracon/S. Bray

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-15E Slitting Mill Rd East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-DE-0007.0000-RD
20170831-4
Latitude: 39.943865° Longitude: -75.5016°
Approximate Surface Elev: 421 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
SILTY SAND WITH GRAVEL (SM), reddish brown, loose to very dense *(continued)* Similar, with weathered rock					15	13-22-50/5"			
32.0	389+/-								
Run 1, Cored through boulder, highly weathered rock		35			18		NR	2 2 2 2 3	
37.0	384+/-								
Run 2, Similar		40			10		NR	NR	
42.0	379+/-								
Similar, dense		45			11	13-14-18 N=32			
50.0	371+/-	50			3	50/3"			
Run 3, Soft, highly weathered, dark greenish gray to reddish brown, fine to medium-grained, GNEISS, primary joint set, low angle, very close to close, rough, decomposed to discolored, slightly open to wide 1.5-inch quartz vein at 52 feet					54		0	2 3 3 3 2	
55.0	366+/-	55							
Run 4, Similar to 58 feet, highly to completely weathered At 58 feet: Hard, moderately weathered, gray to white, fine to medium-grained, GNEISS, moderately dipping foliation, primary joint set, low angle to moderately dipping, very close to close spacing, rough discolored, moderately open to open					57		16	3 3 3 3 4	
60.0	361+/-	60							

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

Notes:
NR - Not Recorded

WATER LEVEL OBSERVATIONS
Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-13-2017 | Boring Completed: 09-14-2017
Drill Rig: CME-850X | Driller: Terracon/S. Bray
Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-15E Slitting Mill Rd East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-DE-0007.0000-RD
20170831-4
Latitude: 39.943865° Longitude: -75.5016°
Approximate Surface Elev: 421 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
		Run 5, SImilar, slightly to moderately weathered, light gray to yellowish gray More weathered, brown from 63.4 to 64.8 feet				60		36	2 3 3 3 4	
65.0	356+/-		65							
		Run 6, Very hard, fresh to slightly weathered, dark gray, GNEISS, primary joint set, horizontal to low angle, close to wide spacing, rough, fresh to discolored, tight to moderately open				60		78	3 3 3 3 3	
70.0	351+/-		70							
		Run 7, Similar, slightly weathered, dark gray to light gray, primary joint set along foliation, low angle to moderately dipping, very close to close spacing				57		36	2 3 3 3 2	
75.0	346+/-		75							
		Run 8, Hard to very hard, fresh to slightly weathered, dark gray, aphanitic to fine-grained GNEISS with quartz intrusions, primary joint set along foliation, low angle to moderately dipping, close spacing, rough, fresh to discolored, tight to moderately open White to yellow quartz intrusion from 76.5 to 77.8 feet White quartz intrusion from 78.3 to 78.8 feet				60		86	5 5 7 7 0	
80.0	341+/-		80							
		Run 9, Similar, less quartz intrusions, close to moderately close spacing				60		86	5 5 5 5 5	
85.0	336+/-		85							
		Run 10, Similar, wide spacing				60		100	6 7 7 7 7	
90.0	331+/-		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

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-13-2017 | Boring Completed: 09-14-2017

Drill Rig: CME-850X | Driller: Terracon/S. Bray

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-15E Slitting Mill Rd East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-DE-0007.0000-RD
20170831-4
Latitude: 39.943865° Longitude: -75.5016°

Approximate Surface Elev: 421 (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 11, Similar, close to moderately close spacing									
					60		72	7 6 7 7 6	
95.0	326+/-	95							
Run 12, Similar, moderately close spacing									
					60		100	6 6 6 6 6	
100.0	321+/-	100							
Boring Terminated at 100 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

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-13-2017 | Boring Completed: 09-14-2017

Drill Rig: CME-850X | Driller: Terracon/S. Bray

Project No.: J217P078 | Exhibit: A-2

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

Boring No.:	B6-15W	Lithology :	Gneiss
Sample No.:	1	Moisture Content :	As received
Sample Depth:	48 feet	Lab Temperature :	70° F
Sampling Date:	9/11/17	Loading Rate:	55 psi/s
		Time to Failure:	20 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	67,610 lb
Length:	4.10 in	Compressive Strength:	21,958 psi
L/D:	2.07	Compressive Strength:	151.39 Mpa
End Area:	3.08 in^2	Unit Weight	183 pcf

Before the Test

After the Test

Drawing # :	PA-DE-0007.0000-RD
PO # :	20170831-4
Crossing :	Slitting Mill Road
Spread :	Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/12/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/18/2017

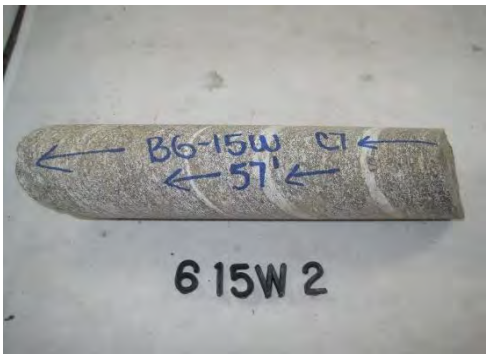
ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B6-15W	Lithology :	Gneiss
Sample No.:	2	Moisture Content :	As received
Sample Depth:	57 feet	Lab Temperature :	70° F
Sampling Date:	9/11/17	Loading Rate:	55 psi/s
		Time to Failure:	6 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	18,800 lb
Length:	4.75 in	Compressive Strength:	6,106 psi
L/D:	2.40	Compressive Strength:	42.10 Mpa
End Area:	3.08 in^2	Unit Weight	N/A pcf

Unit weight is not available

Before the Test



After the Test

Drawing # : PA-DE-0007.0000-RD
PO # : 20170831-4
Crossing : Slitting Mill Road
Spread : Spread 6

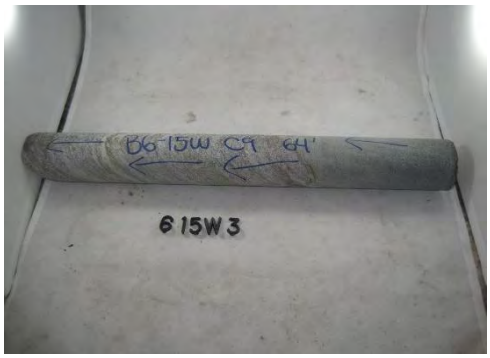
Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/12/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/18/2017

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

Boring No.:	B6-15W	Lithology :	Gneiss
Sample No.:	3	Moisture Content :	As received
Sample Depth:	64 feet	Lab Temperature :	70° F
Sampling Date:	9/11/17	Loading Rate:	55 psi/s
		Time to Failure:	9 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	29,290 lb
Length:	3.98 in	Compressive Strength:	9,513 psi
L/D:	2.01	Compressive Strength:	65.59 Mpa
End Area:	3.08 in^2	Unit Weight	210 pcf

