HORIZONTAL DIRECTIONAL DRILL ANALYSIS
PENNSYLVANIA DRIVE
PADEP SECTION 105 PERMIT NO.: E15-862
PA-CH-0124.0000-RD
(SPLP HDD No. S3-0310)

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This reevaluation of the horizontal directional drill (HDD) installation of a 20-inch diameter pipeline under Pennsylvania Drive 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 S3-0310 was initiated after the temporary injunction issued by the PADEP Environmental Hearing Board on July 25, 2017. The 16-inch pipeline HDD had one (1) inadvertent return (IR) and a subsidence event; therefore, installation of the second pipeline (20-inch diameter) requires reevaluation. The IR for the 16-inch pipeline was easily remediated, and the HDD was completed when the pipe was pulled on 11/04/2019.

The 20-inch pipeline HDD is referred to herein as HDD S3-0310.

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.

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.

PENNSYLVANIA DRIVE
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ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 4,227 feet (ft)
- Entry/Exit angle: 8-10 degrees
- Maximum Depth of cover: 125 ft
- Depth below stream crossing: 30-63 ft
- Depth below wetlands: 20-35 ft
- Pipe design radius: 2,000 ft

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

INADVERTENT RETURN DISCUSSION

The IR event occurring during completion of the HDD S3-0310 16-inch happened at approximately 125 ft before tool exiting while the reaming tool was being pulled towards the HDD entry. On October 29, 2019, the driller notified inspectors that a loss of pressure occurred. In accordance with the April 2018 IR plan requirements, the monitoring PG and two workers began an inspection of the HDD alignment and adjacent areas, and observed an upland IR of drilling fluid on the ground surface approximately ten feet north of stream S-C69. Drilling operations immediately stopped. The estimated loss of drilling fluid was 150 gallons to the upland ground between stream S-C69 and wetland W-C37. The initial mud recovery/restoration activities consisted of sandbag and absorbent sock containment. After cleanup activities were completed, collection berms were installed and the HDD restarted. This IR did not reactivate during the completion of reaming, nor during swabbing and pulling of the 16-inch pipe. The occurrence of the upland IR is attributed to thin, relatively weak overburden comprised of decomposed granitic rock as the reaming tool was approaching exit at the southeast end of the HDD. Similar upland IRs have been experienced at other HDDs in this geologic setting, especially for relatively long HDDs which require an increase in fluid pressure to maintain circulation back to the drill rig or exit pit (varying by HDD phase) as the tools are ascending to exit.

On November 1, 2019, a subsidence feature appeared on top of the drill path, approximately 80 ft in front of the HDD exit pit. This feature developed from the unraveling of the overburden above bedrock into the annulus during the swabbing phase of the HDD. The root cause of these features is water movement through the overburden (groundwater percolation) where the overburden has little to no cohesion capability. As the overburden above the annulus sloughs into the annulus, the feature enlarges and propagates towards the land surface tracking backwards to the direction of the groundwater flows, and ultimately appears at the land surface. SPLPs drilling specialists and monitoring PGs believe the inducing factors in this instance were the significant rainfall received in the preceding week, concentrated surface runoff to this surface location, and vibrations of the operating equipment at the HDD exit point.

GEOLOGIC ANALYSIS

Bedrock underlying the area of HDD S3-0320 is predominantly Pre-Cambrian age gneiss differentiated as felsic & intermediate gneiss, and graphitic felsic gneiss. The felsic & intermediate gneiss is present within the approximate southeastern half of the profile and graphitic felsic gneiss occurs within the approximate northwestern half of the profile. The regional structural fabric and contact between the gneiss units trends northeast. The region is structurally complex and regional mapping shows the local gneiss bodies dipping steeply to the south. Discontinuities in the form of joints, fractures and faults are imprinted in the bedrock units across the region. These features can act as conduits for groundwater movement and/or represent areas of weakness in the rock. However, no major structural features have been mapped in proximity of the HDD S3-0310 alignment. 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. Several fracture traces were mapped proximal to the site with five crossing the HDD alignment. These are identified in Attachment 1. No karstic bedrock is mapped proximal to the HDD alignment. A band of small historic graphite mines is documented running east-west, approximately 3,000 feet north of the northeast entry/exit, but not in the area of the HDD. The logs of geotechnical borings proximal to the HDD indicate the gneissic bedrock is highly weathered and fractured to depths of 49 and 67 feet but regionally can exceed 100 feet.

Attachment 1 provides a discussion on the geology and the results of geotechnical investigations performed for HDD S3-0310.

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

Most groundwater in the gneissic units of Chester County is stored in the unconsolidated weathered rock near the land surface with lesser amount stored in the underlying bedrock fractures. Based on the soil borings and borings advanced into bedrock, groundwater has been encountered in both the soil/weathered bedrock zone and more competent bedrock. Groundwater aquifer recharge occurs vertically through the unconsolidated overburden materials and downward into the more competent bedrock horizon. The storage of groundwater and direction of groundwater flow in the more competent fractured bedrock is expected to occur in fractures and zones of fracture concentration. Most of the HDD S3-0320 alignment occupies upland terrane and is considered a groundwater recharge area where southwesterly groundwater flow paths originate.

A PAGWIS search of domestic well listings from showed the average well yield was 15.4 gpm with a range from 1 to 60 gpm. Water levels recorded in the geotechnical borings advanced in the area of the HDD ranged from 25 to 52 feet below ground surface (ft bgs). The deeper core borings reported a water level at 9 ft bgs in B6-20E and it was reported that groundwater was not encountered in the B6-8W that was advanced to a depth of 112 feet.

The surface elevation for the proposed profile at the northwest entry/exit is 476 feet above mean sea level (ft amsl) and the surface elevations for the southeast entry/exit is 439 ft amsl. A representative water level elevation of approximately 465 feet amsl was recorded at two geotechnical borings (S3-0310 SB-01 and SB-02) on profile uplands. Therefore, there is the potential groundwater discharge at the southeast entry/exit when the pilot boring is complete, as occurred during the pilot drill for the 16-inch pipe and the driller should have resources in place to manage groundwater production.

Attachment 1 provides an expanded discussion on the hydrogeology at this location.

ADJACENT FEATURES ANALYSIS

This HDD is located in Uwchlan and Upper Uwchlan Townships in Chester County, Pennsylvania, approximately 0.5 miles southwest of where Route I-76 passes over SR Route 100, and 1.2 miles east of Marsh Creek Lake. The land use at this HDD location is light commercial development and vacant land. Water resources crossed by the HDD alignment include three (3) streams and one forested/emergent wetland. The HDD alignment is within an existing SPLP permanent easement containing one existing SPLP pipeline.

SPLP identified twenty-eight (28) parcels within 450 ft of the HDD alignment. SPLP sent each of these landowners a 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.

As a result of this public outreach, SPLP confirmed that all parcels are hooked to public water or no water source is located on the parcels. 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 Re-Evaluation 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 S3-0310 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 alignment is within an existing SPLP utility easement and parallels an existing SPLP pipeline but also crosses public water and sewer utility lines while passing through and under multiple commercial properties, and multiple buried utilities owned by other companies along Pennsylvania Drive. An open cut/conventional auger bore construction plan to replace the proposed HDD is technically feasible. It appears sufficient space is available beginning on the northeast side of Pennsylvania Drive and continuing to the original southeastern endpoint. To implement an open cut/auger bore construction plan, however, would require cooperation or condemnation of multiple private land owners to accept a revised permanent easement, or second permanent easement outside of the current easement where sufficient space would be available to install a new pipeline by conventional methods. 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 construction to occur very close to existing pipelines and other underground infrastructure, and would be immediate to multiple aboveground commercial structures.

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 Stockton Drive and Pennsylvania Drive The HDD also avoids direct open cut impacts to streams S-H3, S-H4, S-C67, S-C68, S-C69 and wetlands W-C37 and W-H1.

Although technically feasible, open cut techniques were proposed during the original assessment and permitting of the Pennsylvania Pipeline Project, and not approved by the landowners. Accordingly, obtaining the necessary easement to employ open cut techniques at this stage will likely require condemnation proceedings. Given that the one upland IR experienced during drilling for installation of the 16-inch pipeline were readily contained and cleaned up and resulted in no harm to human health or the environment, SPLP's opinion is that an HDD crossing of this area remains 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 as well as subset footages and road intersect/crossing within the length of the permitted HDD. Obtaining the necessary easements to employ a conventional auger bore at this stage, however, will likely require condemnation proceedings. Given that the one upland IR experienced during drilling for installation of the 16-inch pipeline was readily contained and cleaned up and resulted in no harm to human health or the environment, SPLP's opinion is that an HDD crossing of this area remains 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 there are two straight subsection of the HDD alignment where Direct Pipe bore would be feasible, implementation of one or more Direct Pipe bores in combination with open cut installation segments would require additional easements for the workspace for setup of the equipment and re-alignment of the pipeline installation as discussed above. Obtaining the necessary easements to employ a direct pipe bore at this stage, however, will likely require condemnation proceedings. Given that the one upland IR experienced during drilling for installation of the 16-inch pipeline was readily contained and cleaned up and resulted in no harm to human health or the environment, SPLP's opinion is that an HDD crossing of this area remains 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 development and bypasses or directly avoids impacting multiple commercial properties, underground utilities, aquatic resources and multiple roadways.

There are no existing alternative utility corridors within one mile to the north or south of the existing SPLP easement, and residential neighborhoods occur immediately to the north of I-76, and within 0.2 miles south of the SPLP easement and current HDD alignment.

Accessing alternative corridors would require creation of an additional utility easement to deviate away from the existing ROW. 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 commercial or residential properties. 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 condemnation proceedings to acquire a new easement as described. Given that the upland IR experienced during drilling for installation of the 16-inch pipeline was readily contained and cleaned up and resulted in no harm to human health or the environment, SPLP's opinion is that the current route is preferred.

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: 4,344 ft
- Entry/Exit angles: 12 - 15 degrees
- Maximum depth of cover: 175 ft
- Depth below stream crossings: 36 - 81 ft
- Pipe design radius: 2,000 - 2,400 ft

The redesigned HDD profile has been lowered 53 ft below the design depth originally permitted. This new profile increases the angle of entry into the southeast radius, and lowers the profile depth 23-24 ft below the installed 16-inch pipeline to reduce the potential for IRs. All of the design factors are below the pipeline stress allowances.

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. No water supply impacts occurred during installation of the 16-inch pipe and all landowners within 450 ft of S3-0310 are connected to public water. As such, the risk of a water supply impact is very small. Upland and punch out IRs are common on entry and exit of HDD drilling tools. The IR during construction of the 16-inch line was easily managed, without impacts to water resources. Although IRs originating from deeper locations along the profile did not occur during construction of the 16-inch line, measures will be taken to minimize that type of 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 the previous IR, and potential zones of fracture concentration identified by fracture trace analysis, so that monitoring can be enhanced when drilling through these locations;

- The S3-0310 20-inch HDD will be drilled as an intercept drill to minimize drilling fluid pressures within the entry and exit radius of the profile to reduce IR potential;

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

- During the reaming phase, the driller can implement both push and pull reaming to minimize IR potential at this HDD;

- The HDD contractor is utilizing casing installations to manage the potential for overburden unraveling to the HDD annulus as a subsidence prevention measure;

- 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;

- 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 at depths of 70 ft bgs and greater. 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

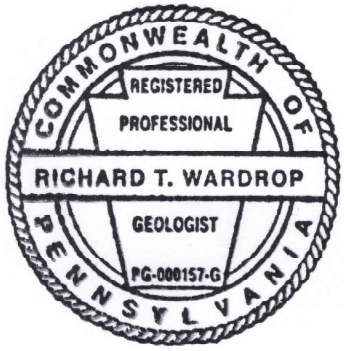
Pertaining to Horizontal Directional Drilling Practices and Procedures; Conventional Construction Alternatives; and Environmental Effects

February 3, 2020

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

Date:

Pertaining to the practice of geology

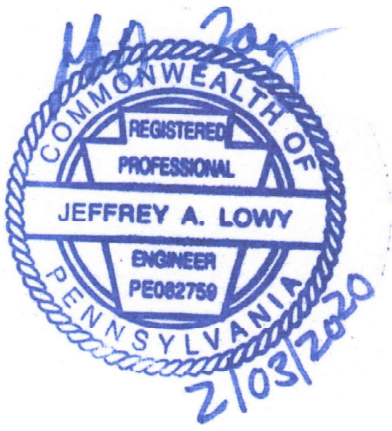


2/3/2020

Richard T. Wardrop, P.G.
License No. PG-000157-G
Groundwater & Environmental Services, Inc.
Lead Hydrogeologist

Date:

Pertaining to the pipeline stress and HDD geometry



2/3/2020

Jeffrey A. Lowy, P.E.
License No. PE 082759
Rooney Engineering, Inc.
Civil Engineer

Date:

PENNSYLVANIA DRIVE
PADEP SECTION 105 PERMIT NO.: E15-862
PA-CH-0124.0000-RD
(SPLP HDD No. S3-0310)

ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

HDD HYDROGEOLOGIC REEVALUATION REPORT

Mariner Southeast II
Spread 6
HDD S3-0310
Pennsylvania Drive
Upper Uwchlan and Uwchlan Townships,
Chester County, Pennsylvania

Prepared for:

Sunoco Pipeline, L.P.

Prepared by:

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

October 2020

HDD HYDROGEOLOGIC REEVALUTION REPORT

Mariner Southeast II
Spread 6
HDD S3-0310
Pennsylvania Drive
Upper Uwchlan and Uwchlan Township,
Chester County, Pennsylvania

February 2020

Prepared for:

Sunoco Pipeline, LP
535 Fritztown Road
Sinking Spring, Pennsylvania 19608

Prepared by:

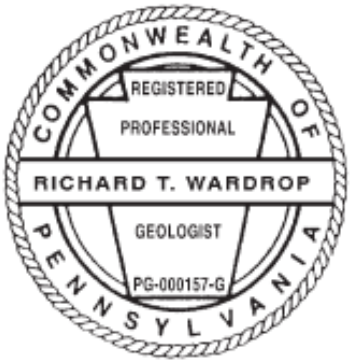
Richard T. Wardrop, P.G.
Principal Hydrogeologist

Reviewed by:

David J. Demko VP, P. G.
Program Manager

Groundwater & Environmental Services, Inc.
440 Creamery Way, Suite 500
Exton, Pennsylvania 19341
(610) 458-1077

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 in the Commonwealth of Pennsylvania and that it is within my professional expertise to verify the correctness of the information.



February 3, 2020

Richard T. Wardrop, P. G. Date

Lic. No. PG000157G

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FIGURES

ATTACHMENTS

1.0 INTRODUCTION

Sunoco Pipeline, LP, (SPLP) retained Groundwater & Environmental Services, Inc. (GES) to prepare HDD Hydrogeologic Reevaluation Reports (HRRs) for horizontal directional drills (HDDs) for the Mariner Southeast II pipeline project. The project involves installation of a 20-inch and a 16-inch diameter natural gas liquid pipeline parallel to one another. This HRR is for installation of the 20-inch pipeline referred to as HDD S3-0310 Pennsylvania Drive, which is located in Upper Uwchlan and Uwchlan Townships, Chester County, Pennsylvania. During the reaming phase of construction for the 16-inch pipeline an inadvertent return (IR) and ground subsidence occurred. According to the requirements of Stipulated Order EHB Docket No. 2017-009-L signed August 10, 2017, installation of the 20-inch pipeline requires a HDD Reevaluation, including this HRR, because an IR occurred during construction of the first of the two pipelines.

The discussion presented in this report compares the plan and profile for HDD S3-0320 developed by Tetra Tech/Rooney, revised 10/21/16 (permitted profile) to the new proposed plan and profile (revised 11/01/2019), and the as-built profile for the 16-inch line pilot hole (see **Attachment A**). In terms of horizontal distance, the permitted profile is 4,227 feet long, the proposed profile is 4,344 feet long, and the completed 16-inch line has a horizontal distance of 4,367 feet. The profile stationing on the land surface is slightly different between the permitted and proposed profiles as the northwest entry/exit on the proposed profile is approximately 97 feet northwest of the permitted profile and the southeast entry/exit of the proposed profile is approximately 20 feet southeast of the permitted profile.

