HORIZONTAL DIRECTIONAL DRILL ANALYSIS
LITTLE CONESTOGA ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E15-862
PA-CH-0100.0000-RD
(SPLP HDD# S3-0290)

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This reanalysis of the horizontal directional drill (HDD) installation of a 20-inch diameter pipeline that traverses Little Conestoga Road in Upper Uwchlan Township, Chester County, Pennsylvania is in accordance with the Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L for HDDs listed on Exhibit 3 of the Stipulated Order.

The installation of the 16-inch diameter pipeline using HDD was initiated before the temporary injunction issued by the Pennsylvania Department of Environmental Protection (PADEP) Environmental Hearing Board on July 25, 2017. The 16-inch HDD had an inadvertent return (IR) on the installation of the first pipe (16-inch) and therefore, the installation of the second pipe (20-inch) requires reanalysis. The IRs associated with the HDD of the 16-inch pipe were fully remediated and the HDD of the 16-inch pipe was completed.

The 20-inch pipe HDD is referred to herein as HDD S3-0290.

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. Characteristics of the redesigned HDD and stress allowances are provided in Horizontal Directional Drill Redesign section at the end of this report.

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 2,564 feet (ft)
- Entry/Exit angle: 10 degrees and 14 degrees
- Maximum depth of cover: 170 ft
- Maximum depth of cover under wetland H17: 70 ft
- Maximum depth of cover under stream S-H11: 46 ft
- Pipe design radius: 2,200 ft

ROOT CAUSE ANALYSIS FOR THE 20-INCH PIPE INSTALLATION IR

The occurrence of the IR events during the installation of the 16-inch pipe at S3-0290 occurred near the southeast entry/exit where the overburden is thin relative to the HDD profile. The HDD was approximately 50-60 feet below ground surface at the time of the IRs. The geophysical study revealed a zone of fractured weathered bedrock in the same area as the two IRs. The increased drilling fluid pressure to maintain returns to the point of entry and shallow profile associated with HDD entry/exit, within the weathered/fractured bedrock, are the contributing factors to the occurrence of the IRs near the entry/exit of S3-0290. The IR information presented graphically on Figures 1 and 2 in Attachment 2 presents the plan and cross section views of IR events occurring during installation of the 16-inch pipe. This figure presents the dates and locations of IRs occurring during this HDD in relation to the tool location in the profile and allows for correlation to geologic monitoring data collected by the geologists during active drilling. In addition, Section 3.0 of the HDD Hydrogeologic Reevaluation Report included as Attachment 1 provides additional details concerning dates, locations, and geologic conditions associated with IRs and losses of circulation (LOCs) experienced during installation of the 16-inch pipe. SPLP utilized all the foregoing information obtained during installation of the 16-inch pipe in the assessment of construction alternatives and the proposed revisions to the 20-inch HDD profile.

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GEOLOGIC ANALYSIS

HDD S3-0290 is in southeastern Pennsylvania within the Piedmont Physiographic Province, Piedmont Upland Section. Broad, rounded to flat-topped hills and shallow valleys with low to moderate topographic relief, characterizes the Piedmont Uplands Section. The geology of this region is generally comprised of meta-igneous and metasedimentary rocks (gneiss and schist) of Proterozoic to Early- to Mid-Paleozoic age that have been severely folded and fractured. Rolling rounded and flat-topped hills and shallow valleys characterize the area of HDD S3-0290. Based on published mapping, the majority of the HDD bore profile passes through graphitic gneiss (referred to as the Pickering Gneiss), with the northwest end of the HDD passing through a metadiabase.

Based upon the data obtained from vertical geotech bores at both ends of the HDD, the HDD profile will pass through overburden and weathered bedrock until achieving 50 ft of depth below ground surface (bgs). From 50 to 100 ft of depth bgs, bedrock consistency improves with core recoveries generally near or at 100%, but bedrock strength is variable, with RQD values ranging from 0 to 100. The maximum profile depth is at an elevation of 278 ft; which correlates to -216 ft on the west end geotech core, and -103 ft on the east end geotech core. Based on the geotech data the horizontal run of the HDD will be a minimum of 30 ft below the top of a bedrock zone having 100% recovery values, with RQD values ranging from 20 – 100.

The geophysical survey data indicates potential fracture zones crossing the HDD alignment at a frequency of approximately one every 100 to 200 feet in the northwestern part of the alignment, with a greater density (generally one every 50 to 100 feet in the southeastern part of the alignment; however, data recovery to profile depth was limited to the eastern 300 ft of the revised HDD profile. The IRs discussed above occurred adjacent to HDD stations 22+57 and 22+90 on the revised profile. At these locations, both the seismic refraction data profile and the electrical resistivity profile indicate a fracture zone; therefore, these areas will require enhanced monitoring efforts during the second drilling effort.

Attachment 1 provides an extensive discussion on the geology and the results of the geotechnical and geophysical investigations performed at this location.