Before the Test



After the Test

Drawing # :	PA-DE-0007.0000-RD
PO # :	20170831-4
Crossing :	Slitting Mill Road
Spread :	Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/12/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/18/2017

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

Boring No.:	B6-15W	Lithology :	Gneiss
Sample No.:	4	Moisture Content :	As received
Sample Depth:	73 feet	Lab Temperature :	70° F
Sampling Date:	9/11/17	Loading Rate:	55 psi/s
		Time to Failure:	10 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	33,220 lb
Length:	4.55 in	Compressive Strength:	10,789 psi
L/D:	2.30	Compressive Strength:	74.39 Mpa
End Area:	3.08 in^2	Unit Weight	170 pcf

Before the Test

After the Test

Drawing # :	PA-DE-0007.0000-RD
PO # :	20170831-4
Crossing :	Slitting Mill Road
Spread :	Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/12/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/18/2017

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

Boring No.:	B6-15E	Lithology :	Gneiss
Sample No.:	6	Moisture Content :	As received
Sample Depth:	66 feet	Lab Temperature :	70° F
Sampling Date:	9/13/17	Loading Rate:	55 psi/s
		Time to Failure:	13 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	43,650 lb
Length:	3.75 in	Compressive Strength:	14,176 psi
L/D:	1.89	Compressive Strength:	97.74 Mpa
End Area:	3.08 in^2	Unit Weight	189 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-DE-0007.0000-RD
PO # :	20170831-4
Crossing :	Slitting Mill Road
Spread :	Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	D. Savage
Project No.	J217P078		Test Date:	10/16/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/18/2017

Photograph 1: B6-15W, Samples C-1 to C-4 (23 to 43 feet)

Photograph 2: B6-15W, Samples C-5 to C-8 (43 to 63 feet)

Photograph 3: B6-15W, Samples C-9 to C-12 (63 to 83 feet)

Photograph 4: B6-15W, Samples C-13 to C-16 (83 to 103 feet)

Photograph 5: B6-15W, Samples C-17 to C-18 (103 to 113 feet)

Photograph 1: B6-15E, Samples C-1 to C-4 (32 to 60 feet)

Photograph 2: B6-15E, Samples C-5 to C-8 (60 to 80 feet)

Photograph 3: B6-15E, Samples C-9 to C-12 (80 to 100 feet)

Attachment C

Geophysical Survey Report

Tetra Tech - June 5, 2019

TETRA TECH

MEMO

To:	Mr. Larry Gremminger, Sunoco LLP
From:	Chris Sollenberger, PG
Date:	June 5, 2019
Subject:	Segment 3B, Horizontal Directional Drill S3-0560, Delaware/Chester County, Pennsylvania

Sunoco LLP contracted Tetra Tech to investigate the subsurface geology of the referenced segment location to acquire a refined profile for the top of bedrock, a better assessment of the bedrock competency, and locate potential fractures and faults which may intersect the Horizontal Directional Drill (HDD) Segment S3-0560 in Aston, Pennsylvania. A summary of these activities is provided below.

MAPPED GEOLOGY

HDD Segment S3-0560 is mapped in published literature as being underlain by the following geology (Dicken, et al, 2005):

The **Felsic and Intermediate Gneiss** is Precambrian-aged, light buff to light pink, and fine to medium grained. Most of the mineral grains are about 1 millimeter (mm) in diameter. Primary minerals are quartz, microcline, hornblende, and some biotite. Banding is poorly developed and massive. Its thickness is unknown (Geyer and Wilshusen, 1982). This formation is the predominant geologic unit in the work area. It is found to the north and the south of the alignment and contacts the Mafic gneiss and the Ultramafic Serpentinite rocks. Outcrops of the contacted formations are found to the east of the work area.

GEOPHYSICAL INVESTIGATION

Due to the known conditions on the above listed HDD alignment, two geophysical methods were used to provide optimal investigation data: Multichannel Analysis of Seismic Waves (MASW) Seismic and Seismic Refraction. Both techniques provide 2-dimensional information which provides the data refinement for the HDDs the client has requested. Both methods were used on all HDD alignments. Data collection was performed using 10 feet spacing between shot points and geophones. A brief description of the methods is provided below.

MASW Seismic

The MASW technique involves the generation and detection of surface waves, and the analysis of their frequencies and phase velocities to generate 2-dimensional, cross-sectional images of the shear wave velocity distribution with depth. The method involves the generation of compressional waves at the ground surface and the measurement of first-arrival signals that are related to near-surface materials and bedrock materials. Two-dimensional cross sections are generated that show the approximate depth to geologic horizons and their velocities.

Seismic Refraction

The seismic refraction method provides information regarding the seismic velocity structure of the subsurface. The method is based upon the generation and propagation of an elastic wave (compressional P-wave) into the subsurface. The P-wave propagates through the ground and is refracted along interfaces that mark an increase in

Tetra Tech, Inc.
240 Continental Drive, Suite 200, Newark, DE
Tel 302-738-7551 Fax 302-454-5988 tetratech.com

velocity. Part of the P-wave energy is refracted back to the ground surface and is subsequently monitored by a series of co-linear, vibration-sensitive devices called geophones that are placed at the ground surface. The resulting seismic waveforms are recorded on a seismograph and analyzed to determine the depth and velocities of subsurface seismic layers.

The physical properties of earth materials (fill, sediment, rock) such as compaction, density, hardness, and induration dictate the corresponding seismic velocity of the material. Additionally, other factors such as bedding, fracturing, weathering, and water saturation can also affect seismic velocity. In general, low velocities are typically indicative of loose soil, poorly compacted fill material, poorly to semi-consolidated sediments, deeply weathered, and highly fractured rock. Conversely, high velocities are indicative of competent rock or dense and highly compacted sediments and fill. The highest velocities are measured in un-weathered and un-fractured rock.

The quality of the field data is critical to the construction of an accurate depth and velocity profile. Strong, clear "first-break" information from refracted interfaces will make the data processing, analysis, and interpretation much more accurate and meaningful. Vibrational noise or poor subsurface conditions can decrease the ability to accurately locate and determine seismic waves from the interfaces.

There are two basic approaches to seismic refraction data analysis: layer-cake and tomographic inversion. The former is the more traditional approach; however, tomography has become more popular as faster computers have made it much more feasible than in the past.