HDD S3-0310 is located approximately 0.5 miles southwest of where Route I-76 passes over SR Route 100, and approximately 1.2 miles east of Marsh Creek Lake. A map depicting the location of the HDD with topographic information for the surrounding area is presented as **Figure 1**.

This report presents the following information:

- Geologic and hydrogeologic characteristics in the area of HDD S3-0310;
- Summaries of studies performed pertinent to reevaluation, including fracture trace analysis and geotechnical borings;
- A site conceptual model; and
- A reevaluation summary with conclusions.

The contents of this report were developed from interpretation of published information, field observations made during drilling and installation of the 16-inch pipeline, and related field studies. In the summer of 2015, Tetra Tech conducted a site geotechnical boring program. Additional geotechnical borings were advanced by Terracon in August and September 2017. Please note that GES did not oversee or direct either geotechnical boring 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. The geotechnical reports, boring logs, and any core photographs that resulted from these programs were generated by SPLP's contractors. GES relied on these reports 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 IRs 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 the potential risks of adverse effects on man-made structures (ex. roadways, parking lots and buildings) proximal to the HDD alignment.

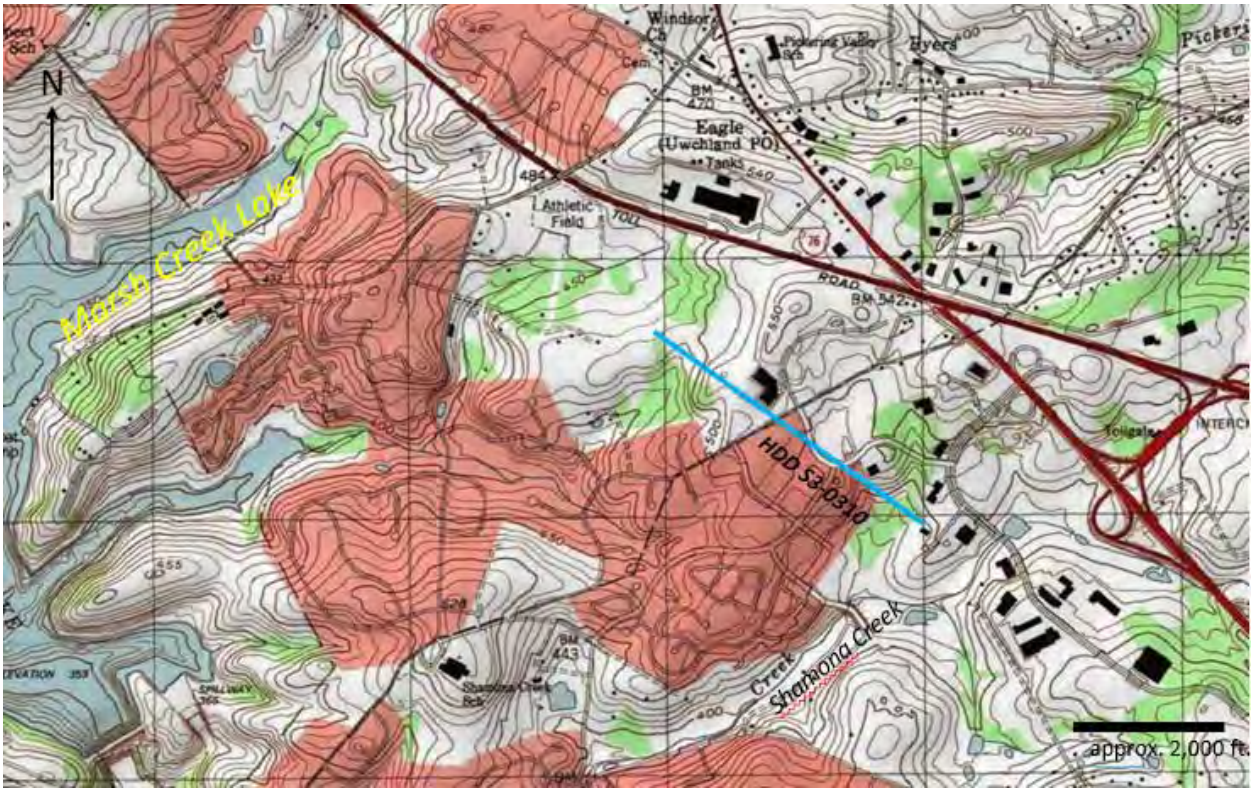


Figure 1. Site Location Map (modified from PaGEODE).

2.0 HDD GEOLOGY / HYDROGEOLOGY

2.1 Physiography

HDD S3-0310 is located within the Piedmont Upland Section of the Piedmont Physiographic Province, which is characterized by broad, rounded to flat-topped hills and shallow valleys. The area surrounding the HDD is comprised of light industrial properties.

2.1.1 Topography

The topography along HDD S3-0310 has low relief. The southeastern entry/exit (Station 0+00) has an elevation of 442 feet above mean sea level (ft amsl) for the permitted profile and 439 ft amsl for the proposed profile. Moving northwest along a relatively flat-topped hill the surface gradually rises to an elevation of approximately 529 ft amsl, and then gradually lowers to the northwest entry/exit, which is at an elevation of 474 ft amsl on the permitted profile and at 476 ft amsl on the proposed profile.

2.1.2 Hydrology

The topographic surface local to the HDD is draining southwest. The northwest half of the alignment drains into an unnamed tributary to Marsh Creek Lake and the southeastern end drains to Shamona Creek. Shamona Creek flows southwest and south to its confluence with East Branch Brandywine Creek at Dowlin.

Most of the water resources associated with HDD S3-0310 are minor and located on the southeast half of the alignment, southeast of Station 19+00 on the proposed profile. Moving northwest to southeast, the streams include S-H1, S-H2, S-H3, S-H4, S-C67, S-C68 and S-C69. Similarly, the wetlands include W-H1, W-C36, and W-C37 (see **Attachment A**).

2.2 Geology

2.2.1 Soils

Based on information obtained from the National Resource Conservation Service Web Soil Survey database (USDA NRCS WSS) for Chester County, soils underlying HDD S3-0320 include the Nashaminy silt loam on 3 to 8 percent slopes, the Califon loam on 3 to 8 percent slopes; the Gladstone gravelly loam on 3 to 8 and on 8 to 15 percent slopes, the Cokesbury silt loam on 0 to 3 percent slopes. The soil present at the southeast entry/exit is the Nashaminy silt loam and the Califon loam, and the soil present at the northwest entry/exit is the Gladstone gravelly loam. Most of these soil types are described as colluvium or residuum derived from weathering of the underlying gneissic bedrock, with varying amounts of clay, silt, sand and gravel. The Nashaminy silt loam is a residuum of underlying diabase bedrock with similar grain sizes. Most of the soils are considered well drained except for the Califon loam, which is considered moderately well drained and the Cokesbury silt loam, which is considered poorly drained. The depth of bedrock weathering to create these soils is reported as generally greater than five feet and the depth to the water table ranges from 0.0 to greater than 80 inches.

2.2.2 Bedrock Lithology

Bedrock underlying the area of HDD S3-0320 is predominantly Pre-Cambrian age gneiss differentiated as felsic & intermediate gneiss, and graphitic felsic gneiss (see **Figure 2** and **Attachment A**). The felsic & intermediate gneiss (ggd) is present within the approximate southeastern half of the profile and graphitic felsic gneiss of two types (gg and gqm) occurs within the approximate northwestern half of the profile. The felsic & intermediate gneiss (ggd) unit occurs southeast of Station 17+50 and is comprised of quartz, feldspar and mica. It is light pink to greenish gray, medium grained, and has not discernable banding. The gqm graphitic felsic gneiss unit occurs from approximately Station 17+50 to 21+00 (proposed profile) and is a light to dark grey, medium-grained gneiss composed of quartz, feldspar and biotite. The gg graphitic felsic gneiss unit occurs northwest of Station 21+00, is a light to medium grey, and is composed of quartz,

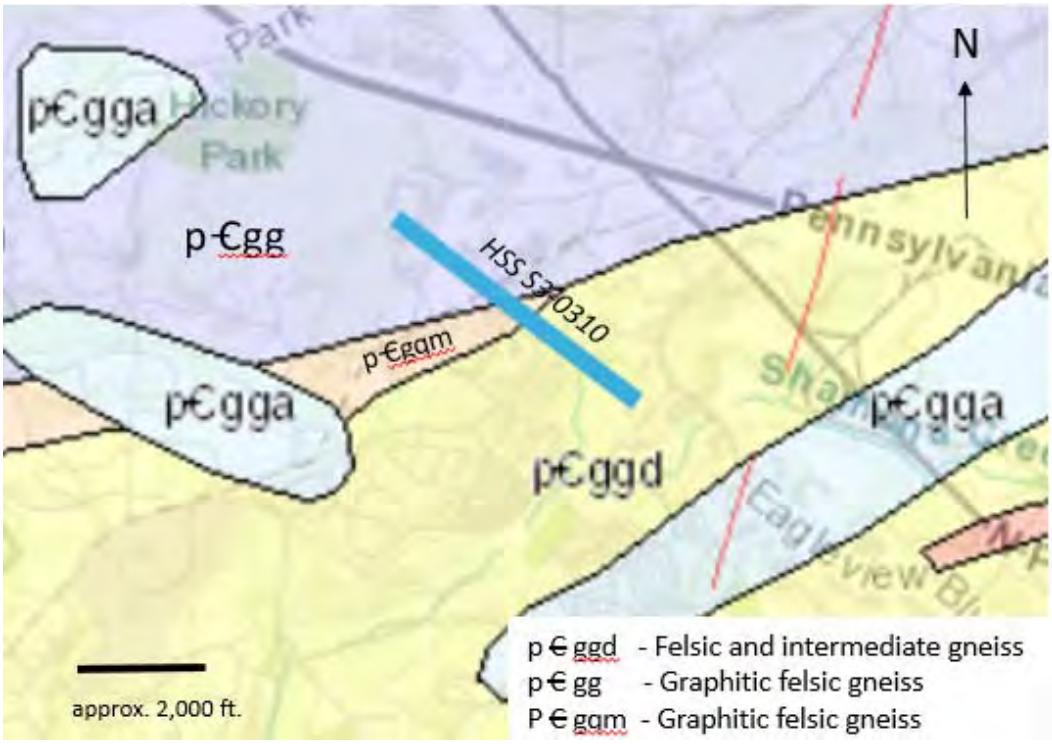


Figure 2. Bedrock Geology (modified from PaGEODE).

orthoclase, hornblende, biotite, graphite and small areas of marble. The gg unit has distinct and very common flaggy banding, includes the Pickering Gneiss (PaGEODE).

2.2.3 Structure

The regional structural fabric and contact between the gneiss units trends northeast. The region is structurally complex and cross-Section A-A' in Berg, et. al. (1980) shows the local gneiss bodies dipping steeply to the south. Discontinuities in the form of joints, fractures and faults are imprinted in the bedrock units across the region. These features can act as conduits for groundwater movement and/or represent areas of weakness in the rock. However, no major structural features have been mapped in proximity of the HDD S3-0310 alignment.

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 expression 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.

Figure 3 shows the fracture trace mapping conducted for this reevaluation. This mapping was performed using aerial stereographic pairs flown in the fall of 1937. As such, much of the land surface appears undeveloped and fracture traces are more easily seen. Several orientations are present in the fracture trace proximal to the alignment with many oriented northeast.

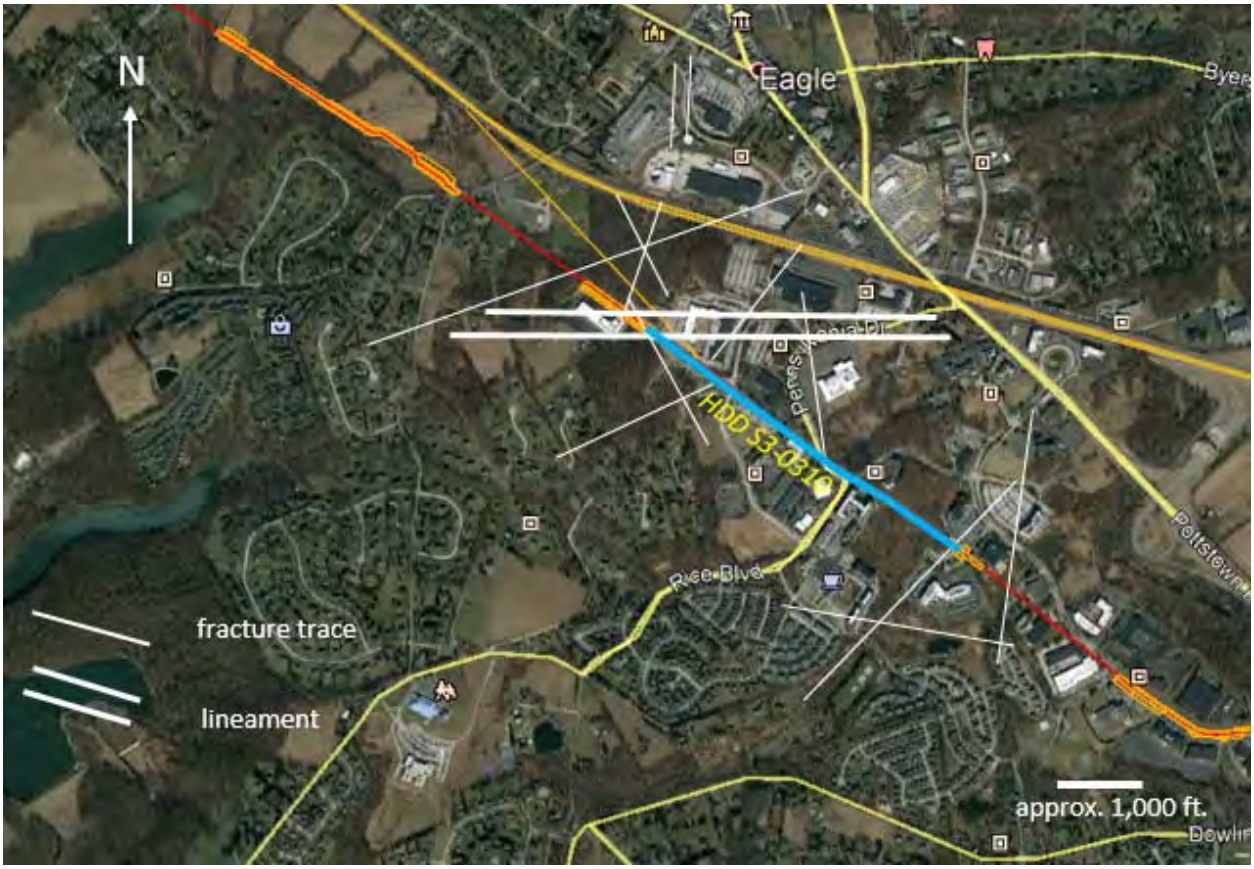


Figure 3. Fracture Trace Map (modified from GoogleEarth™)

As shown on the proposed profile in **Attachment A**, the following fracture trace features cross the proposed alignment:

- an east-west trending lineament through the northwest entry/exit
- a north-northwest trending fracture trace near the northwest entry/exit the southern end of a north-south trending fracture trace at Station 18+00
- a northeast trending fracture trace through the southeast entry/exit
- a northeast trending fracture trace approaching Station 32+50 from the west
- a northeast trending fracture trace approaching Station 35+00 from the east

2.2.5 Karst

Based on published geologic data, no karst features are anticipated within the LOD of HDD S3-0310. The potential of karst conditions is not anticipated because carbonate rock is not mapped proximal to the HDD alignment and no carbonate rock was logged in the geotechnical borings (see Section 2.2.8). The contact between the gneissic units and carbonate valley of Chester County begins over two miles SE of the HDD alignment.

2.2.6 Mining

No historic or current, surface or deep, mineral mining operations have been identified in the area of the HDD in Upper Uwchlan and Uwchlan Townships. Many commercial attempts were made historically to mine graphite from the Pickering Gneiss in a band of small mines running west to east in a line approximately 3,000 feet north of the northwest entry/exit. Bascom and Stose (1938) mapped over a dozen graphite mines along this line that are no longer operating. Given these locations, it is not anticipated that any historic mining operations will effect installation of the 20-inch pipe.