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

In general, groundwater flow proximal to HDD S3-0290 moves along gradients established by a water table surface that is a subdued reflection of the local topography. The alignment of HDD S3-0290 passes from the northwest to the southeast in the Marsh Creek Watershed with groundwater flow in the HDD bore alignment being towards Marsh Creek/Marsh Lake to the south and southwest.

Based on soil borings and borings advanced into bedrock, groundwater has been encountered in both the soil/weathered bedrock zone and 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.

A PAGWIS search of wells completed in gneissic bedrock in Uwchland and Upper Uwchlan Townships in Chester County was completed. The wells listed with recorded static water levels, had water levels ranging from 4 to 170 ft bgs with an average of 36 ft-bgs. The published median well yield for the graphitic gneiss is typically 10 gallons per minute (gpm) or less; wells can have potential yields of 35 gpm from wells properly sited and developed. The PAGWIS search indicated a range in well yields from 0 to 200 gallons per minute with an average of 21 gallons per minute.

As discussed below in the Adjacent Features section, most residences in the area of this HDD appear to be on public water.

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

ADJACENT FEATURES ANALYSIS

The crossing of Little Conestoga Road is located in Uwchlan Township in Chester County, approximately 11.8 miles (mi) south of the community of Pottstown, and approximately 30.2 mi northwest of Philadelphia, Pennsylvania.

The pipeline route utilizes an existing SPLP pipeline easement from the north side of the intersection of Milford Road with Little Conestoga Road to approximately 800 ft southeast of Highview Road. This HDD is set under Little Conestoga Road, Milford Road, an existing SPLP pump station, three driveways within a residential development, various utilities (overhead electric lines and underground utilities, including water lines, telephone lines, and a storm sewer line) situated immediately adjacent and parallel to or crossing perpendicular to the easement, Highview Road, one wetland, and two streams. Wetland H17 is comprised of palustrine emergent and forested cover types. Both streams (streams S-H11 and S-H10) drain to a Chapter 93 designated high quality stream, Marsh Creek that is stocked with trout. The presence of these features necessitated the HDD to avoid effects on: public infrastructure; utilities; residences; two high quality streams and their floodways; and one wetland, including its forested components.

SPLP has identified all landowners with property located within 450 ft of the HDD alignment. SPLP sent each of these landowners a notice letter via both certified and first class mail that included an offer to sample the landowner's private water supply/well 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 Project Right-of-Way agent for the local area and provide SPLP with information regarding: (1) whether the landowner has a well; (2) where that well is located, and its depth and size if known; and (3) whether the landowner would like to have the well 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, and Office of Programs at PADEP's Central Office.

SPLP's public outreach results indicated the presence of one (1) water well within 450 ft of the proposed HDD. A second well (WL-09052017-613-02) was located beyond the 450-foot search zone, at 565 feet from the alignment. A depiction of the identified private water well and those with public water service is provided in Attachment 2.

There were no water well impact complaints during the installation of the 16-inch pipeline, therefore, it is expected that neither water well will be impacted by the installation of the 20-inch pipeline.

ALTERNATIVES ANALYSIS

As required by the Order, the reanalysis of HDD S3-0300-20 includes an evaluation of open cut alternatives and a re-route analysis. As part of the Pennsylvania Department of Environmental Protection (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.

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The HDD as permitted is an alternative plan of installation to a conventional open trench construction plan to avoid direct impacts to two streams, their associated floodways and forested wetland riparian areas, wetland H17, parallel and conflicting utilities, public infrastructure (Little Conestoga Road, Milford Road, and Highview Road), and several residences.
Alteration of the current permitted route and plans for installation would require major modifications of the state Chapter 102 and Chapter 105 permits, and authorization issued by the U.S. Army Corps of Engineers.

Open-cut Analysis

During the Pennsylvania Department of Environmental Protection (PADEP) Chapter 105 permit process for the Pennsylvania Pipeline Project, SPLP created and submitted for review a project-wide alternatives analysis. The baseline route provided for the pipeline construction to cross every wetland and stream on the project by open trench construction procedures. The alternatives analysis submitted to PADEP conceptually analyzed the feasibility of any alternative to trenched resource crossings (e.g., reroute, bore, HDD). The decision making processes for switching from an open cut to HDD is discussed thoroughly in the submitted alternatives analysis and was an important part of the overall PADEP approval of HDD plans as currently permitted. Where HDDs are planned and received PADEP Chapter 105 and 102 authorizations, they have already been evaluated to be the preferred alternative based on several variables that led the SPLP and PADEP to believe there would be less impacts on the environment in general, and aquatic and upland natural resources specifically, if these resources were drilled rather than trenched.

Considering the location of adjacent features and existing utilities, an excavation of sufficient size to accommodate an open trench construction method could result in disturbances to adjacent residences and damages and disruption to service on existing utility lines and public infrastructure (e.g., Little Conestoga Road, Milford Road, and Highview Road). Additionally, use of conventional open-cut would directly affect 304.5 square feet of state water bottoms, 0.258 acre of floodway, and 0.219 acre of wetlands, including conversion of 0.040 acre of forested wetlands.