SITE ACTIVITIES

Subsurface Environmental Technologies (SET) used a Geode 24 Channel seismograph to collect refraction data and surface wave data. For typical data collection spreads, 24 geophones are placed in a straight line every 10 linear feet, starting at 0 and up to 230 feet. An impact source (a sledge hammer hitting a strike plate) would strike a plastic plate at seven locations along the survey line to create seismic waves. The strike locations were located at distances of -50, 0, 55, 115, 185, 230, and 280 feet from the starting station of the survey spread. Once completed, the second survey line was laid out and overlapped the previous line by a minimum 50 feet to ensure adequate data collection between each survey spread. After that survey was completed, the collection of elevation data was required to process the seismic data. Global Positioning System (GPS) data was used to collect the elevation along the seismic spreads. Due to the proximity of running greenhouse equipment and traffic along HDD S3-0560, SET elected to change the survey geometry by adding two additional data collection points to the standard data collection locations for a total of nine locations. SET increased the total data points to eliminate any issues created by the operating equipment. The nine strike locations are -50, 0, 35, 75, 115, 155, 185, 230, and 280 feet from the starting station of the survey spread. No other alterations were made to the standard data collection procedure.

The geologic seismic survey for HDD S3-0560 started on the north end of the alignment on January 7, 2019. Data collection for the alignment was completed on January 9, 2019. During a site reconnaissance conducted with SET on January 4, 2019, it was determined that data could not be collected in particular areas due to privately owned driveways and landscaped structures along the Limit of Disturbance (LOD).

SET used the adjusted nine data collection points and the 50 feet of overlap for every seismic spread along S3-0560. One survey spread needed to be altered to ensure good quality data was collected. On Spread 1, the -50 -foot data collection point needed to be reduced to -40 feet so that the strike location would be on material that would activate the data collection software. No other issues were encountered along HDD S3-0560.

During the survey work, a hand-held GPS unit was used to record the locations of data points for reference to be able to relocate areas as needed. Following completion of the survey, elevation data was collected by a Pennsylvania licensed surveyor (Dewberry LLC), which was required to process the seismic data.

There were no days where data collection could not be conducted due to weather. However, due to onsite conditions data collection was delayed down on the following days:

- January 7, 2019 – Landscape supply yard operations creating background noise
- January 8, 2019 – Traffic along Slitting Mill Road creating background noise
- January 9, 2019 – Traffic along Slitting Mill Road creating background noise

DATA GAPS

Data could not be collected between the following stations along S3-0560:

- Station 15611+90 to 15612+50 – The section crossed a driveway and a landscaped structure

RESULTS AND SUMMARY

The results of the geophysical investigation are attached. Refraction data were unable to reach the proposed depth of the HDD at multiple locations due to encountering bedrock at a higher elevation than the HDD depth, but the mappable segments were included in the images. The MASW data extended to the depth of the HDD. Review of the data indicates a lack of significant fractures and faulting in this segment of the HDD. A lower velocity zone was noted at the southeastern end of the HDD, which could correspond with a minor fracturing zone. Review of the geologic map of the area did not indicate the presence of major geologic structures, such as faults, in the vicinity of S3-0560. It should be noted that due to the presence of physical obstacles, the segments, while straight, did not all run parallel to the HDD alignment. Therefore, the HDD alignment project on the cross-section should be considered approximate. Based on review of the data, despite no major fractures or faulting being detected, the 16-inch diameter HDD will be passing through relatively softer bedrock materials during the installation than the 20-inch diameter HDD.

ATTACHMENTS:

Figure – Site Map
Figure – Geologic Map

Appendix 1 – SET Final Report

REFERENCES:

Dicken, Connie L., Nicholson, Suzanne W., Horton, John D., Kinney, Scott A., Gunther, Gregory, Foose, Michael P., and Mueller, Julia A.L. 2005. *Integrated Geologic Map Databases for the United States: Delaware, Maryland, New York, Pennsylvania, and Virginia.* U.S. Geological Survey Open-File Report 2005-1325, U.S. Geological Survey, Reston, VA. Retrieved from https://mrdata.usgs.gov/geology/state/state.php?state=PA

Geyer, Alan R., Wilshusen, J. Peter. 1982. *Engineering characteristics of the rocks of Pennsylvania: environmental geology supplement to the state geologic map*. Retrieved from https://www.gis.dcnr.state.pa.us/geology/index.html

Shultz, Charles H. 1999. *The Geology of Pennsylvania,* Commonwealth of Pennsylvania Department of General Services. pp 235-237.