2.2.7 Rock Engineering Properties

The properties of the bedrock units as described in Geyer and Wilshusen (1982) are as follow:

Felsic & intermediate gneiss (ggd) [granodiorite and granodioritic gneiss]:

- No bedding.
- Joints / fractures occur in a blocky pattern, moderately developed, moderately abundant, irregular; widely spaced; open and moderately dipping.
- Difficult to excavate, expect large surface and near-surface boulders, slow drilling rates.

Graphitic gneiss (gg and gqm)

- Banding is distinct and very common; bands are flaggy in thickness.
- Joints are the most common fractures, platy pattern, well developed, moderately to highly abundant, regular, moderately to closely spaced, open and steeply dipping to vertical.
- Weathered portions may be excavated moderately easily, moderate drilling rates.

2.2.8 Results of Geotechnical Borings

Tetra Tech

In the summer of 2015, Tetra Tech advanced four (4) geotechnical borings proximal to the HDD S3-0310 alignment in support of designing the HDD. From northwest to southeast, these included borings S3-0310 SB-01, S3-0310 SB-02, S3-0310 SB-03, and S3-0320 SB-01. Their locations relative to the proposed alignment and depths are, as follows:

- S3-0310 SB-01 – due northeast of Station 34+80; 73.8 feet deep
- S3-0310 SB-02 – approximately 310 feet southwest of Station 25+50; 51.5 feet deep
- S3-0310 SB-03 - due northeast of Station 8+00; 30 feet deep
- S3-0320 SB-01 – approximately 125 feet east of the southeast entry/exit; 30 feet deep

The logs for these borings are provided in **Attachment B**.

At each geotechnical boring location, split spoon samples were collected through a hollow stem auger. In general, the unconsolidated materials are described as variably colored, fine to medium sand with little to some silt and lesser fractions of gneiss gravel, derived from the weathering of gneissic bedrock. Groundwater was encountered in S3-0310 SB-01 at 30.5 feet below ground surface (ft bgs), in S3-0310 SB-02 at 51.5 ft bgs and in 0320 SB-01 at 25 ft bgs. No groundwater was observed at S3-0310 SB-03.

Bedrock coring was attempted at S3-0310 SB-02 from 45 ft bgs to total boring depth at 51.5 ft bgs. All of the core was described as highly weathered gneiss with 0 to 13 percent rock quality determination (RQD) values. Coring was also performed at S3-0320 SB-01from 53.0 to 61.3 ft bgs with similar results.

Terracon

In August and September 2017, Terracon advanced two geotechnical borings in the area of HDD S3-0310 to further evaluate local geologic conditions. B6-8W was advanced approximately 150 feet east of the southeast entry/exit and B6-20E was advanced approximately 830 feet northwest of the northwest entry/exit within the ME II right of way. Core recoveries and RQD values for each boring are shown on **Figure 4**.

B6-8W was drilled to a total depth of 112 feet. Rock coring began at 17 ft bgs. Highly weathered and fractured orange, brown and grey gneiss, with most core recovery at 42 to 50 percent, and most RQD at 0 to 22 percent, was logged from 17 to 67 ft bgs.

B6-20E

Depth (feet)	Apprx. Elev. Elevation (ft amsl)	REC (perc)	RQD (perc)
16	443		
21	438	62	36
26	433	25	15
31	428	7	7
36	423	45	25
41	418	47	7
46	413	73	35
49	410	0	0
51	408	67	58
56	403	90	43
61	398	88	41
66	393	97	81
71	388	97	73
76	383	100	93
81	378	98	76
86	373	100	86
91	368	95	83
96	363	100	80
101	358	100	52
106	353	100	43
111	348	100	65
116	343	100	48
121	338	88	63
126	333	93	93
131	328	97	73
136	323	92	70

Water @9.0 ft bgs

B6-8W

Depth (feet)	Apprx. Elev. Elevation (ft amsl)	REC (perc)	RQD (perc)
17	447		
22	442	68	0
27	437	42	0
32	432	0	0
37	427	73	0
42	422	72	7
47	417	78	22
52	412	84	0
57	407	58	0
62	402	93	43
67	397	85	8
72	392	100	42
77	387	100	64
82	382	100	70
87	377	100	66
92	372	100	61
97	367	100	26
102	362	100	71
107	357	100	28
112	352	100	66

Water not encountered

RQD Classifications

V. Poor	0	25
Poor	25	50
Fair	50	75
Good	75	90
Excellent	90	100

Figure 4. Core Recovery and RQD for Borings B6-20E and B6-8W

From 67 ft bgs to the total depth of 112 feet, the rock was logged as more competent grey-brown to grey gneiss with 100 percent recovery, but with variable RQDs ranging from 26 to 70 percent. The lowest horizontal section of the proposed profile is at an elevation of 349 ft amsl, below the bottom B6-8W. The drill log noted that no water was encountered during advance of the boring.

B6-20E was drilled to a depth of 136 feet and coring began at approximately 16 ft bgs. Low RQDs were reported in highly weathered bedrock to a depth of 49 feet. RQDs for the remainder of the boring ranged from 41 to 93 with zones of higher strength rock from 61 to 96 ft bgs and from 121 to 136 ft bgs. The lowest

horizontal section of the proposed profile is at an elevation of 349 ft amsl, in a zone where the RQD for B6-20E varied 43 to 65 percent. A water level measurement of 9.0 ft bgs was recorded for B6-20E.

2.3 Hydrogeology

2.3.1 Occurrence of Groundwater

Most groundwater in the gneissic units of Chester County is stored in the unconsolidated weathered rock near the land surface with lesser amount stored in the underlying bedrock fractures. Based on soil borings and borings advanced into bedrock, groundwater has been encountered in both the soil/weathered bedrock zone and more competent bedrock, under water-table conditions. Groundwater aquifer recharge occurs vertically through the unconsolidated overburden materials and downward into the more competent bedrock horizon. The storage of groundwater and direction of groundwater flow in the more competent fractured bedrock is expected to occur in discontinuities (fractures) sometimes in zones of fracture concentration as indicated by mapped fracture traces. Most of the HDD S3-0320 alignment occupies upland terrane and is considered a groundwater recharge area.

Water well surface casing length can be an approximate predictor of the thickness of the weathered bedrock zone but is subject to over estimation given the fact that drillers often install casing some distance into competent bedrock and use 20-foot increments of casing. PAGWIS data indicates for wells within one mile of the HDD alignment, casing lengths averaged 83 feet and could be as long as 405 feet. The total depths of the wells ranged from 56 to 510 ft bgs. Depth to bedrock ranged from 10 to 195 ft bgs and static water levels ranged from 6 to 73 ft bgs. Based on these well characteristics the water production zone for local wells could be approximated as a zone between 20 and 510 ft bgs.

2.3.2 Well Yields and Water Levels

McGreavy and Sloto (1977) reported yields from the gneissic rocks in Chester County from 0 to 300 gallons per minute (gpm), with one anomalously high yield of 650 gpm. Domestic well listings from the aforementioned PAGWIS search showed the average yield was 15.4 gpm with a range from 1 to 60 gpm. Groundwater was encountered in three of the four Tetra Tech geotechnical test borings that were advanced to a maximum depth of 73.8 ft bgs. The water levels in these three boring ranged from 25 to 52 ft bgs. The deeper core borings advanced by Terracon reported a water level at 9 ft bgs in B6-20E and it was reported that groundwater was not encountered in the B6-8W that was advanced to a depth of 112 feet.

2.3.3 Ground Elevation between HDD entry/exits

The surface elevation for the proposed profile at the northwest entry/exit is 476 ft amsl and the surface elevations for the southeast entry/exit is 439 ft amsl. A representative water level elevation of approximately 465 feet amsl was recorded at two geotechnical borings (S3-0310 SB-01 and SB-02) on profile uplands. As such, the drilling plan for HDD S3-00310 should account for a potential groundwater discharge at the southeast entry/exit when the pilot boring is complete, such as the one that occurred during the pilot drill for the 16-inch pipe (see Section 3.0).

2.3.4 Water Supply Wells within 450 feet of Alignment

HDD-S3-0310 was included in the implementation of SPLP's original 150-foot water supply survey and subsequent 450-foot water supply survey (see **Figure 4**). Certified letters were sent to land owners with parcels that intersect a border drawn 450-feet in all directions from the HDD alignment.

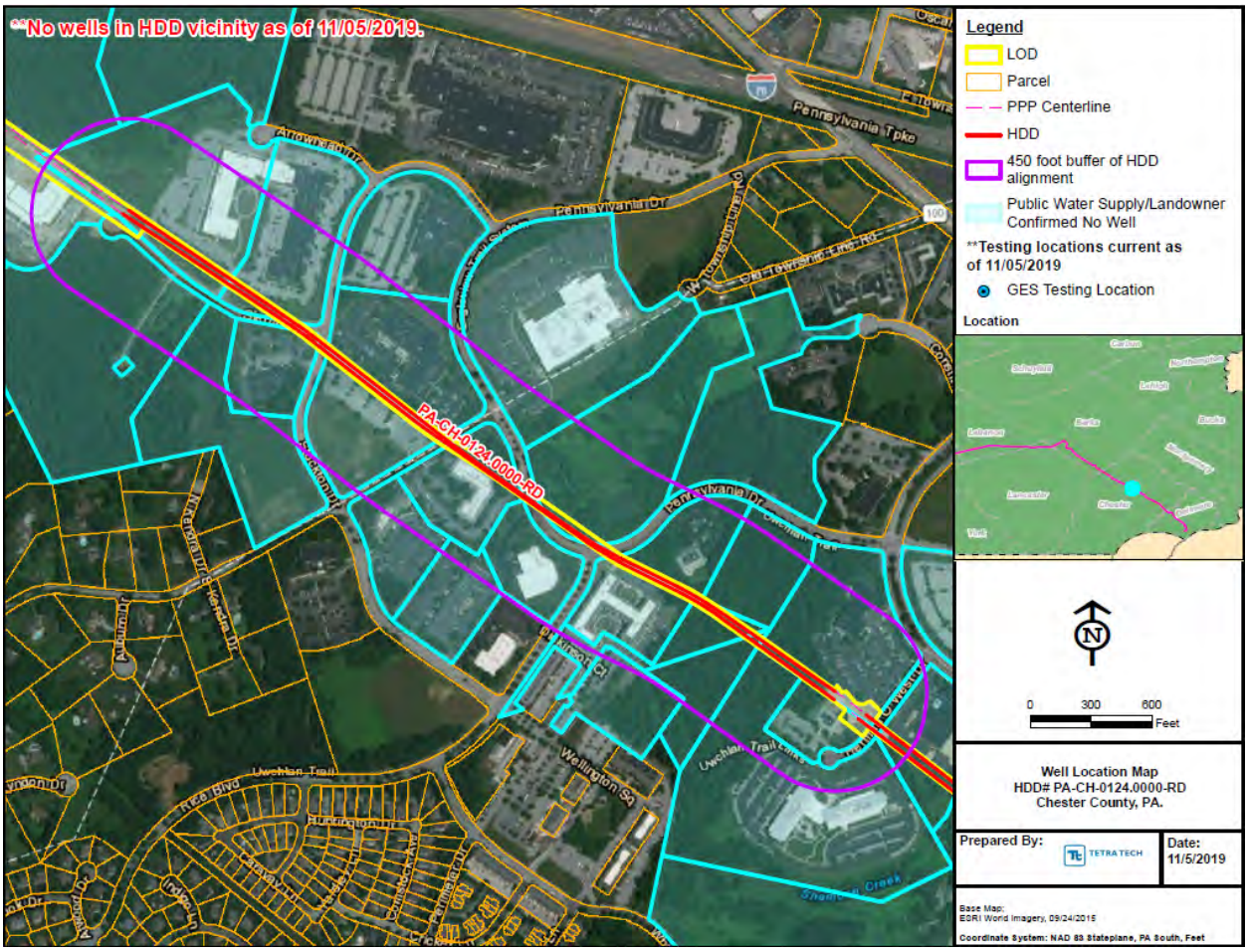


Figure 4. 450-foot Water Supply Survey.

SPLP received no other affirmative responses and it is concluded that all landowners with parcels touching the 450-ft survey perimeter are on public water.

2.4 Summary of Geophysical Studies

As of the submittal of this hydrgeologic reevaluation, no geophysical studies have been performed for the design of HDD S3-0310. Surveys of the first hundred feet or more at each end of the proposed profile and of the installed 16-inch pipe are pending.

3.0 OBSERVATIONS TO DATE

3.1 On This HDD Alignment

The pilot boring for the 20-inch pipe at S3-0310 began on 7/17/2017, traveling southeast to northwest and achieved a horizontal distance of 4,098 feet by 12/22/2017. At that time, drilling activity was suspended prior to completion of the pilot hole. No IRs occurred during the initial drilling. In the meantime, SPLP management decided to install the 16-inch pipe at HDD S3-0310 once drilling was resumed. On 7/15/2019, the driller reoccupied the original, incomplete, pilot boring and jetted in tools to the cutting face advancing from southeast to northwest. A 14-inch surface casing was installed at the southeast entry/exit on 7/16/2019 and the pilot hole was enlarged and advanced using a 12.578-inch diameter pilot bit. By 8/24/2019, the pilot boring was completed without any IRs. A groundwater discharge occurred flowing from the casing at the southeast entry/exit throughout HDD construction during 2019 and was first recognized in 2017. Flows varied from 0 to 60 gpm and mostly occurred when drilling activities were suspended. This constant discharge was successfully managed throughout construction activity using frac tanks for settling out solids, vacuum trucks for hauling water off site and filter bags for an on-site discharge.

On 8/26/2019, reaming began using a 26-inch diameter cutter advancing from northwest to southeast. On 10/29/2019, at approximately 1355 hours, the driller notified inspectors that a loss of pressure occurred. The PG and two workers began an inspection of the travel path and observed an upland IR with drilling fluid accumulating on the ground surface approximately ten feet north of stream S-C69. The driller was notified and drilling operations immediately stopped. Upon further inspection drilling mud was observed coming out of the ground along a hillside about 20 feet east of LOD and travelling downslope to the travel path area, an estimated 150 feet northwest of the southeast entry/exit. The estimated loss of drilling fluid was 150 gallons to the upland ground between stream S-C69 and wetland W-C37. The initial mud recovery/restoration activities consisted of sandbag and absorbent sock containment. These actions were followed up with vacuuming the drilling fluid and using brushes and squeegees to collect the mud for vacuuming. After cleanup activities were completed, the ground was covered with hay and two sandbag collection berms were installed. One berm was installed immediately beneath the mud exit point along the hillside and the second was installed above the travel path north of stream S-C69. Cleanup was completed by 1600 hours. This IR did not reactivate during the remainder of reaming, swabbing and pulling of the 16-inch pipe. The occurrence if the upland IR is attributed to thin, relatively weak overburden comprised of decomposed granitic rock as the reaming cutter was approaching exit at the southeast end of the HDD. Similar upland IRs have been experienced at other HDDs in this geologic setting, especially for relatively long HDDs which require an increase in fluid pressure to maintain circulation back to the drill rig as the bit is ascending to exit and relatively weak overburden materials are thinning. It is more common for this type of upland IR to occur during the pilot phase of drilling; however, in this case, the IR occurred during reaming.

On 11/1/2019, the driller was swabbing the drill hole from northwest to southeast using a 24-inch bit. At 1315 a ground collapse was observed over the HDD alignment a short distance southeast of the northwest entry/exit at Station 42+50 on the proposed profile (see **Attachment A**). At the time of discovery, dimensions of the collapse were estimated to be 25 by 20 feet wide and approximately 30-feet deep. No existing pipeline exposures were observed. The existing Sunoco utility (8-inch pipeline) was located approximately ten feet west of collapse. Due to its close proximity to the collapse, the mud plant was demobilized from the LOD. A trench box was installed to provide immediate support to the sidewalls. Following installation of the trench box, the area was backfilled with bentonite bringing the level of bentonite above groundwater seeps observed on sidewalls of the collapse. Sheet piling was installed on the

west sidewall to further stabilize the area. The remaining gap between the sheet pile and the collapsed area was backfilled with sand.

The area of collapse remained stable as the 24-inch swab was completed on 11/2/2019. Pulling of the 16-inch pipe commenced on 11/4/2019 and was completed on 11/7/2019. Five-inch tremie pipes were installed on the outside of the 16-inch pipe for approximately 150 feet at both ends of the HDD. On 11/8/2019, 18 cubic yards of grout was pumped into the pipe annulus at the northwest end and 21 cubic yards were pumped into the annulus at the southeast end using the tremie pipes. The collapse feature was filled with 36 cubic yards of flowable fill and six cubic yards of grout.

On 11/9/2019 groundwater was flowing into the southeast mud pit at approximately 30 gpm, indicating further treatment of the groundwater discharge was required. Filter bags and filter socks were set up to manage the discharge to ground within the drainage of stream S-C69, which drains to wetland W-C37. Subsequently grout injections were used to seal the annulus near the southeast entry/exit and the discharge has subsided.

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. These IRs have typically occurred where bedrock is weathered and densely fractured (sometimes indicated by a fracture trace or fracture trace intersection) or where the profile approaches an entry/exit point, closer to the surface, where unconsolidated overburden material thins and there is less overburden strength to contain drilling fluid pressures. Drilling fluid pressure tend to increase at the end of relatively long HDDs in order to maintain circulation back to the drill rig. In some cases, overburden thickness is reduced where the deepest part of the profile passes under a stream occupying a section of the alignment with the lowest surface elevation along the profile.

4.0 SUMMARY AND CONCLUSIONS OF HDD HYDROGEOLOGIC EVALUATION

4.1 HDD Site Conceptual Model

HDD S3-0310 within a light industrial setting in Upper Uwchlan and Uwchlan Townships, Chester County, PA. The HDD alignment traverses relatively flat, upland ground, with a high spot at approximately Station 28+50 on the proposed profile (see **Attachment A**). The topographic surface local to the HDD is draining southwest. The northwest half of the alignment drains into an unnamed tributary to Marsh Creek Lake and the southeastern end drains to Shamona Creek.

Forty-percent of the HDD alignment lies within the Felsic and intermediate gneiss unit and 60 percent lies within the graphitic gneiss units of Chester County. In general, the alignment transects bedrock with a thick covering of highly weathered and fractured bedrock (saprolite) over more competent bedrock. Examination of geotechnical boring data indicates the thickness of the zone of weaker material averages approximately 65 feet but regionally can be over 100 feet thick. Fracture trace analysis identified three potential zones of fracture concentration crossing the proposed alignment, one at the northwest entry/exit where a lineament and fracture trace intersect, the second where a fracture trace crosses the alignment at approximately Station 18+00, and the third where a fracture trace intersects the southeast entry/exit. Two other fracture traces were identified approaching, but not crossing, the alignment at Stations 32+70 and 34+80 on the proposed profile. The lineament/fracture trace intersection is proximal to the location of ground collapse that occurred during drill hole swabbing on 11/1/2019. The IR that occurred during reaming on 10/29/2019 was not associated with a fracture trace.

The current permitted profile for the 20-inch line ranges from 0 to approximately 125 ft bgs. The deepest, horizontal section of the permitted profile is at an elevation of approximately 404 ft amsl. In contrast, the proposed profile is designed to achieve an elevation with maximum overburden of 180 feet. This is achieved by steepening the entrance/exit angles at the northwest and southeast entry/exits two and seven degrees, respectively, and increasing the radius from 2,000 to 2,400 feet. As such, the deepest, horizontal section of the proposed profile is at an elevation of approximately 349 ft amsl. Additionally, the proposed profile runs approximately 24 feet deeper than the as-built 16-inch line. The only IR that occurred during installation of the 16-inch pipe was an upland IR that occurred on 10/29/2019 at the end of a reaming run when the cutter was on the ascent of the profile to exit at the southeast entry/exit. No water sources were impacted by the IR. Here saprolitic overburden materials were thinning and drilling fluid pressures may have been increasing to maintain circulation. Drilling mud was observed coming out of the ground along a hillside about 20 feet east of LOD and an estimated 150 feet northwest of the southeast entry/exit. The estimated loss of drilling fluid was 150 gallons that was easily managed. Precautionary containment was installed at the location and the IR did not reactivate during completion of HDD construction. This IR was not associated with the geologic discontinuities indicated by the fracture trace analysis. Similar occurrences of highly manageable IRs should be anticipated during construction of the 20-inch line; however, given the density of water resources approaching the southeast entry/exit, the risk of an IR impacting a water resource is elevated.

Based on various sources of local water level data in relation to the proposed profile, most of the profile will be within saturated conditions. The elevation of the northwest entry/exit on the proposed profile is 476 ft amsl and southeast entry/exit is at 439 ft amsl. A representative water level elevation of approximately 465 feet amsl was recorded at two geotechnical borings (S3-0310 SB-01 and SB-02) on profile uplands. As such, there is likely a pressure head difference between the elevation of the local water table and the southeast entry/exit. Consistent with this indication, a relatively constant groundwater discharge ranging from 0 to 60 gpm occurred at the southeast entry/exit during periods of non-drilling during construction of the 16-inch line and needed to be managed. A similar discharge should be anticipated during construction of the 20-inch line.

No private water supply wells were identified on land parcels that intersect a 450-feet survey limit drawn around the S3-0310 alignment and there were no well owner complaints associated with installation of the 16-inch line. Therefore, there is very little risk of a water supply impact during the installation of the 20-inch line. Most of the water resources associated with HDD S3-0310 are minor and located on the southeast half of the alignment, southeast of Station 19+00 on the proposed profile. Moving northwest to southeast, the streams include S-H1, S-H2, S-H3, S-H4, S-C67, S-C68 and S-C69. Similarly, the wetlands include W-H1, W-C36, and W-C37 (see **Attachment A**).

During a swab pass for the 16-inch line installation, a ground collapse occurred over the HDD alignment, southeast of the northwest entry/exit at Station 42+50 on the proposed profile. The existing Sunoco utility (8-inch pipeline) was located approximately ten feet west of collapse and no other existing pipeline exposures were observed. The collapse occurred in response to a void created by the raveling of unconsolidated saprolitic material during pilot drilling, reaming and swabbing of the drill hole. Saprolitic materials may be thicker and highly fractured here due to the intersection of a lineament and fracture trace in the general area. A trench box was installed within the feature to provide immediate support to the sidewalls. Following installation of the trench box, the area was backfilled with bentonite bringing the level of bentonite above groundwater seeps observed on the collapsed area sidewalls. Sheet piling was installed on the west sidewall to further stabilize the area. The remaining gap between the sheet pile and the collapsed area was backfilled with sand. These actions stabilized the feature and construction of the 16-inch line proceeded to completion. After the 16-inch pipe was pulled, the collapse feature was filled with flowable fill and the annulus was tremie grouted for approximately 150 feet at each end of the HDD.

4.2 Conclusions and Recommendations

The synthesis of regional and local geologic data together with past performance during drilling for the 16-inch pipeline indicate that the risk of IRs remains, especially on the end of the pilot profile during ascent to exit. For the 16-inch line, this occurred at the southeast exit; however, a similar response would be expected at the northwest end if the pilot for the 20-inch line were drilled southeast to northwest. Although this type of IR normally occurs during the pilot drilling phase of HDD construction, it occurred during reaming for the 16-inch line, indicating the risk is present during all phases of drilling. Given the position of water resources due northwest of the southeast entry/exit, this risk includes potential impacts to those water resources in addition to the risk of upland IRs. As such, drilling operations should account for conditions identified in this HRR to minimize the risk of IRs.

Managing drilling fluid circulation at slightly lower annular pressures and slightly higher viscosities may help to preclude LOCs and IRs. An additional approach is to manage the installation using an intercept drill with the intercept completed in the horizontal run of the alignment. This would reduce increasing annular pressure with distance as the pilot approaches exit. Other measures to manage IR risk would include push reaming the final 200 feet before the exit point, before pull reaming the entire profile, and methods to stabilize subsurface materials near the entry/exits, prior to pilot drilling. These measures would include the installation of surface casing for a couple hundred feet at each end of the profile. Surface casing would also reduce the risk of ground collapse near entry/exits, such as that which occurred during construction of the 16-inch line.

No private water supply wells were identified on land parcels that intersect a 450-feet survey limit drawn around the S3-0310 alignment and there were no well owner complaints associated with installation of the 16-inch line. Therefore, there is very little risk of a water supply impact during the installation of the 20-inch line.

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 planned profile for the 20-inch line at S3-0310 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 minimize the likelihood of an impact to the environment. Furthermore, based on such information, expertise and experience, GES believes that implementation of the proposed 20-inch profile for S3-0310 represents a very small risk of any impact to an active private water supply based on distance to private water sources.

5.0 REFERENCES

Bascom, F and G. W. Stose, 1938. *Geology and Mineral Resources of the Honeybrook and Phoenixville Quadrangles, Pennsylvania*, USGS Bull. 891.

Berg, T. M., Edmunds, W. E., Geyer, A. R., and others, compilers, 1980, Geologic map of Pennsylvania (2nd ed.): Pa Geol. Surv., 4th ser., Map 1, 3 sheets, scale 1:250,000.

Geyer, A. R. and J. P. Wilshusen, rev. 1982, *Engineering Characteristics of the Rocks of Pennsylvania.*, Pa Geol. Surv., 4th ser., EGR-1, 300 p.

McGreavy, L. J. and R. A. Sloto, 1977, *Ground-water resources of Chester County, Pennsylvania,* USGS, WRI 77-67, 76 p.

PaGEODE (Pennsylvania Department of Conservation and Natural Resources) (https://www.gis.dcnr.state.pa.us/geology/index.html).

PAGWIS (Pennsylvania Groundwater Information System)
(Pennsylvania Department of Conservation and Natural Resources)
(http://dcnr.state.pa.us/topogeo/groundwater/pagwis/records/index.htm).

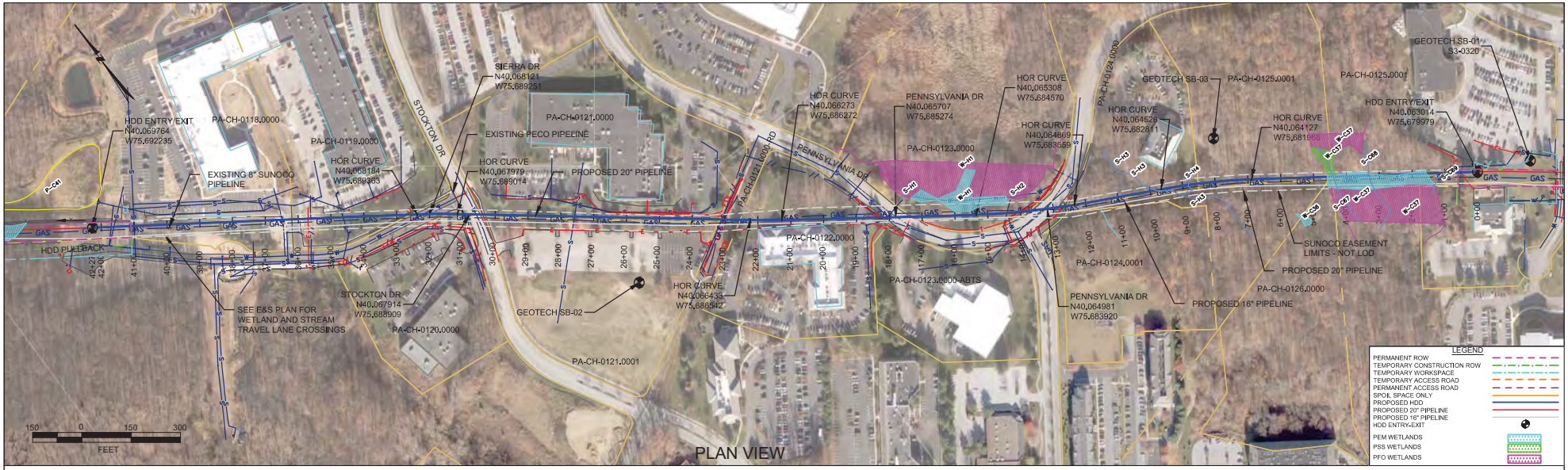
USDA NRCS WSS - Web Soil Survey
(United States Department of Agriculture, Natural Resources Conservation Service)
(https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

Attachment A

Plan and Profiles

HDD S3-0320 Permitted Plan and Profile, rev. 10/21/16

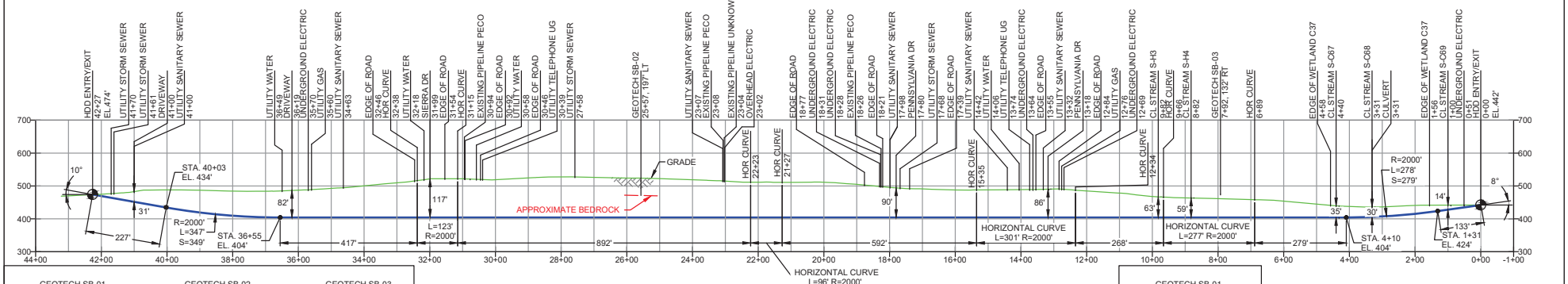
Proposed Plan and Profile, rev. 11/01/2019, showing IR and geology



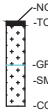
PLAN VIEW

CHESTER COUNTY, PENNSYLVANIA - UWCHLAN TOWNSHIP
S3-0310

PROFILE VIEW



GEOTECH SB-01



-NG EL. 495'
-TOPSOIL (0' - 0.1')
-GROUNDWATER (30.5')
-SM (0.1' - 73.8')
-COMPLETION DEPTH EL. 421'

GEOTECH SB-02

-NG EL. 516'
-TOPSOIL (0' - 0.3')
-CL (0.3' - 6.5')
-GROUNDWATER (38.0')
-SM (6.5' - 45.0')
-FRACTURED GNEISS (45.0' - 51.5')
-COMPLETION DEPTH EL. 471'

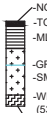
GEOTECH SB-03

-NG EL. 475'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 12.0')
-SM/GM (12.0' - 14.0')
-SM (14.0' - 30.0')
-COMPLETION DEPTH EL. 435'

NOTE: REFER TO TEST BORING LOG S3-0310 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=):4227'
   HDD PIPE LENGTH (S=):4232'
   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.

GEOTECH SB-01



-NG EL. 450'
-TOPSOIL (0' - 0.2')
-ML (0.2' - 9.0')
-GROUNDWATER (25.0')
-SM (9.0' - 53.0')
-WEATHERED GNEISS (53.0' - 61.3')
-COMPLETION DEPTH EL. 389'

NOTE: REFER TO TEST BORING LOG S3-0320 FOR COMPLETE SOIL MATERIAL DESCRIPTION

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-6.32	TO	ES-6.35	EROSION & SEDIMENT PLAN
SHEET 19	TO	SHEET 20	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	10/21/16	RMB	10/21/16	AAW	10/21/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
0	ISSUED FOR CONSTRUCTION	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16

Sunoco Logistics Partners L.P.