Legend

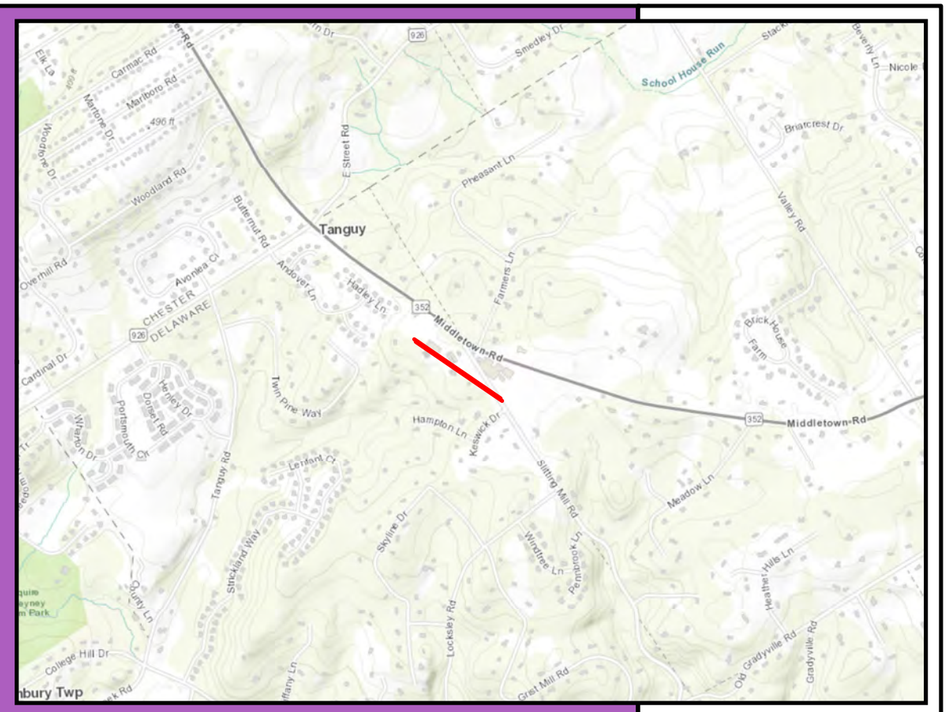
Segment

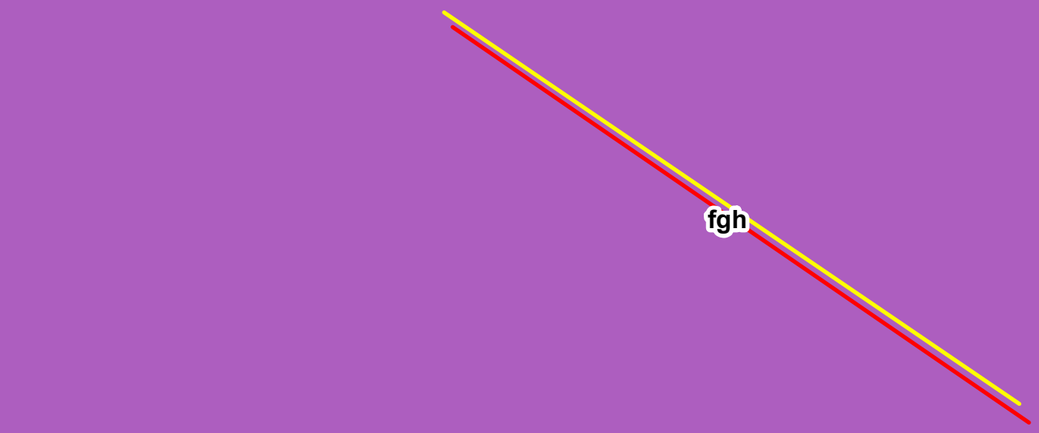
- SP1
- SP2
- SP3
- SP4
- SP5
- SP6

FIGURE
Sunoco Pipeline
HDD S3-0560 Alignment
Pennsylvania
June 2019

TETRA TECH

S:\03-Projects\Commercial\Sunoco PPL\Data\GIS\FIGURE - HDD S3-0560.mxd - chris.sollenberger - 6/3/2019 SML





Legend

- Dikes and Other Similar Features
- S3-0560
- S3-0560-16

Geologic Formation

- fgh - Felsic and Intermediate Gneiss

0 50 100 200 300 400
Feet

Reference: Dicken, Connie L., Nicholson, Suzanne W., Horton, John D., Kinney, Scott A., Gunther, Gregory, Foose, Michael P., and Mueller, Julia A.L. 2005. Integrated Geologic Map Databases for the United States: Delaware, Maryland, New York, Pennsylvania, and Virginia. U.S. Geological Survey Open-File Report 2005-1325, U.S. Geological Survey, Reston, VA. Retrieved from https://mrdata.usgs.gov/geology/state/state.php?state=PA

FIGURE
Sunoco Pipeline
Geologic Map
HDD S3-0560 Alignment
Pennsylvania
June 2019

TETRA TECH

S:\03-Projects\Commercial\Sunoco PPL\Data\GIS\FIGURE - HDD S3-0560 geo.mxd - chris.sollenberger - 6/3/2019 SML

APPENDIX 1 – SET FINAL REPORT

Seismic Survey Areas
Alignment 560, Spreads 1-5

Sunoco Pipeline Site
Aston, Pennsylvania

Legend:

560 Spread3 — Seismic Spread Location (odd)

570 Spread4 — Seismic Spread Location (even)

Notes:

(1) The primary objectives of the geophysical investigation were (a) to map the soil/bedrock interface, (b) to estimate bedrock competency, (c) to locate potential faults and major fractures, and (d) to locate significant weathered zones, voids, or "soft" spots at the site. This information will be valuable to the Horizontal Directional Drilling (HDD) crews in anticipating potential locations where inadvertent returns (IRs) or loss of returns (LORs) may occur. SET collected seismic refraction and seismic surface wave (multichannel analysis of surface waves,MASW) data along concurrent lines for this project.

(2) SET used a hammer and strike plate to collect the seismic data. An accelerated weight drop and dedicated truck were available on-site each day, in the event that it could have been used in a safe and unobtrusive manner. Unfortunately, the accelerated weight drop could not be used along roads due to traffic control issues and potential residential objections.

(3) The quality of the seismic data varied along Survey Area 560. As anticipated, the highest quality data was acquired in areas away from roadways and wet, saturated areas and the lowest quality data was observed next to roadways and human activities. The increased energy output of the accelerated weight drop in these "noisier" areas may have increased the data quality.

(4) SET processed the seismic data using five Geometrics software packages. The refraction arrivals were chosen with "Pickwin" and the data was processed using "Plotrefa" to generate the Seismic Refraction Tomography profiles. The MASW data was processed with "Surface Wave Analysis Wizard" to generate the dispersion curves, and the program "Wave Equation (Surface Wave Analysis)" to generate the MASW tomographic cross sections.

(5) SET placed stakes at the beginning and end points (geophones 1 and 24) of each spread, and their coordinates were measured and recorded by a licensed surveyor. SET used this survey point data for placement of the spreads on Figure 1.

(6) The items on this figure may not be all inclusive. SET does not warrant the fact that additional buried features may be present at this site.

Approximate Scale (U.S. Survey Feet)