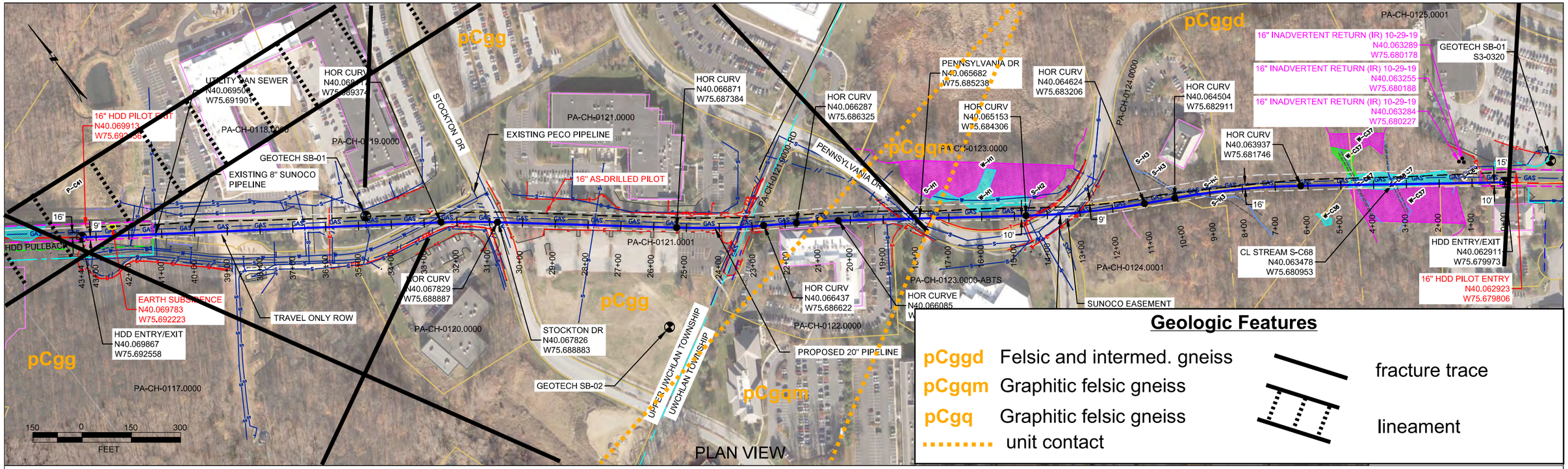
TETRA TECH ROONEY
(303) 792-5911

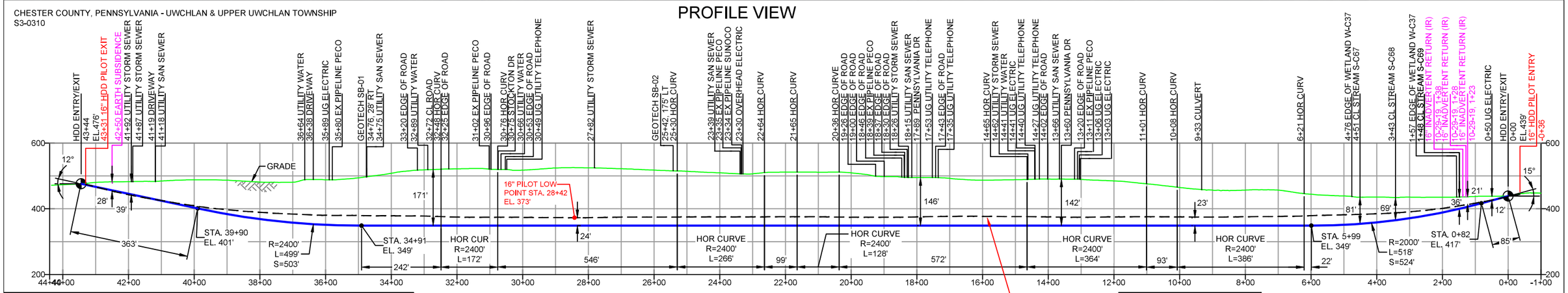
SUNOCO PIPELINE, L.P.

20-INCH HORIZONTAL DIRECTIONAL DRILL
PENNSYLVANIA DRIVE
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=300'

DWG. NO: PA-CH-0124.0000-RD





GEOTECH SB-01
- NG EL. 495'
- -TOPSOIL (0' - 0.1')
- -GROUNDWATER (30.5')
- -SM (0.1' - 73.8')
- -COMPLETION DEPTH EL. 421'

GEOTECH SB-02
- NG EL. 516'
- -TOPSOIL (0' - 0.3')
- -CL (0.3' - 6.5')
- -GROUNDWATER (38.0')
- -SM (6.5' - 45.0')
- -FRACTURED GNEISS (45.0' - 51.5')
- -COMPLETION DEPTH EL. 471'

GEOTECH SB-03
- NG EL. 475'
- -TOPSOIL (0' - 0.3')
- -SM (0.3' - 12.0')
- -SM/GM (12.0' - 14.0')
- -SM (14.0' - 30.0')
- -COMPLETION DEPTH EL. 435'

NOTE: REFER TO TEST BORING LOG S3-0310 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=):4344'
   HDD PIPE LENGTH (S=):4365'
   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.

GEOTECH SB-01
- NG EL. 450'
- -TOPSOIL (0' - 0.2')
- -ML (0.2' - 9.0')
- -GROUNDWATER (25.0')
- -SM (9.0' - 53.0')
- -WEATHERED GNEISS (53.0' - 61.3')
- -COMPLETION DEPTH EL. 389'

NOTE: REFER TO TEST BORING LOG S3-0320 FOR COMPLETE SOIL MATERIAL DESCRIPTION

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-6,32	TO	ES-6,35	EROSION & SEDIMENT PLAN	
SHEET 19	TO	SHEET 20	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP4	ADDED IR, EARTH SUBSIDENCE AND 16" AS-DRILLED INFORMATION	MRS	11/01/19	RMB	11/01/19	AMC	11/01/19
EP3	SWITCHED 20" CENTERLINE LOCATION AND INCREASED DEPTH OF DRILL	MRS	02/11/19	RMB	02/11/19	AMC	02/11/19
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	10/21/16	RMB	10/21/16	AAW	10/21/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
0	ISSUED FOR CONSTRUCTION	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
PENNSYLVANIA DRIVE
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=300'

DWG. NO: PA-CH-0124.0000-RD

Attachment B

Geotechnical Reports

Tetra Tech, 2015

Terracon, August 2017

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:	730 STOCKTON, DOWNINGTOWN, PA		Page 1 of 1
HDD No.:	S3-0310	Dates(s) Drilled: 07-28/29-15	Inspector: E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 30.5	Total Depth (ft): 73.8
Boring Location Coordinates:		40° 4' 6.762" N	75° 41' 23.914" 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 (1")					
1	3.0	5.0	0.1		12		DARK BROWN FINE TO MEDIUM SAND WITH SOME SILT, TRACE FINE	1	3	4	5	**7**
							ROCK FRAGMENTS.					
2	8.0	10.0			16		DR, YELLOWISH BROWN FINE TO MEDIUM SAND WITH SOME SILT,	1	5	12	15	**17**
							TRACE FINE GNEISS FRAGMENTS.					
3	13.0	14.2			20		DR, YELLOWISH BROWN AND WHITE FINE TO MEDIUM SAND WITH	21	50	50/2"		**>50**
							SOME SILT, TRACE FINE GNEISS FRAGMENTS.					
4	18.0	19.9			19		DR, YELLOWISH BROWN AND WHITE FINE TO MEDIUM SAND WITH	5	21	41	50/5"	**>50**
							SOME SILT, TRACE FINE GNEISS FRAGMENTS.					
5	23.0	24.5			12		DR, YELLOWISH BROWN AND DARK BROWN FINE TO MEDIUM SAND	1	23	50/5"		**>50**
							WITH SOME SILT, WITH A LITTLE FINE GNEISS FRAGMENTS.					
6	28.0	29.4			16		DR, YELLOWISH BROWN AND DARK BROWN FINE TO MEDIUM SAND	7	41	50/5"		**>50**
							WITH A LITTLE SILT, WITH A LITTLE FINE GNEISS FRAGMENTS.					
7	33.0	33.8			9		DR, YELLOWISH BROWN AND DARK BROWN FINE TO MEDIUM SAND	8	50/4"			**>50**
							WITH SOME SILT, WITH A LITTLE FINE GNEISS FRAGMENTS.					
8	38.0	40.0			15	SM	DR, VARIEGATED YELLOWISH BROWN TO BROWNISH YELLOW FINE	13	15	30	29	**45**
							SAND WITH SOME SILT. (WHITE AND BLACK LAYER)					
9	43.0	44.5			15		DR, VARIEGATED YELLOWISH BROWN TO BROWNISH YELLOW FINE	3	13	50		**63**
							SAND WITH SOME SILT.					
10	48.0	49.9			6		DR, VARIEGATED YELLOWISH BROWN TO BROWNISH YELLOW FINE	2	15	23	50/5"	**38**
							SAND WITH SOME SILT.					
11	53.0	54.4			8		DR, VARIEGATED (BROWN, BLACK, WHITE, YELLOW) CEMENTED FINE	25	18	50/5"		**>50**
							TO MEDIUM SAND, SOME SILT, TRACE F-C GNEISS FRAGMENTS.					
12	58.0	59.0			6		DR, VARIEGATED (BROWN, BLACK, WHITE, YELLOW) FINE TO MED.	15	50/6"			**>50**
							SAND, SOME SILT, A LITTLE F-C GNEISS FRAGMENTS. (USCS: SM).					
13	63.0	63.8			10		DR, VARIEGATED (BROWN, BLACK, WHITE, YELLOW) FINE TO MED.	15	50/4"			**>50**
							SAND, SOME SILT, A LITTLE F-C GNEISS FRAGMENTS.					
14	68.0	68.9			8		DR, REDDISH BROWN AND WHITE FINE TO MEDIUM SAND WITH SOME	15	50/5"			**>50**
							SILT, WITH A LITTLE F-C GNEISS FRAGMENTS.					
15	73.0	73.8			10		DR, REDDISH BROWN AND WHITE FINE TO MEDIUM SAND WITH SOME	25	50/4"			**>50**
				73.8			SAND, SOME SILT, A LITTLE F-C GNEISS FRAGMENTS. (USCS: SM).					

Notes/Comments:

Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

WET ON SPPON AT 30.5' CAVED AT 72'.
WATER LEVEL THROUGH AUGERS AT 30.5'.

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:	630 STOCKTON, DOWNINGTOWN, PA		Page 1 of 1
HDD No.:	S3-0310	Dates(s) Drilled: 07-30-15	Inspector: E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 38.0	Total Depth (ft): 51.5
Boring Location Coordinates:		40° 3' 59.736" N	75° 41' 16.420" 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 (3")					
1	3.0	5.0	0.3		18	CL	BROWN WITH RED NODULES SILTY CLAY AND FINE SAND, TRACE	3	3	5	9	**8**
				6.5			FINE GRAVEL. (USCS: CL).					
2	8.0	10.0	6.5		14	SM	DR, VARIEGATED (BROWN, RED, WHITE) FINE TO MEDIUM SAND WITH A	5	15	31		**46**
							LITTLE SILT.					
3	13.0	13.8			13		DR, VARIEGATED (BROWN, RED, WHITE) FINE TO MEDIUM SAND WITH A	12	50/4"			**>50**
							LITTLE SILT, TRACE F-C ROCK FRAGMENTS.					
4	18.0	20.0			18		DR, VARIEGATED (BROWN, RED, WHITE) FINE TO MEDIUM SAND WITH A	3	13	22	31	**35**
							LITTLE SILT, TRACE F-C ROCK FRAGMENTS.					
5	23.0	25.0			21		DR, VARIEGATED (BROWN, RED, WHITE) FINE TO MEDIUM SAND WITH A	3	13	22	24	**35**
							LITTLE SILT, TRACE F-C ROCK FRAGMENTS.					
6	28.0	30.0			24		DR, VARIEGATED (DARK BROWN, WHITE, REDDISH BROWN) FINE TO	2	10	12	21	**22**
							MEDIUM SAND WITH A LITTLE SILT, TRACE MICA.					
7	33.0	34.5			13		DR, VARIEGATED (DARK BROWN, WHITE, REDDISH BROWN) FINE TO	1	15	50		**65**
							MEDIUM SAND WITH A LITTLE SILT, TRACE MICA.					
8	38.0	38.6			4		DR, REDDISH BROWN FINE TO MEDIUM SAND WITH SOME SILT, TRACE	12	50/2"			**>50**
							FINE GEISS ROCK FRAGS.					
9	43.0	43.5		45.0	0		NO RECOVERY (AUGER CUTTINGS - SIMILAR TO S8).	50/6"				**>50**
							AUGER REFUSAL AT 45'.					
							ROCK CORING					
RUN 1	45.0	50.0	45.0		42	DECOMPOSED TO WEATH. ROCK	INTENSELY FRACTURED GRAY, WHITE AND RED GNEISS.	TCR: 70%, SCR: 32%, RQD: 13%				
RUN 2	50.0	51.0			12		INTENSELY FRACTURED DARK GRAY AND WHITE GNEISS (GRAVEL)	TCR: 100%, SCR: 25%, RQD: 0%				
RUN 3	51.0	51.5		51.5	5		INTENSELY FRACTURED DARK GRAY GNEISS (GRAVEL)	TCR: 83%, SCR: 67%, RQD: 0%				
							DIFFICULTY WITH CORE BARRELL JAMBING WITH ROCK GRAVEL.					
							OUT OF WATER AT 51.5', LARGE WATER LOSS.					
							CORE TESTING RESULTS (RUN 1, DEPTH 47-47.5'):					
							COMPRESSIVE STRENGTH: 5,390 PSI					
							UNIT WEIGHT: 159.5 PCF					

Notes/Comments:

Pocket Pentrometer Testing
S1: 3.25 TSF

DR: DECOMPOSED ROCK

WET ON SPOON AT 38'.
WATER LEVEL THROUGH AUGERS AT 38'. CAVED AT 42'.

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
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Newark, Delaware 19713
302.738.7551
fax: 302.454.5988

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	WORLED TRAVEL, Inc., 620 PENNSYLVANIA DRIVE, EXTON, PA		Page 1 of 1
HDD No.:	S3-0310	Dates(s) Drilled: 06-14-15	Inspector: E. WATT
Boring No.:	SB-03	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:		40° 3' 52.538" N	75° 40' 55.207" 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	4.0	0.3		10	SM	BROWN AND LIGHT BROWN FINE TO MEDIUM SAND AND SILT, WITH	11	50/6"			**>50**
							A LITTLE FINE GRAVEL.					
2	8.0	9.9			23		DR WEATHERED TO A BROWN, LIGHT BROWN, WHITE F-M SAND, SOME	25	14	21	50/5"	**35**
				12.0			SILT, TRACE UNWEATHERED F-GRAVEL (GNEISS). (USCS: SM)					
3	13.0	13.4	12.0		5	SM/ GM	DR WEATHERED TO A LIGHT BROWN F-M SAND WITH SOME SILT, AND	50/5"				**>50**
				14.0			FINE TO COARSE UNWEATHERED GNEISS GRAVEL.					
4	18.0	18.5	14.0		5	SM	DR WEATHERED TO A WHITE AND LIGHT BROWN FINE SAND, A LITTLE	50/5"				**>50**
							SILT, WITH A LITTLE FINE UNWEATHERED GNEISS GRAVEL.					
5	23.0	23.2			2		DR WEATHERED TO A WHITE AND LIGHT BROWN FINE SAND, SOME	50/2"				**>50**
							SILT, WITH A LITTLE FINE UNWEATHERED GNEISS GRAVEL.					
6	28.0	28.0		30.0	0		NO RECOVERY.	50/0"				**>50**
							AUGERED TO 30'.					
							CAVED AND DRY AT 26'.					

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.