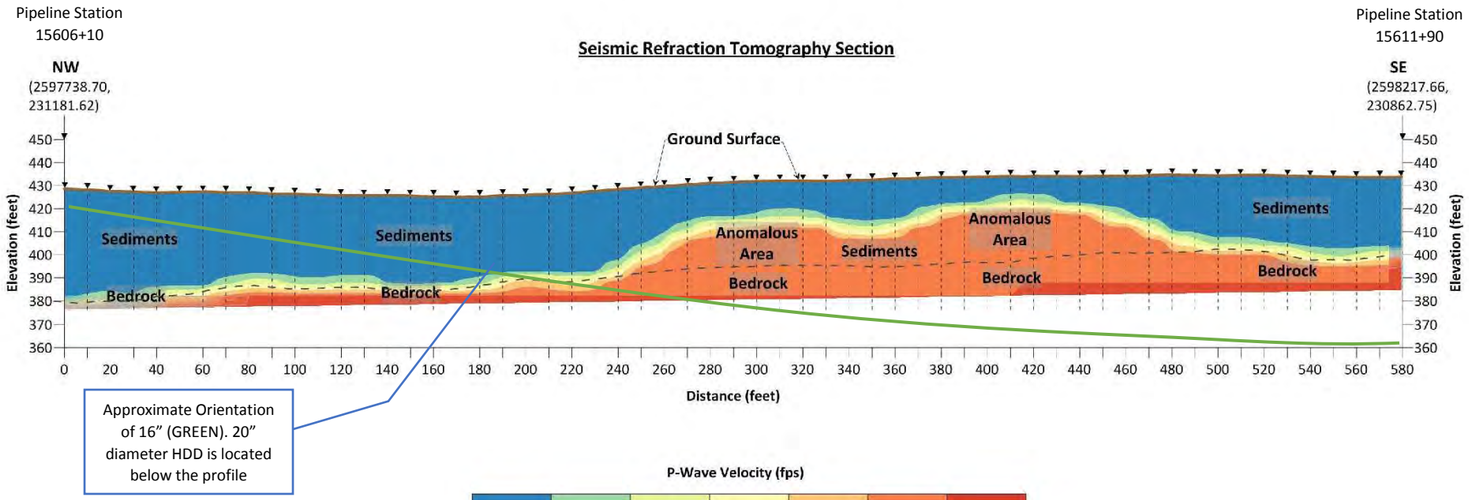
0 — 750 — 1500 — 3000

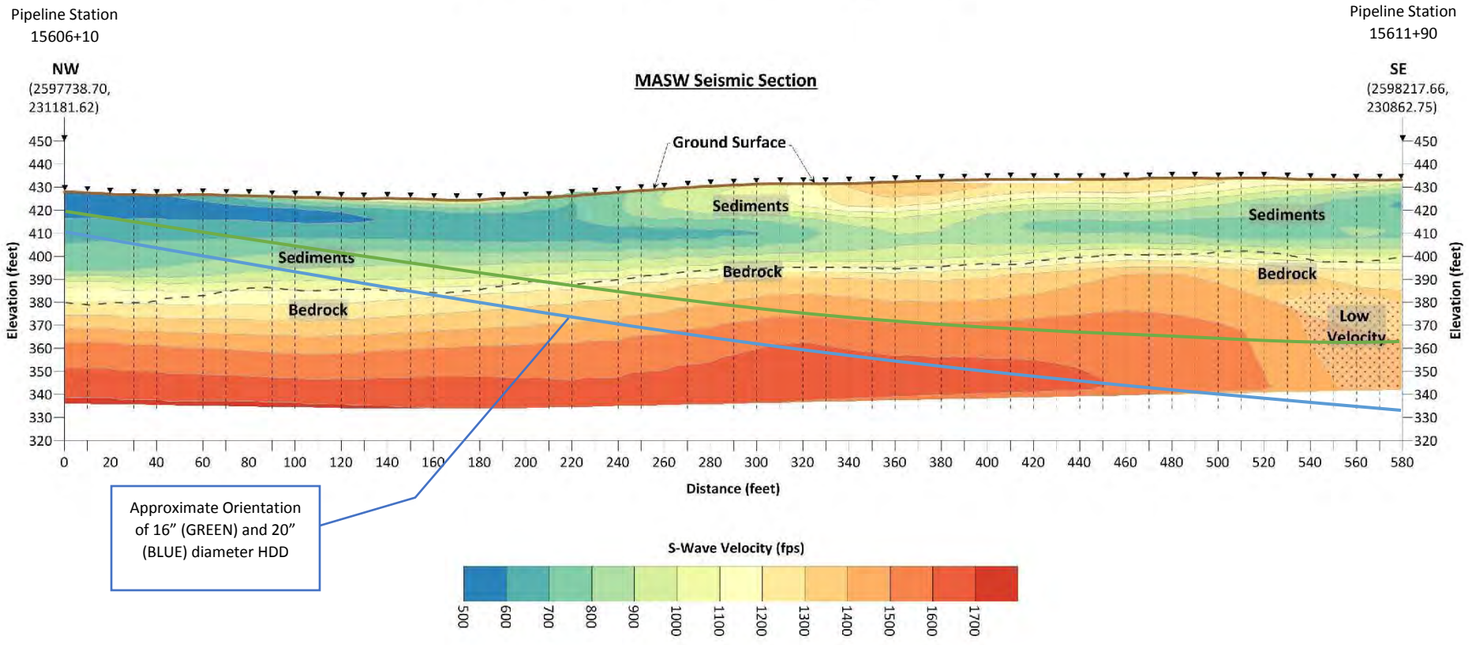
(1 inch = 1500 feet)

SET GEOPHYSICS & DRILLING SERVICES	**SUNOCO SEISMIC ALIGNMENT 560 ANNOTATED HIGH RESOLUTION, GEO-REFERENCED ORTHOPHOTO SHOWING LOCATIONS OF SEISMIC SPREADS 1-3**
SUBSURFACE ENVIRONMENTAL TECH., LLC. 19 BROOKSIDE AVENUE PENNINGTON, NJ 08534	ADDRESS: ASTON, PENNSYLVANIA
	CLIENT: TETRA TECH — FIGURE 1
PROJECT: 18-402G	SUBSURFACE ENVIRONMENTAL TECHNOLOGIES, LLC.
FIGURE DATE: JANUARY 31, 2019	DRAWN BY: P. MILLER, SENIOR GEOPHYSICIST

Seismic Sections
Alignment 560, Spreads 1, 2 and 3

Sunoco Pipeline Site
Aston, Pennsylvania





Notes:

(1) The primary objectives of the geophysical investigation were (a) to map the soil/bedrock interface, (b) to estimate bedrock competency, (c) to locate potential faults and major fractures, and (d) to locate significant weathered zones, voids, or "soft" spots at the site. This information will be valuable to the Horizontal Directional Drilling (HDD) crews in anticipating potential locations where inadvertent returns (IRs) or loss of returns (LORs) may occur. SET collected seismic refraction and seismic surface wave (multichannel analysis of surface waves,MASW) data along concurrent lines for this project.

(2) The seismic refraction tomography (SRT) data indicated the presence of two shallow anomalous areas at 300' and 415'. They may be due to sidescattered energy of some sort but do not represent the true bedrock interface. Bedrock is best observed on the surface wave profile. The MASW data indicated the presence of a low velocity zone near station 560, at the end of the line.

(3) The items on this figure may not be all inclusive. SET does not warrant the fact that additional buried features may be present at this site.

SET GEOPHYSICS & DRILLING SERVICES
SUBSURFACE ENVIRONMENTAL TECH., LLC.
19 BROOKSIDE AVENUE
PENNINGTON, NJ 08534

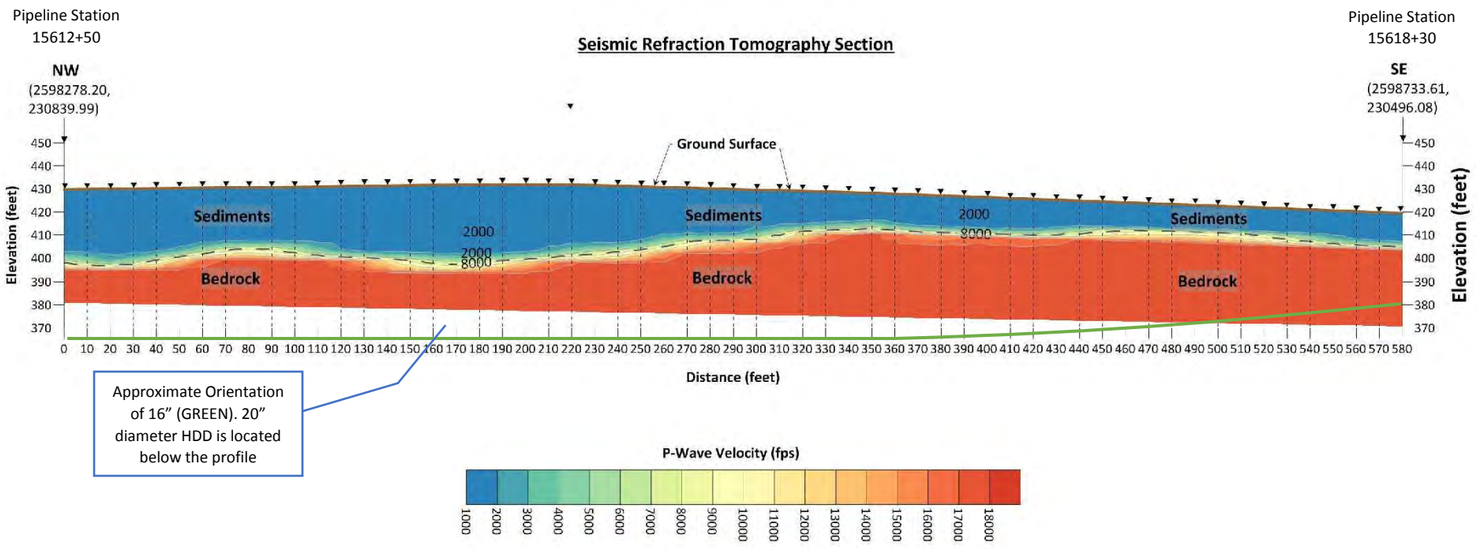
PROJECT:	18-402G
FIGURE DATE:	FEBRUARY 22, 2019