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0310

	Test				Water	Percent	Atterburg Limits (ASTM D4318)			USCS
HDD	Boring	Sample	Depth of Sample (ft.)		Content, %	Silts/Clays, %	Liquid	Plastic	Plasticity	Classif.
No.	No.	No.	From	To	(ASTM D2216)	(ASTM D1140)	Limit, %	Limit, %	Index, %	(ASTM D2487)
S3-0300	SB-02	2	8.0	10.0	23.5	20.5	-	-	-	-
		3	13.0	15.0	31.7	22.6	-	-	-	-
		4	18.0	20.0	41.7	33.1	30	25	5	SM
		5	23.0	25.0	32.2	28.7	-	-	-	-
		6	28.0	30.0	23.4	24.2	-	-	-	-
S3-0310	SB-01	2	8.0	10.0	15.3	20.7	-	-	-	-
		4	18.0	19.9	10.2	24.7	-	-	-	-
		6	28.0	29.4	7.8	15.9	-	-	-	-
		9	43.0	44.5	14.8	25.1	-	-	-	-
		10	48.0	49.9	12.6	33.1	-	-	-	-
		12	58.0	59.0	8.5	36.6	31	25	6	SM
		14	68.0	68.9	13.1	32.3	-	-	-	-
	SB-02	1	3.0	5.0	20.5	67.1	39	22	17	CL
		2	8.0	10.0	8.7	17.3	-	-	-	-
		4	18.0	20.0	6.2	14.8	-	-	-	-
		7	33.0	34.5	13.7	11.9	-	-	-	-
		8	38.0	38.6	10.3	22.7	-	-	-	-
	SB-03	1	3.0	4.0	10.6	44.7	-	-	-	-
		2	8.0	9.9	10.8	28.3	NV	NP	NP	SM
		4	18.0	18.5	4.9	20.1	-	-	-	-
		5	23.0	23.2	4.6	22.8	-	-	-	-

Rock Core Testing Results				
Boring No.	Core Run	Approximate Depth (ft)	Compressive Strength (psi)	Unit Weight (pcf)
S3-0310 SB-02	1	47.0-47.5	5,390	159.5

Notes:

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

ROCK CORE DESCRIPTION SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0310

Location	Boring No.	Core Run	Core Depth (ft)		TCR (%)	SCR (%)	RQD (%)	Depth (ft)		Weathering	Classification	Bedding Thickness (ft)	Color	Discontinuity Data
			From	To				From	To					
S3-0310	SB-2	1	45	50	70	32	13	45	49	Moderate	Gneiss	4	White/Lt. gray	Fractures ranging from 2° to 42°, Avg. 27°
		2	50	51	100	25	0	49	51.5	Heavily	Gneiss	Massive	White/Lt. gray/black	Rubble, two pieces over 3"
		3	51	51.5	83	67	0							

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0310

HDD No.	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
S3-0300	SB-02	Graphitic felsic gneiss - Includes Pickering Gneiss and small areas of marble; dominantly quartz and feldspar with varying amounts of graphite and various metamorphic minerals; medium grained, light to dark gray and greenish gray; sedimentary origin.	Generally level, slightly sloping to the west	Graphitic felsic gneiss (PreCambrian)	Graphitic gneiss	Unknown	See Notes.	Of the 23 well records within 0.5 miles of the site, only one had a recorded bedrock depth. Given the similar geology, bedrock depth is likely to be similar to other locations in this formation
S3-0310	SB-01		Gently sloping to the west				Ranges from 30 to 95 ft bgs, Avg. 75 ft bgs (.5 mile radius)	
	SB-02		Generally level				Ranges from 30 to 95 ft bgs, Avg. 72 ft bgs (.5 mile radius)	
	SB-03		Gently sloping to the South	Felsic and intermediate gneiss (PreCambrian)	Felsic gneiss		Ranges from 30 to 95 ft bgs, Avg. 52 ft bgs (.5 mile radius)	

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

FIELD DESCRIPTION AND LOGGING SYSTEM FOR SOIL EXPLORATION

GRANULAR SOILS

(Sand, Gravel & Combinations)

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

Relative Proportions

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

Particle Size Identification

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

COHESIVE SOILS

(Silt, Clay & Combinations)

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

Plasticity

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

ROCK

(Rock Cores)

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

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

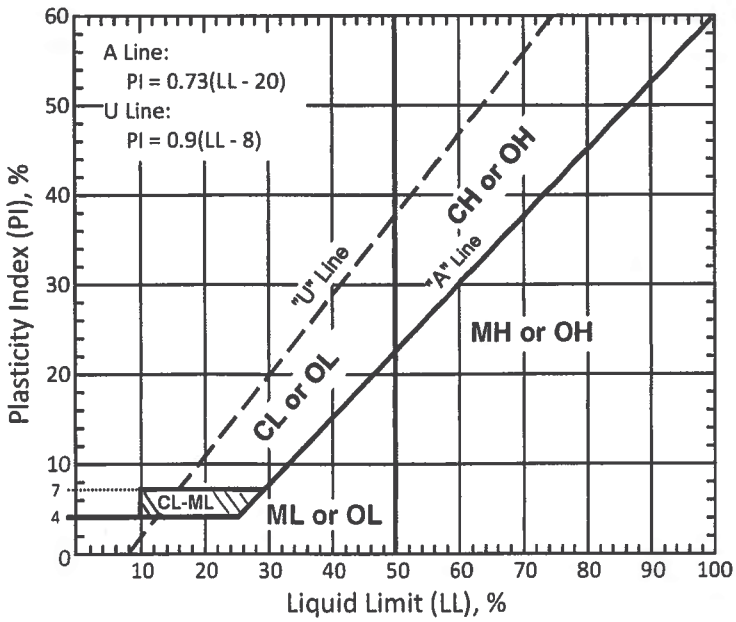
Groundwater observations were made at the times indicated. Groundwater elevations fluctuate throughout a given year, depending on actual field porosity and variations in seasonal and annual precipitation.

UNIFIED SOIL CLASSIFICATION SYSTEM [Casagrande (1948)]

Major Divisions			Group Symbols	Typical Descriptions	Laboratory Classifications		
Coarse Grained Soils (More than half of material is larger than No. 200 sieve)	Gravels More than half of coarse fraction is larger than No. 4 sieve size	Clean gravel (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine Percentage of sand and gravel from grain size curve. Depending on Percentage of fines (fraction smaller than No. 200 sieve), coarse-grained soils are classified as follows: Less than 5 percent GW, GP, SW, SP; More than 12 percent GM, GC, SM, SC; 5 to 12 percent Borderline cases requiring dual symbols[1]	$C_u=\frac{D_{60}}{D_{10}}$ greater than 4: $C_c=\frac{(D_{30})2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting C_u or C_c requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below A Line or I_p less than 4	Limits plotting in hatched zone with I_p between 4 and 7 are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above A line with I_p greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 Sieve)	Clean sands (Little or no fines)	SW	Well graded sands, gravely sands, little or no fines		$C_u=\frac{D_{60}}{D_{10}}$ greater than 6 $C_c=\frac{(D_{30})2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting C_u or C_c requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures		Atterberg limits below A Line or I_p less than 4	Limits Plotting in hatched zone with I_p between 4 and 7 are borderline cases requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits above A line with I_p greater than 7	

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

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



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

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:	568 VALLEYVIEW, DOWNINGTOWN, PA		Page 1 of 1
HDD No.:	S3-0320	Dates(s) Drilled: 06-14 & 08-02-15	Inspector: J. COSTELLO
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller: GREG/OGDEN
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 25.0	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 3' 46.148" N	75° 40' 45.963" 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	0.2			TOPSOIL (2")					
1	3.0	5.0	0.2		22	ML	YELLOWISH BROWN SILT AND FINE SAND, TRACE FINE	7	7	8	12	**15**
				9.0			GRAVEL.					
2	8.0	10.0	9.0		25		DR WEATHERED TO A VARI-COLORED (BRWN, REDDISH BRWN, GRAY,	1	2	7	8	**9**
							WHITE) F-M SAND AND SILT, TRACE FINE GRAVEL (USCS: SM).					
3	13.0	15.0			19		DR WEATHERED TO A BROWN TO REDDISH BROWN FINE TO MEDIUM	1	7	11	11	**18**
							SAND AND SILT, TRACE UNWEATHERED GNEISS GRAVEL.					
4	18.0	20.0			24		DR WEATHERED TO A BROWN TO REDDISH BROWN FINE TO MEDIUM	1	5	9	12	**14**
							SAND AND SILT, TRACE UNWEATHERED GNEISS GRAVEL.					
5	23.0	25.0			22		DR WEATHERED TO A BROWN, BLACK, GRAY, ORANGE BRWN F-M	1	7	11	36	**18**
							SAND AND SILT, TRACE UNWEATHERED GNEISS GRAVEL.(USCS: SM)					
6	28.0	28.8			5	SM	DR WEATHERED TO A LIGHT BROWN AND GRAY, F-M SAND WITH	12	50/3"			**>50**
							SOME SILT, TRACE UNWEATHERED GNEISS GRAVEL.					
7	33.0	35.0			13		DR, WHITE AND GRAY F-M SAND WITH A LITTLE SILT, WITH A LITTLE	2	23	25	29	**48**
(8/2/15)							F-C GNEISS GRAVEL.					
8	38.0	38.8			6		DR, WEATHERED TO A BROWN SILTY FINE SAND, TRACE F-C	14	50/4"			**>50**
							GRAVEL.					
9	43.0	44.3			10		DR, VARIEGATED (WHITE, YELLOW, BROWN, RED) FINE TO MEDIUM	10	32	50/4"		**>50**
							SAND, A LITTLE SILT, WITH A LITTLE F-C GNEISS GRAVEL.					
10	48.0	48.8			8		DR, VARIEGATED (WHITE, YELLOW, BROWN, RED) FINE TO MEDIUM	15	50/4"			**>50**
				53.0			SAND, A LITTLE SILT, WITH A LITTLE F-C GNEISS GRAVEL.					
11	53.0	53.5	53.0		2	DECOMPOSED TO HIGHLY WEATH. GNEISS	HIGHLY WEATHERED GNEISS.	50/6"				**>50**
							AUGER REFUSAL AT 55'.					
							ROCK CORING					
RUN 1	55.0	56.5			10		VARIEGATED GRAY, BROWN, BLACK, RED DECOMPOSED TO	TCR: 55.5%, SCR: 11.1%, RQD: 0%				
RUN 2	56.5	61.3		61.3	24		HIGHLY WEATHERED GNEISS.	TCR: 42%, SCR: 4%, RQD: 0%				
							COULD NOT ROCK CORE ANY DEEPER; BARRELL JAMBING.					
							WATER LEVEL THROUGH AUGERS AT 25'.					
							CAVED AT 28', WATER LEVEL ON CAVE AT 25'.					

Notes/Comments:

Pocket Pentrometer Testing
S1: 3.5 TSF
S2: 2.25 TSF

DR: DECOMPOSED ROCK

ROCK CORE SAMPLES NOT LONG ENOUGH FOR COMPRESSIVE STRENGTH TESTING.

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.

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

Herman O.W. Drive HDD Cores B6-8W and B6-8E
PA-CH-0127.0000-RD
Chester County, Pennsylvania

Exhibit

A-2

EXPLORATION RESULTS

BORING LOG NO. B6-8W Herman O.W. Drive West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0127.0000-RD
20170818
Latitude: 40.06284° Longitude: -75.6795°
Approximate Surface Elev: 464 (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)
		FILL - POORLY GRADED SAND WITH SILT, trace gravel, brown, medium dense				14	4-5-5 N=10			
3.0	461+/-									
		SILT WITH SAND (ML), orange-brown, medium dense	5			16	9-10-12 N=22			
8.0	456+/-									
		POORLY GRADED SAND (SP), trace silt, trace gravel, weathered rock, orange-light brown, dense	10			8	10-18-20 N=38			
17.0	447+/-	Begin rock core at 17 feet	15							
		Run 1, Very soft, very severely to completely weathered, brown/orange/white GNEISS, highly fractured throughout run, no joints could be measured	20			41		0	1 1 1 1 1	
22.0	442+/-									
		Run 2, Similar	25			25		0	1 1 1 1 1 2	
27.0	437+/-									
		Run 3, No recovery	30			0		0	1 1 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: 08-31-2017 | Boring Completed: 09-06-2017

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

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-8W Herman O.W. Drive West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0127.0000-RD
20170818
Latitude: 40.06284° Longitude: -75.6795°
Approximate Surface Elev: 464 (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 3, No recovery *(continued)*				0			1 1	
32.0	432+/-									
		Run 4, Very soft, very severely weathered, brown/orange GNEISS, highly fractured throughout run, no joints could be measured	35			44		0	1 1 1 2 2	
37.0	427+/-									
		Run 5, Similar	40			43		7	1 1 1 2 1	
42.0	422+/-									
		Run 6, Similar	45			47		22	1 1 1 1 2	
47.0	417+/-									
		Run 7, Soft to medium hard, severely weathered, brown/orange/gray GNEISS, highly fractured throughout run, no joints could be measured	50			50.5		0	1 1 1 2 1	
52.0	412+/-									
		Run 8, Similar, soft	55			34.5		0	1 1 1 1 2	
57.0	407+/-									
		Run 9, Moderately hard, severely to moderately weathered, brown/orange/gray GNEISS, primary joint set moderately dipping; secondary joint set high angle, very close	60			56		43	1 1 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: 08-31-2017 | Boring Completed: 09-06-2017

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

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-8W Herman O.W. Drive West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0127.0000-RD
20170818
Latitude: 40.06284° Longitude: -75.6795°
Approximate Surface Elev: 464 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Run	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
62.0	402+/-	Run 9, Moderately hard, severely to moderately weathered, brown/orange/gray GNEISS, primary joint set moderately dipping; secondary joint set high angle, very close *(continued)*	56		2 2
67.0	397+/-	Run 10, Moderately hard to hard, moderately weathered, brown/gray GNEISS, primary joint set moderately dipping; secondary joint set high angle, very close	51	8	1 2 2 1 2
72.0	392+/-	Run 11, Soft to moderately hard, severely to moderately weathered, brown/gray SCHISTOSE GNEISS, primary joint set low angle; secondary joint set moderately dipping, close	60	42	1 2 1 2 1
77.0	387+/-	Run 12, Moderately hard to hard, moderately weathered, brown/gray , coarse-grained GNEISS, primary joint set high angle; secondary joint set moderately dipping, close spacing, moderately wide	60	64	1 2 2 1 2
82.0	382+/-	Run 13, Hard, very slightly weathered, gray, medium-grained GNEISS, primary joint set high angle, close, open	60	70	1 2 2 2 1
87.0	377+/-	Run 14, Similar, slight weathering	60	66	1 2 2 2 2
90		Run 15, Hard, fresh gray/dark gray, medium-grained GNEISS, primary joint set high angle, close, open	60	61	2 2 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: 08-31-2017 | Boring Completed: 09-06-2017

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

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-8W Herman O.W. Drive West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0127.0000-RD
20170818
Latitude: 40.06284° Longitude: -75.6795°
Approximate Surface Elev: 464 (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 15, Hard, fresh gray/dark gray, medium-grained GNEISS, primary joint set high angle, close, open *(continued)*									
92.0	372+/-				60			2 2	
Run 16, Moderately hard, fresh, gray, medium-grained GNEISS, primary joint set high angle, very close, wide; secondary joint set vertical, very close, wide		95			60		26	2 2 2 1 1	
97.0	367+/-								
Run 17, Moderately hard, very slightly weathered, medium-grained GNEISS, primary joint set low angle, close, moderately open; secondary joint set moderate angle, moderately close, open		100			60		71	1 2 2 2 2	
102.0	362+/-								
Run 18, Moderately hard, fresh, dark gray/black medium to fine-grained GNEISS, primary joint set high angle, very close, wide		105			60		28	2 2 2 2 3	
107.0	357+/-								
Run 19, Moderately hard, fresh, dark gray, medium-grained GNEISS, primary joint set high angle, close, open		110			60		66	2 2 3 3 3	
112.0	352+/-								
Boring Terminated at 112 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: 08-31-2017 | Boring Completed: 09-06-2017

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

Project No.: J217P078 | Exhibit: A-1

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

Boring No.:	B6-8W	Lithology :	Gneiss
Sample No.:	1	Moisture Content :	As received
Sample Depth:	84 feet	Lab Temperature :	70° F
Sampling Date:	8/31/17	Loading Rate:	55 psi/s
		Time to Failure:	6 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	19,850 lb
Length:	4.52 in	Compressive Strength:	6,447 psi
L/D:	2.28	Compressive Strength:	44.45 Mpa
End Area:	3.08 in^2	Unit Weight	171 pcf

Before the Test

After the Test

Drawing # :	PA-CH-0127.0000-RD
PO # :	20170818
Crossing :	Herman O.W. Drive
Spread :	Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/17/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/17/2017

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

Boring No.:	B6-8W	Lithology :	Gneiss
Sample No.:	2	Moisture Content :	As received
Sample Depth:	90 feet	Lab Temperature :	70° F
Sampling Date:	8/31/17	Loading Rate:	55 psi/s
		Time to Failure:	1 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	4,220 lb
Length:	4.42 in	Compressive Strength:	1,371 psi
L/D:	2.23	Compressive Strength:	9.45 Mpa
End Area:	3.08 in^2	Unit Weight	175 pcf

Before the Test

After the Test

Drawing # :	PA-CH-0127.0000-RD
PO # :	20170818
Crossing :	Herman O.W. Drive
Spread :	Spread 6