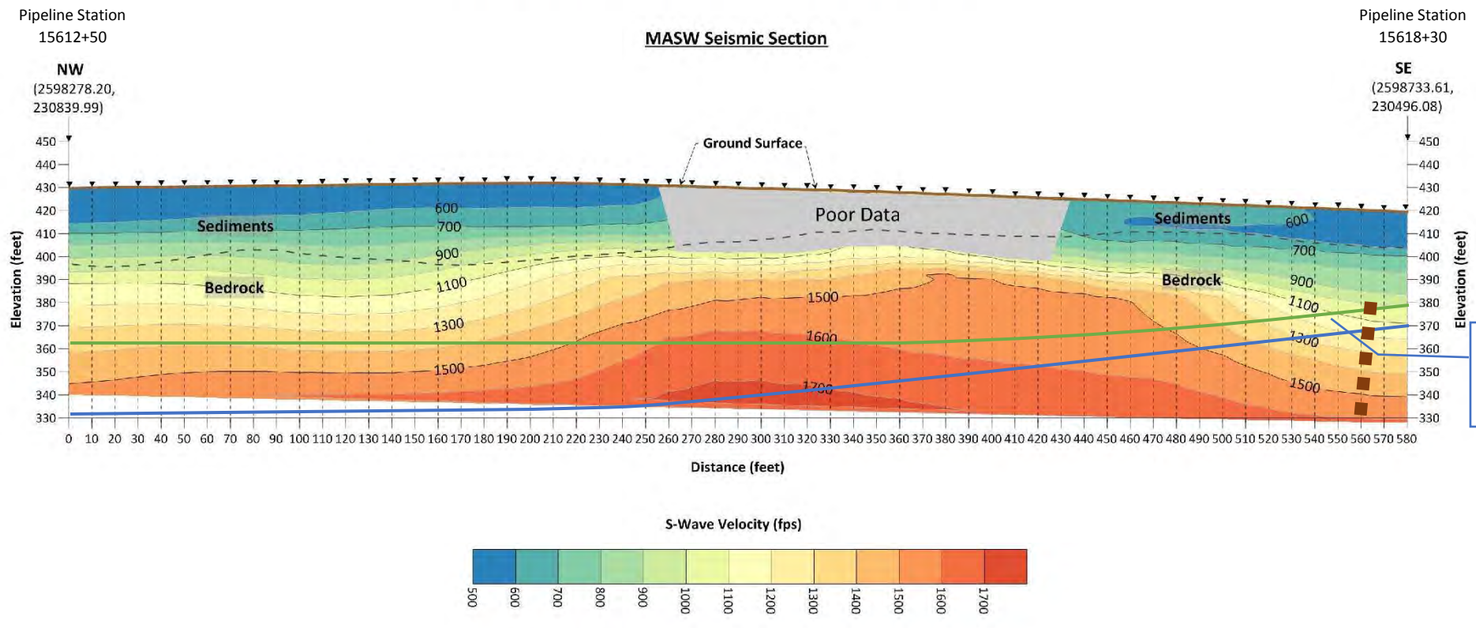
SUNOCO SEISMIC ALIGNMENT 560, SPREADS 1-3 ANNOTATED SRT AND MASW CROSS SECTIONS SHOWING APPROXIMATE SEDIMENT/BEDROCK INTERFACE AND POSSIBLE ANOMALIES

ADDRESS: ASTON, PENNSYLVANIA
CLIENT: TETRA TECH
SUBSURFACE ENVIRONMENTAL TECHNOLOGIES, LLC.
DRAWN BY: P. MILLER, SENIOR GEOPHYSICIST

FIGURE 2

Seismic Sections
Alignment 560, Spreads 4,5 and 6
Sunoco Pipeline Site
Aston, Pennsylvania





Notes:

(1) The primary objectives of the geophysical investigation were (a) to map the soil/bedrock interface, (b) to estimate bedrock competency, (c) to locate potential faults and major fractures, and (d) to locate significant weathered zones, voids, or "soft" spots at the site. This information will be valuable to the Horizontal Directional Drilling (HDD) crews in anticipating potential locations where inadvertent returns (IRs) or loss of returns (LORs) may occur. SET collected seismic refraction and seismic surface wave (multichannel analysis of surface waves,MASW) data along concurrent lines for this project.

(2) The seismic refraction tomography (SRT) data indicated the sediment thickness is approximately 32 feet bgs on the northwestern end of the line and 15 feet on the southeastern end of the line. The MASW data did not indicate the presence of significant fractures, just undulating bedrock.

(3) The items on this figure may not be all inclusive. SET does not warrant the fact that additional buried features may be present at this site.

Brown Dashed Line Indicates Approximate Potential Fracture/Fault Orientation

SET GEOPHYSICS & DRILLING SERVICES

SUBSURFACE ENVIRONMENTAL TECH., LLC.
19 BROOKSIDE AVENUE
PENNINGTON, NJ 08534

SUNOCO SEISMIC ALIGNMENT 560, SPREADS 4-6 ANNOTATED SRT AND MASW CROSS SECTIONS SHOWING APPROXIMATE SEDIMENT/BEDROCK INTERFACE AND POSSIBLE ANOMALIES

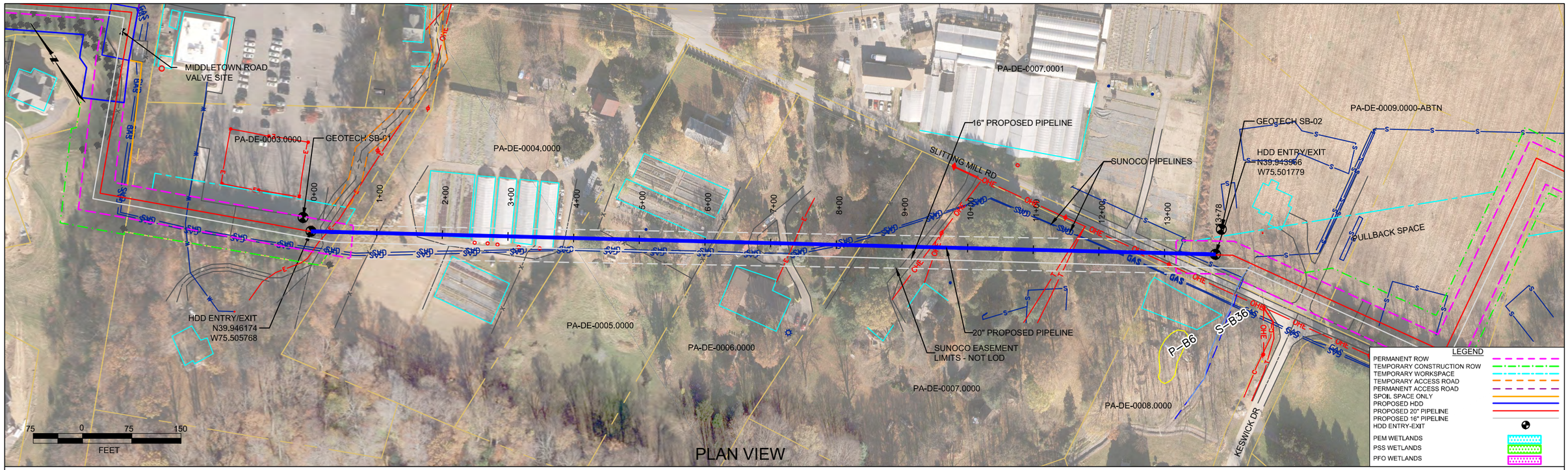
ADDRESS: ASTON, PENNSYLVANIA
CLIENT: TETRA TECH
PROJECT: 18-402G
SUBSURFACE ENVIRONMENTAL TECHNOLOGIES, LLC.
FIGURE DATE: FEBRUARY 22, 2019
DRAWN BY: P. MILLER, SENIOR GEOPHYSICIST

FIGURE 3

SLITTING MILL ROAD CROSSING
PADEP SECTION 105 PERMIT NO. E23-524
PA-DE-0008.0000-RD
(SPLP HDD No. S3-0560)

ATTACHMENT 2

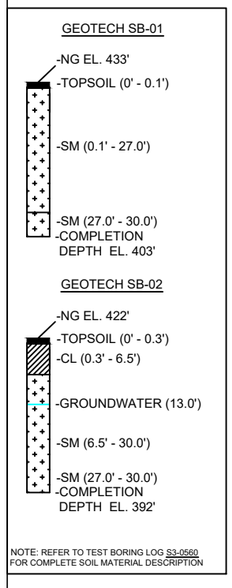
HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



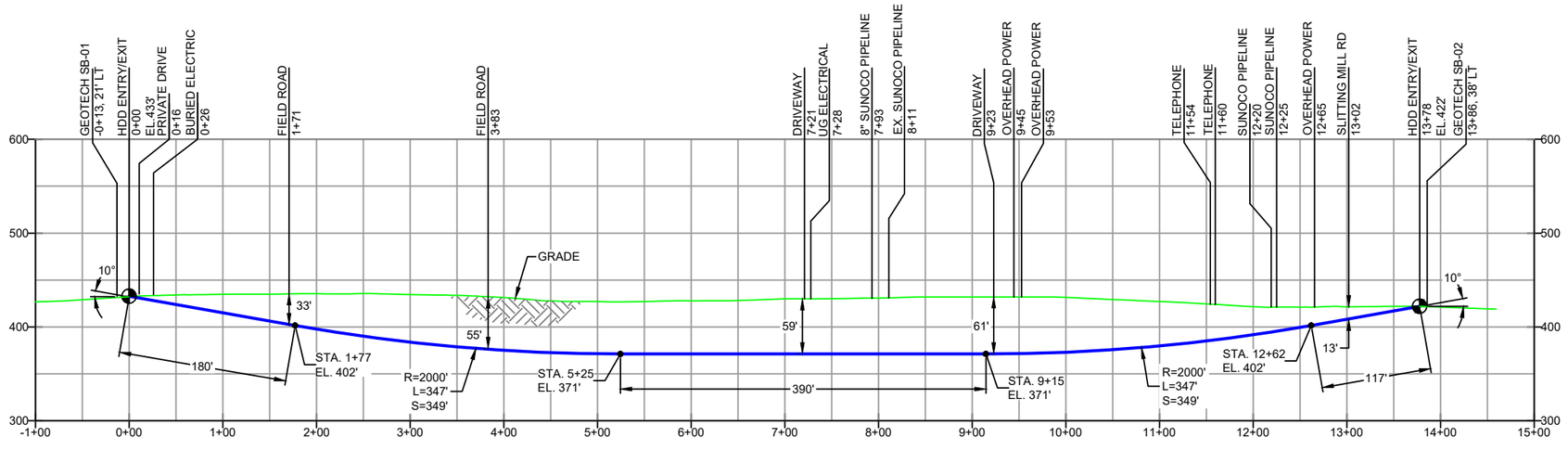
PLAN VIEW

PROFILE VIEW

DELEWARE COUNTY, PA - EDGMONT TOWNSHIP
S3-560



NOTE: REFER TO TEST BORING LOG S3-0560 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING 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=):1378'
   HDD PIPE LENGTH (S=):1385'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
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.

Figure 1. Permitting 20-Inch HDD Plan and Profile

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

ES-6.02	TO	ES-6.03	EROSION & SEDIMENT PLAN	
SHEET 1	TO	SHEET 2	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
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	05/20/16	RMB	05/20/16	AAW	05/20/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ISSUED FOR BID/DESIGN CHANGE	DLM	08/21/15	RMB	08/21/15	AAW	08/21/15
B	ISSUED FOR BID	DLM	07/31/15	RMB	07/31/15	AAW	07/31/15
A	ISSUED FOR REVIEW	KB	03/30/15	RMB	03/30/15	AWW	03/30/15

Sunoco Logistics Partners L.P.