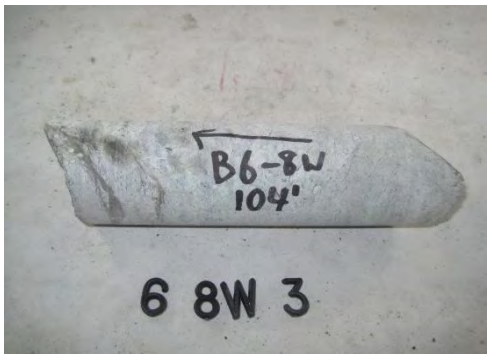
Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/17/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/17/2017

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

Boring No.:	B6-8W	Lithology :	Gneiss
Sample No.:	3	Moisture Content :	As received
Sample Depth:	104 feet	Lab Temperature :	70° F
Sampling Date:	8/31/17	Loading Rate:	55 psi/s
		Time to Failure:	5 min

Diameter:	1.97 in	Maximum Axial Load at Failure:	16,320 lb
Length:	4.53 in	Compressive Strength:	5,354 psi
L/D:	2.30	Compressive Strength:	36.92 Mpa
End Area:	3.05 in^2	Unit Weight	166 pcf

Before the Test



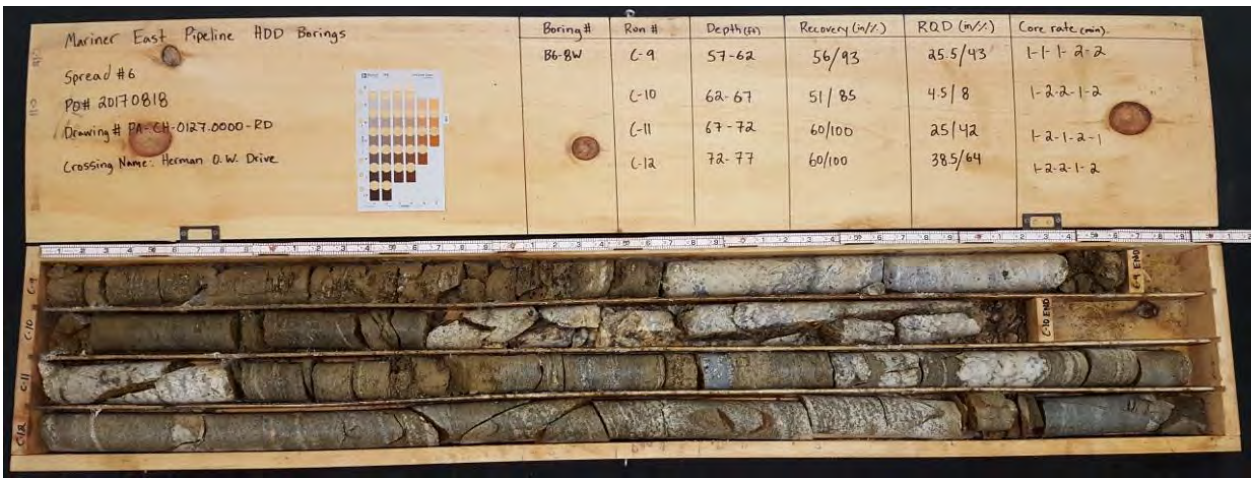
After the Test

Drawing # :	PA-CH-0127.0000-RD
PO # :	20170818
Crossing :	Herman O.W. Drive
Spread :	Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	H. Whitford
Project No.	J217P078		Test Date:	10/17/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/17/2017

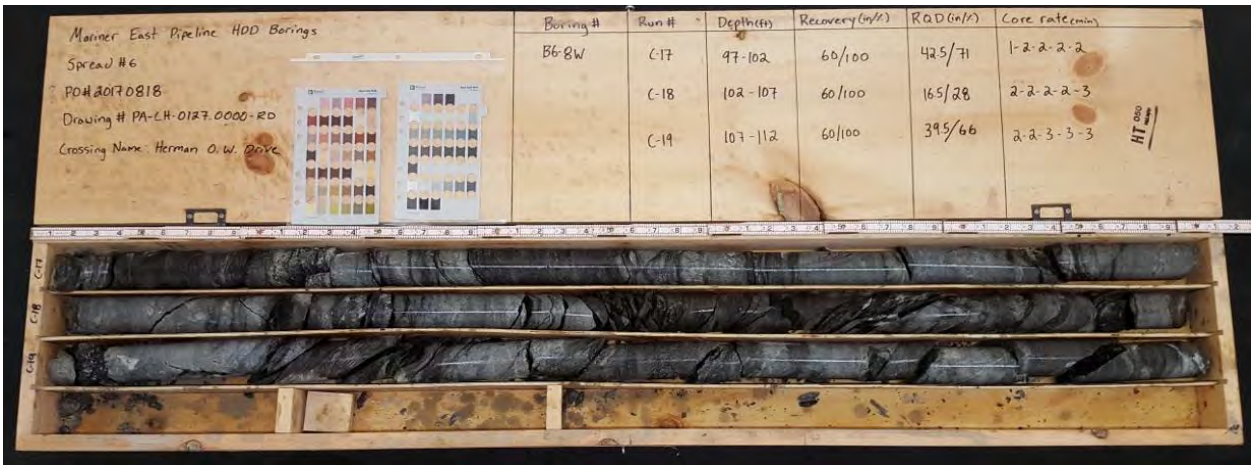
Photograph 1: B6-8W, Samples C-1 to C-4 (17 to 37 feet)

Photograph 2: B6-8W, Samples C-5 to C-8 (37 to 57 feet)

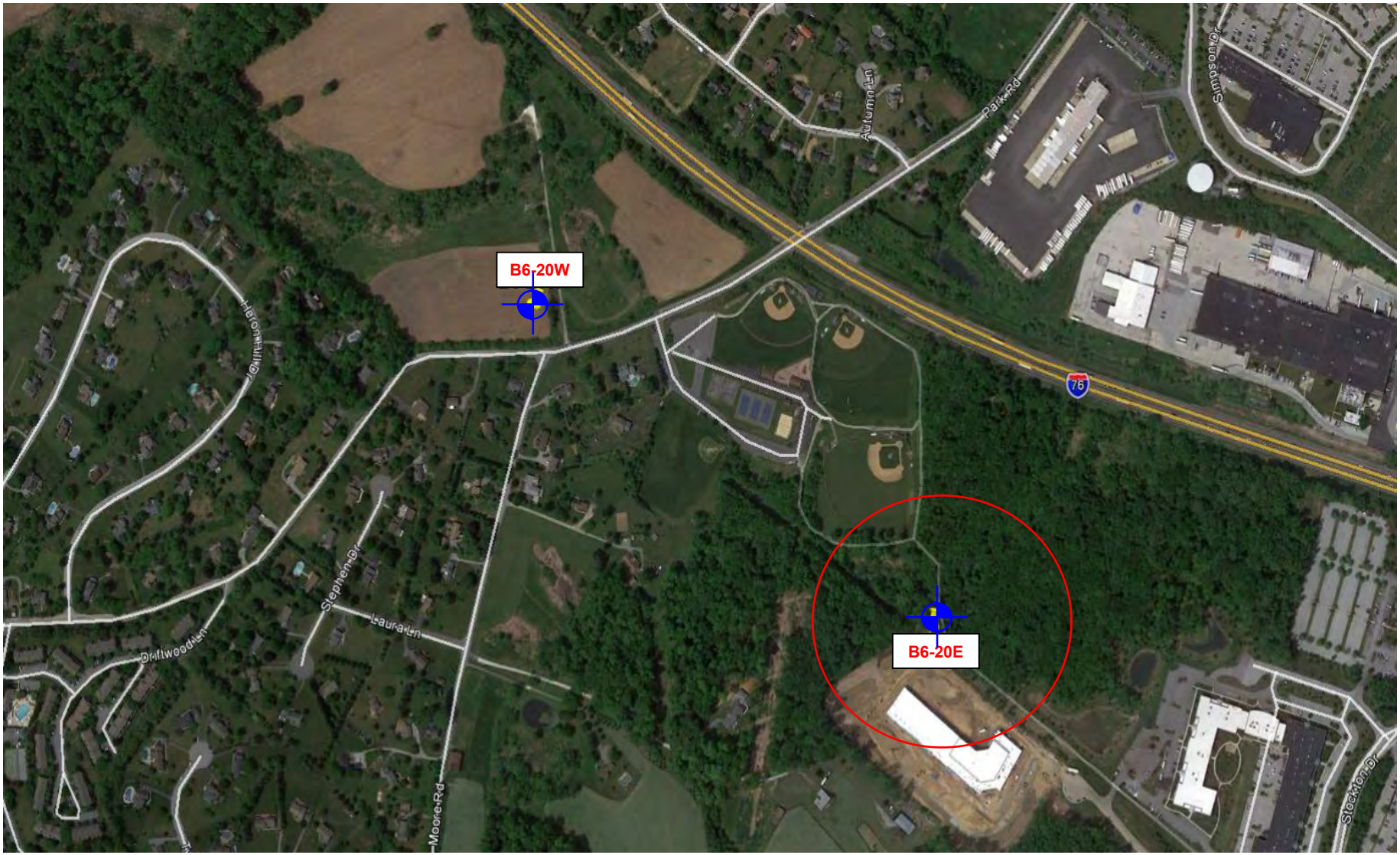


Photograph 3: B6-8W, Samples C-9 to C-12 (57 to 77 feet)

Photograph 4: B6-8W, Samples C-13 to C-16 (77 to 97 feet)



Photograph 5: B6-8W, Samples C-17 to C-19 (97 to 112 feet)



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

Park Road HDD Core B6-20W and B6-20E
PA-CH-0111.0000-RD
Chester County, Pennsylvania

Exhibit

A-2

EXPLORATION RESULTS

BORING LOG NO. B6-20E Park Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0111.0000-RD
20170911
Latitude: 40.071119° Longitude: -75.694655°
Approximate Surface Elev: 459 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	FILL - LEAN CLAY, with rock fragments, trace organic matter, dark brown				4	2-2-2 N=4			0.25
5.0	454+/-	5							
	SANDY LEAN CLAY (CL), brown to gray, stiff to hard, (Residual soil)		▽		13	8-7-7 N=14			0
		10			14	9-19-16 N=35			
16.0	443+/-	15							
	Run 1, Very hard, severely weathered, white with gray and red, QUARTZITE, primary joint set, low angle, close spacing, moderately open; secondary joint set, vertical, close spacing, moderately open to open				37		36	2.5 2.25 2 2 1.5	
21.0	438+/-	20							
	Run 2, Very hard, severely weathered, white with gray and black, QUARTZITE, primary joint set, moderately dipping, close spacing, moderately open				15		15	1 1 1.25 1 1.5	
26.0	433+/-	25							
	Run 3, Completely weathered rock, missing recovery washed out in drill water				4		7	1.5 0.75 1 1 1.5	
		30							

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

▽ *9' on 9/26/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-26-2017

Drill Rig: CME-850 | Driller: Terracon/Peter M.

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-20E Park Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0111.0000-RD
20170911
Latitude: 40.071119° Longitude: -75.694655°
Approximate Surface Elev: 459 (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)
31.0	428+/-					4				
		Run 4, Hard, severely weathered, blue-gray with black, fine-grained, GNEISS, primary joint set, moderately dipping, close spacing, moderately open; secondary joint set, high angle, close spacing, open	35			27		25	0.5 4 2 1.5 2.25	
36.0	423+/-									
		Run 5, Hard to medium hard, severely weathered, blue-gray with black and red-brown, fine-grained, GNEISS, very thin foliation; primary joint set, moderately dipping, very close to close spacing, planar, open	40			28		7	2 1.5 2 2.5 2	
41.0	418+/-									
		Run 6, Similar to 42.2 feet At 42.2 feet: Very hard, moderately to highly weathered, white and black, coarse-grained QUARTZITE, primary joint set, low angle, close spacing, slightly open to open; secondary joint set, vertical, close spacing, moderately open to open; secondary joint set, vertical, close spacing, open	45			44		35	1.5 2.25 3.25 4.5 4.5	
46.0	413+/-									
		From 46 to 49 feet: Completely weathered GNEISS								
49.0	410+/-									
		Run 7, Very hard, moderately weathered, white and black, coarse-grained GNEISS, very thin foliation; primary joint set, vertical, close spacing, slightly open to open	50			16		58	2 2	
51.0	408+/-									
		Run 8, Soft to very hard, moderately weathered to residual soil, blue with gray, brown and white, fine-grained GNEISS, primary joint set, low angle, close to very close spacing, moderately open to open From 55 to 56 feet: Medium to very hard, moderately to completely weathered, blue with white and brown, coarse-grained, healed BRECCIA, planar horizontal foliation; primary joint set, low angle, close, open	55			54		43	2.75 2.25 2.75 1.5 1.5	
56.0	403+/-									
		Run 9, Similar to Run 8, with QUARTZITE from 56.8 to 57.3 feet and healed BRECCIA from 59.3 to 60.3 feet, with occasional seams of pyrite from 59.5 to 60 feet	60			53		41	3 2.25 3 4 2.5	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

▽ *9' on 9/26/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-26-2017

Drill Rig: CME-850 | Driller: Terracon/Peter M.

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-20E Park Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0111.0000-RD
20170911
Latitude: 40.071119° Longitude: -75.694655°
Approximate Surface Elev: 459 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	RECOVERY (In.)	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
61.0	398+/-		53			
		Run 10, Very hard, slightly weathered, blue-gray with white and brown, GNEISS, horizontal, planar, very thin foliation; primary joint set, low angle, close spacing, moderately open; secondary joint set, high angle, close spacing, moderately open Soft, completely weathered zone from 61 to 61.6 feet	58	81	2.25 2.75 3.5 4 5	
66.0	393+/-					
		Run 11, Similar, low angled, planar, thin foliation; primary joint set, moderately dipping, very close to close, open; secondary joint set, high angle, close to moderately close, moderately open, occasional seams of pyrite from 68.5 to 70 feet	58	73	3 3 2 2.75 2	
71.0	388+/-					
		Run 12, Similar	60	93	4 2.75 2.5 2.75 3	
76.0	383+/-					
		Run 13, Similar From 76 to 76.8 feet: Coarse-grained GNEISS, undulated, very thin foliation; low angle joints	59	76	3.5 2.25 1.75 2.25 3	
81.0	378+/-					
		Run 14, Similar From 85.8 to 86 feet: Completely weathered	60	86	3 2 3.25 3 1.5	
86.0	373+/-					
		Run 15, Similar	57	83	3 2 2.25 2 1.75	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

▽ *9' on 9/26/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-26-2017

Drill Rig: CME-850 | Driller: Terracon/Peter M.

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-20E Park Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0111.0000-RD
20170911
Latitude: 40.071119° Longitude: -75.694655°
Approximate Surface Elev: 459 (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)
91.0	368+/-	Run 15, Similar *(continued)*				57				
		Run 16, Similar, primary joint set, moderate angle, slightly open, close, no secondary joints From 94.5 to 95.3 feet: Highly fractured zone From 95.3 to 95.8 feet: Vertical joints	95			60		80	2.75 2 2 2.5 3	
96.0	363+/-	Run 17, Very hard, severely to slightly weathered, gray with black and white, fine-grained, FELSIC GNEISS, low angle, undulated, thin foliation; primary joint set, low angle, close spacing, slightly open to open; secondary joint set, vertical, close spacing, moderately open	100			60		52	3 3 2.75 3.5 3.5	
101.0	358+/-	Run 18, Similar, tertiary joint set, vertical, close spacing, moderately open From 103.3 to 104.3 feet: Highly fractured zone From 104.8 to 105.6 feet: Vertical joint	105			60		43	3.25 2.25 3.25 3.5 3.25	
106.0	353+/-	Run 19, Similar, secondary joint set, high angle, close spacing, moderately open From 109 to 109.4 feet and 110 to 110.5 feet: very coarse grained PEGMATITE seams	110			60		65	3 2 3.25 2.75 2.75	
111.0	348+/-	Run 20, Similar, primary joint set, moderately dipping, close spacing, moderately open; secondary joint set, high angle, close, moderately open to open From 112.3 to 112.7 feet and 114.8 to 115.7 feet: Very coarse grained PEGMATITE	115			60		48	3.5 2 2.75 3 3	
116.0	343+/-	Run 21, Similar From 116.8 to 118.1 feet: Highly fractured zone At 117.8 feet: Coarse-grained seam of PEGMATITE	120			53		63	3.75 3 4.5 4.5 3.25	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

▽ *9' on 9/26/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-26-2017

Drill Rig: CME-850 | Driller: Terracon/Peter M.

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-20E Park Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0111.0000-RD
20170911
Latitude: 40.071119° Longitude: -75.694655°
Approximate Surface Elev: 459 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Run / Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
121.0	338+/-					53				
		Run 22, Hard, slightly weathered, gray with white, coarse-grained PEGMATITE, horizontal, planar, thin foliation	125			56		93	5.5 5 5 3.25 4	
126.0	333+/-									
		Run 23, From 126 to 129 feet: Similar to Run 22, PEGMATITE, sharp contact at 129 feet From 129 to 131 feet: Similar to Run 20, FELSIC GNEISS From 130.5 to 130.8 feet: Coarse grained	130			58		73	4 3.5 4.5 5 4	
131.0	328+/-									
		Run 24, Similar to Run 20, FELSIC GNEISS, primary joint set, moderately dipping, close spacing, moderately open to open; secondary joint set, vertical, close spacing, slightly open to open From 133 to 134.8 feet: Vertical fracture	135			55		70	5 4.5 4.75 5 5	
136.0	323+/-									
		Boring Terminated at 136 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

▽ *9' on 9/26/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-25-2017 | Boring Completed: 09-26-2017

Drill Rig: CME-850 | Driller: Terracon/Peter M.

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.:	B6-20E	Lithology :	Quartzite
Sample No.:	1	Moisture Content :	As received
Sample Depth:	16 feet	Lab Temperature :	70° F
Sampling Date:	9/25/17	Loading Rate:	55 psi/s
		Time to Failure:	8 min

Diameter:	1.96 in	Maximum Axial Load at Failure:	26,680 lb
Length:	4.50 in	Compressive Strength:	8,843 psi
L/D:	2.30	Compressive Strength:	60.97 Mpa
End Area:	3.02 in^2	Unit Weight	161 pcf

Before the Test

After the Test

Drawing # :	PA-CH-0111.0000-RD
PO # :	20170911
Crossing :	Park 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.		Review Date :	10/16/2017

77 Sundial Ave., Suite 401 W
Manchester, New Hampshire

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

Boring No.:	B6-20E	Lithology :	Quartzite
Sample No.:	2	Moisture Content :	As received
Sample Depth:	27 feet	Lab Temperature :	70° F
Sampling Date:	9/25/17	Loading Rate:	55 psi/s
		Time to Failure:	13 min

Diameter:	1.96 in	Maximum Axial Load at Failure:	43,820 lb
Length:	4.61 in	Compressive Strength:	14,523 psi
L/D:	2.35	Compressive Strength:	100.14 Mpa
End Area:	3.02 in^2	Unit Weight	176 pcf

Before the Test

After the Test

Drawing # :	PA-CH-0111.0000-RD
PO # :	20170911
Crossing :	Park 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 :	10/16/2017

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

Boring No.:	B6-20E	Lithology :	Gneiss
Sample No.:	3	Moisture Content :	As received
Sample Depth:	54 feet	Lab Temperature :	70° F
Sampling Date:	9/25/17	Loading Rate:	55 psi/s
		Time to Failure:	16 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	52,160 lb
Length:	4.55 in	Compressive Strength:	16,770 psi
L/D:	2.29	Compressive Strength:	115.63 Mpa
End Area:	3.11 in^2	Unit Weight	177 pcf

Before the Test

Photographs are mislabeled as 6-20E-1

After the Test

Drawing # :	PA-CH-0111.0000-RD
PO # :	20170911
Crossing :	Park 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 :	10/16/2017

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

Boring No.:	B6-20E	Lithology :	Gneiss
Sample No.:	4	Moisture Content :	As received
Sample Depth:	76 feet	Lab Temperature :	70° F
Sampling Date:	9/25/17	Loading Rate:	55 psi/s
		Time to Failure:	8 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	26,320 lb
Length:	4.25 in	Compressive Strength:	8,548 psi
L/D:	2.15	Compressive Strength:	58.94 Mpa
End Area:	3.08 in^2	Unit Weight	178 pcf

Before the Test

Photographs are mislabeled as 6-20E-2

After the Test

Drawing # :	PA-CH-0111.0000-RD
PO # :	20170911
Crossing :	Park 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.		Review Date :	10/16/2017

77 Sundial Ave., Suite 401 W
Manchester, New Hampshire

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

Boring No.:	B6-20E	Lithology :	Gneiss
Sample No.:	5	Moisture Content :	As received
Sample Depth:	87 feet	Lab Temperature :	70° F
Sampling Date:	9/25/17	Loading Rate:	55 psi/s
		Time to Failure:	5 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	15,210 lb
Length:	4.56 in	Compressive Strength:	4,940 psi
L/D:	2.30	Compressive Strength:	34.06 Mpa
End Area:	3.08 in^2	Unit Weight	168 pcf

Before the Test

Photographs are mislabeled as 6-20E-3

After the Test

Drawing # :	PA-CH-0111.0000-RD
PO # :	20170911
Crossing :	Park 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 :	10/16/2017

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

Boring No.:	B6-20E	Lithology :	Gneiss
Sample No.:	6	Moisture Content :	As received
Sample Depth:	96 feet	Lab Temperature :	70° F
Sampling Date:	9/25/17	Loading Rate:	55 psi/s
		Time to Failure:	11 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	35,110 lb
Length:	4.52 in	Compressive Strength:	11,288 psi
L/D:	2.27	Compressive Strength:	77.83 Mpa
End Area:	3.11 in^2	Unit Weight	172 pcf

Before the Test

Photographs are mislabeled as 6-20E-4

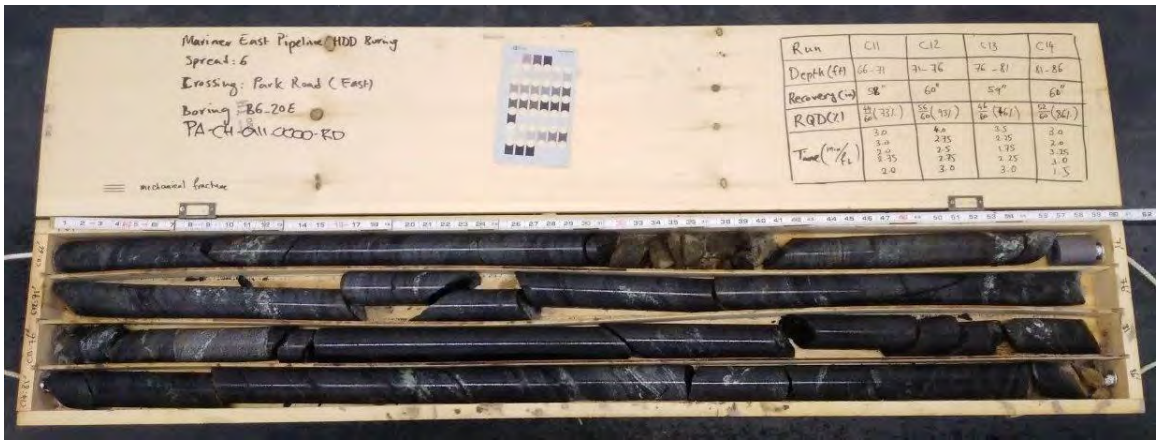
After the Test

Drawing # :	PA-CH-0111.0000-RD
PO # :	20170911
Crossing :	Park 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 :	10/16/2017

Photograph 1: B6-20E, Samples C-1 to C-5 (16 to 41 feet)

Photograph 2: B6-20E, Samples C-6 to C-10 (41 to 66 feet)



Photograph 3: B6-20E, Samples C-11 to C-14 (66 to 86 feet)

Photograph 4: B6-20E, Samples C-15 to C-18 (86 to 106 feet)

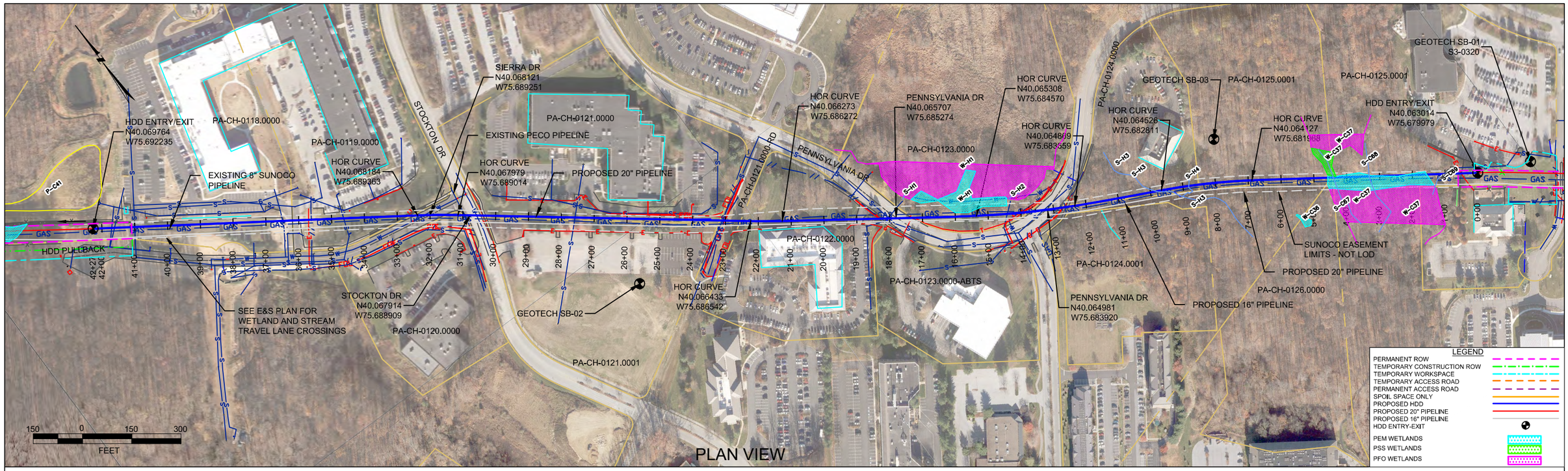
Photograph 5: B6-20E, Samples C-19 to C-22 (106 to 126 feet)

Photograph 6: B6-20E, Samples C-23 to C-24 (126 to 136 feet)

PENNSYLVANIA DRIVE
PADEP SECTION 105 PERMIT NO.: E15-862
PA-CH-0124.0000-RD
(SPLP HDD No. S3-0310)

ATTACHMENT 2

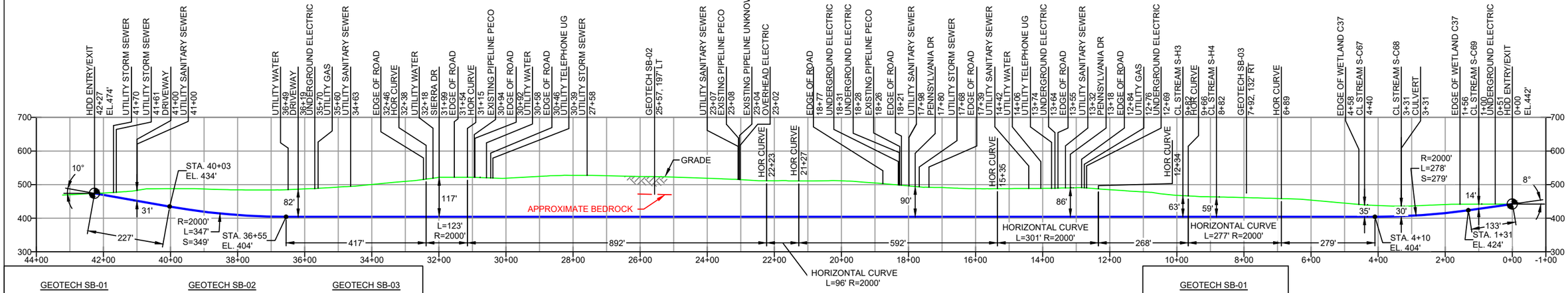
HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



PLAN VIEW

PROFILE VIEW

CHESTER COUNTY, PENNSYLVANIA - UWCHLAN TOWNSHIP
S3-0310



GEOTECH SB-01
-NG EL. 495'
-TOPSOIL (0' - 0.1')
-GROUNDWATER (30.5')
-SM (0.1' - 73.8')
-COMPLETION DEPTH EL. 421'

GEOTECH SB-02
-NG EL. 516'
-TOPSOIL (0' - 0.3')
-CL (0.3' - 6.5')
-GROUNDWATER (38.0')
-SM (6.5' - 45.0')
-FRACTURED GNEISS (45.0' - 51.5')
-COMPLETION DEPTH EL. 471'

GEOTECH SB-03
-NG EL. 475'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 12.0')
-SM/GM (12.0' - 14.0')
-SM (14.0' - 30.0')
-COMPLETION DEPTH EL. 435'

NOTE: REFER TO TEST BORING LOG S3-0310 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=):4227'
   HDD PIPE LENGTH (S=):4232'
   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.

GEOTECH SB-01
-NG EL. 450'
-TOPSOIL (0' - 0.2')
-ML (0.2' - 9.0')
-GROUNDWATER (25.0')
-SM (9.0' - 53.0')
-WEATHERED GNEISS (53.0' - 61.3')
-COMPLETION DEPTH EL. 389'

NOTE: REFER TO TEST BORING LOG S3-0320 FOR COMPLETE SOIL MATERIAL DESCRIPTION

Figure 1.

Permitted 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-6.32	TO	ES-6.35	EROSION & SEDIMENT PLAN	
SHEET 19	TO	SHEET 20	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	MRS	10/21/16	RMB	10/21/16	AAW	10/21/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
0	ISSUED FOR CONSTRUCTION	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

20-INCH HORIZONTAL DIRECTIONAL DRILL
PENNSYLVANIA DRIVE
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=300'

DWG. NO: PA-CH-0124.0000-RD

PLAN VIEW

PROFILE VIEW

CHESTER COUNTY, PENNSYLVANIA - UWCHLAN & UPPER UWCHLAN TOWNSHIP
S3-0310

GEOTECH SB-01
- NG EL. 495'
- -TOPSOIL (0' - 0.1')
- -GROUNDWATER (30.5')
- -SM (0.1' - 73.8')
- -COMPLETION DEPTH EL. 421'

GEOTECH SB-02
- NG EL. 516'
- -TOPSOIL (0' - 0.3')
- -CL (0.3' - 6.5')
- -GROUNDWATER (38.0')
- -SM (6.5' - 45.0')
- -FRACTURED GNEISS (45.0' - 51.5')
- -COMPLETION DEPTH EL. 471'

GEOTECH SB-03
- NG EL. 475'
- -TOPSOIL (0' - 0.3')
- -SM (0.3' - 12.0')
- -SM/GM (12.0' - 14.0')
- -SM (14.0' - 30.0')
- -COMPLETION DEPTH EL. 435'

NOTE: REFER TO TEST BORING LOG S3-0310 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH SB-01
- NG EL. 450'
- -TOPSOIL (0' - 0.2')
- -ML (0.2' - 9.0')
- -GROUNDWATER (25.0')
- -SM (9.0' - 53.0')
- -WEATHERED GNEISS (53.0' - 61.3')
- -COMPLETION DEPTH EL. 389'

NOTE: REFER TO TEST BORING LOG S3-0320 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=):4344'
   HDD PIPE LENGTH (S=):4365'
   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.

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

ES-6.32	TO	ES-6.35	EROSION & SEDIMENT PLAN	
SHEET 19	TO	SHEET 20	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP4	ADDED IR, EARTH SUBSIDENCE AND 16" AS-DRILLED INFORMATION	MRS	11/01/19	RMB	11/01/19	AMC	11/01/19
EP3	SWITCHED 20" CENTERLINE LOCATION AND INCREASED DEPTH OF DRILL	MRS	02/11/19	RMB	02/11/19	AMC	02/11/19
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	10/21/16	RMB	10/21/16	AAW	10/21/16
EP1	REVISED PER PADEP COMMENTS	MRS	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16
0	ISSUED FOR CONSTRUCTION	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16

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SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
PENNSYLVANIA DRIVE
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=300' | DWG. NO: PA-CH-0124.0000-RD