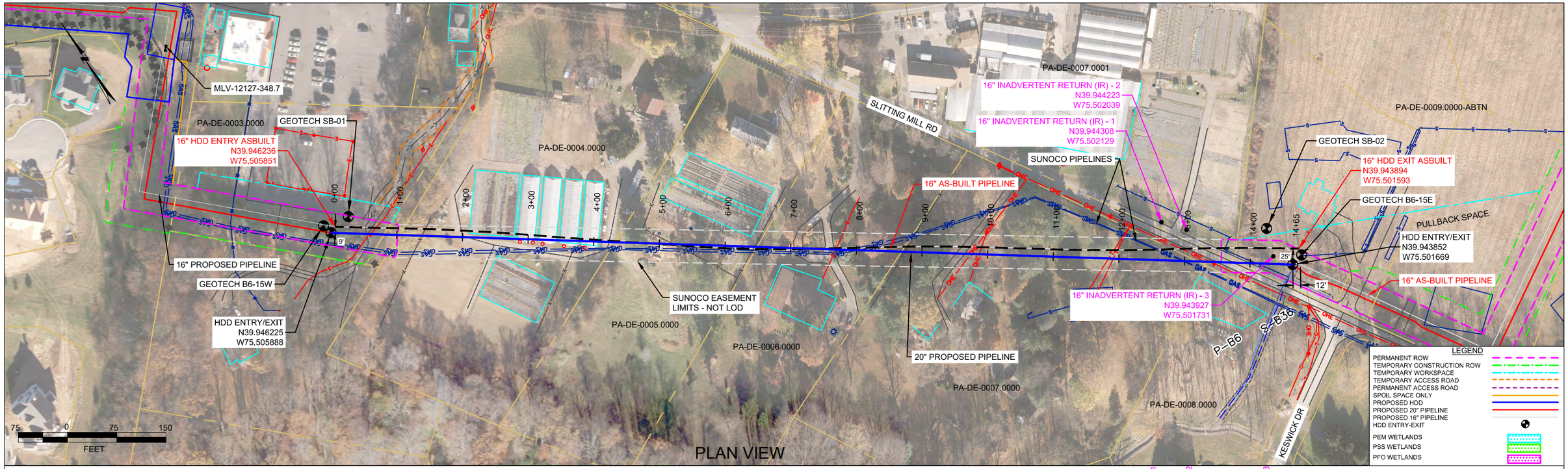
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

20-INCH HORIZONTAL DIRECTIONAL DRILL
SLITTING MILL RD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'

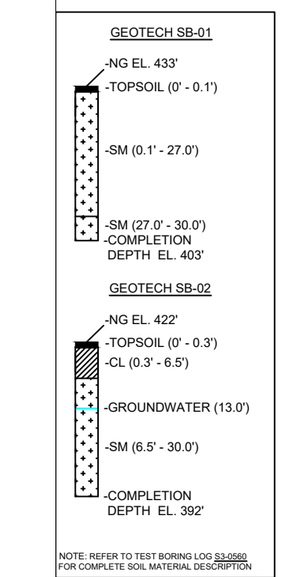
DWG. NO: PA-DE-0008.0000-RD



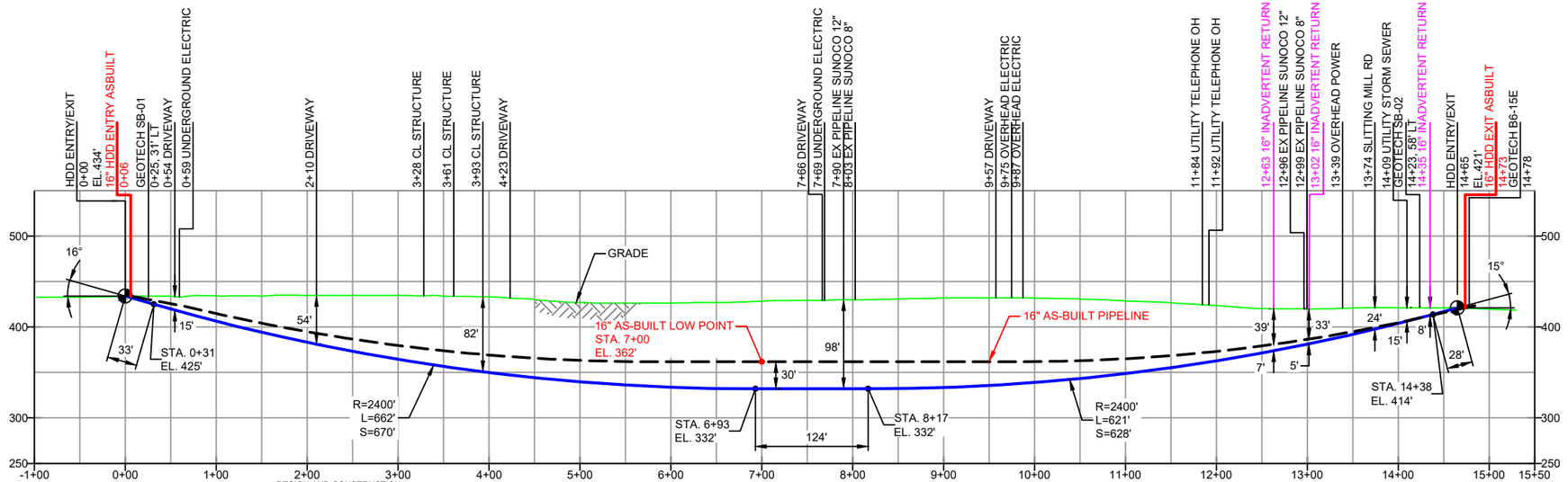
PLAN VIEW

PROFILE VIEW

DELEWARE COUNTY, PA - EDGMONT AND THORNBURY TOWNSHIP
S3-0560

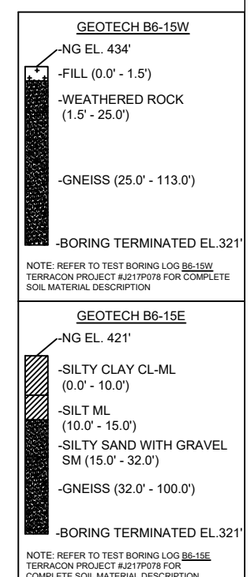


NOTE: REFER TO TEST BORING LOG S3-0560 FOR COMPLETE SOIL MATERIAL DESCRIPTION



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=):1465'
   HDD PIPE LENGTH (S=):1483'
   20" x 0.456" W.T., X-65, APISL, 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.



NOTE: REFER TO TEST BORING LOG B6-15W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

NOTE: REFER TO TEST BORING LOG B6-15E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

Figure 2. Revised 20-Inch HDD Plan and Profile

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-6.02	TO	ES-6.03	EROSION & SEDIMENT PLAN
SHEET 1	TO	SHEET 2	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	SWITCHED 20" CENTERLINE LOCATION, INCREASED DEPTH OF DRILL AND ADDED GEOTECH INFORMATION	MRS	03/14/19	RMB	03/14/19	AMC	03/14/19
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	05/20/16	RMB	05/20/16	AAW	05/20/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ISSUED FOR BID/DESIGN CHANGE	DLM	08/21/15	RMB	08/21/15	AAW	08/21/15
B	ISSUED FOR BID	DLM	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
SLITTING MILL RD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'

DWG. NO: PA-DE-0008.0000-RD