Conventional Auger Bore Analysis

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 foot at a time, or less, varying by the underlying substrate. Conventional auger bores for the 16 and 20-inch pipelines, attempted at longer distances, have at times had alignment drift and elevation deflections which have complicated installation. Drift and deflection are safety concerns when boring adjacent to in-service pipelines and other utilities.

The western 1,900 ft of the proposed HDD crosses two public roads and avoids surface disturbance within and adjacent to six (6) residential home sites. This length exceeds the technical limits of performance by a conventional auger bore.

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.

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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.

SPLP's construction contractors have successfully completed one (1) Direct Pipe Bore approximately 925 ft on the PPP. The western portion of the proposed HDD extends approximately 1,900 ft to cross two public roads and avoid surface disturbance within and adjacent to six (6) residential home sites. This length of crossing is longer than our contractors are willing to attempt using this construction method.

Re-Route Analysis

The general route of the Pennsylvania Pipeline Project in this area of the state generally proceeds from the northwest to the southeast. There are no nearby existing utility corridors that can be considered as possible alternative routes.

No practicable re-route option lies to the south of the proposed route. Marsh Creek Reservoir occurs south of the project route, and attempting to route around the lake would induce a reroute of the entire project many miles in extent, and would require establishing a Greenfield utility corridor. Compared to this proposed HDD which is only 2,660 ft in extent, a hypothetical Greenfield route would affect many previously unencumbered properties; would increase the number and extent of Waters of the Commonwealth to be crossed; result increased clearing of forested habitats; and would place the pipeline in near proximity to many residential home sites.

A 1.01 mile reroute to the north of the HDD is technically feasible. This would entail adjusting the project route prior to this HDD's northwest entry/exit point to proceed north, cross under the Pennsylvania Turnpike, then proceed east for 0.7 miles parallel to the turnpike, cross Little Conestoga Road, then turn south, cross under the turnpike, and then re-intersect the existing project route just east of this HDDs southeast entry/exit point. There is no existing utility corridor here, however; therefore, this route would create a Greenfield utility corridor and would result in encumbering previously unaffected properties. The route would still cross two Waters of the Commonwealth and possible forested wetlands, and would pass in near proximity or immediately adjacent to five residential home sites. Both crossings of the turnpike would require "mini" HDD's or direct pipe bores to achieve the required depth of cover under the highway. Considered against the possibility of additional IR's occurring on the proposed HDD, which are readily contained and cleaned up with minimal affect to natural resources, the permanent taking of the new easement and likely need to use condemnation against previously unaffected landowners results in SPLP's opinion that managing the proposed HDD is the preferred option.

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HORIZONTAL DIRECTIONAL DRILL REDESIGN

SPLP has considered all geologic data and the results of the installation of the 16-inch pipeline and has made further adjustments to the plan of construction for the 20-inch pipeline to include a redesign of the 20-inch HDD. 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: 2,640 (ft)
- Entry/Exit angle: 16 – 18 degrees
- Maximum Depth of cover: 200 ft
- Pipe design radius: 2,400 ft

The HDD redesign is limited by presence of wetlands and streams adjacent to the southeast entry/exit point. These resources occur before and after the entry/exit, and if the profile were extended 500 ft further to the southeast, additional wetlands occur again before and after another possible entry/exit point. As a result, the profile cannot be redesigned to be constructed on the southeast end to avoid Waters of the Commonwealth above the profile while at shallow depths. The presence of these natural resources is a limiting factor to the profile redesign.

The northwest entry/exit point could be extended further to the northwest; however, the risk of IRs would not be reduced by this change.

The entry and exit angles have been maximized to the drilling rigs maximum adjustment level, and the allowable breakover stress radius to tie-in the HDD pipeline pull segment to the conventionally laid pipe. The northwest entry/exit angle exceeds the breakover stress allowance of the pipeline, which will be managed by digging down the pipeline trench at this location and ramping it at an angle to the northwest to prevent exceeding the pipe's free stress tolerance, or a custom fabricated pipe bend will be welded at the tie-in

The entry and exit radius to the horizontal run of the profile at 2400 ft is well below the pipe stress allowance; however, adjusting either of these radii to a tighter curve; would result in increasing the entry/exit angles; which are already at or above allowable limits for equipment operations or pipe free stress curvature.

Since the root cause of the IRs as discussed above is identified as the shallow depth of cover while within overburden and weathered rock, the redesigned HDD profile has maximized the depth of cover below the prior IR locations as a preventative measure.

To correct the drilling pressures identified as contributing to the IR's on the 16-inch pipeline installation, the 20-inch pipeline will be drilled from east to west, or from low elevation to high elevation on the profile.

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 and increased the depth of profile an additional 34 ft at the location of the IRs occurring during installation of the 16-inch pipeline; therefore, adjustments to the plan of construction for the 20-inch pipeline represent a reduced risk of IRs. IRs are common on entry and exit of the drilling tool and other measures are required to minimize IR potential. Upon the start of this HDD, SPLP will employ the following HDD best management practices:

- 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, to help manage development pressures that can induce an IR;

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

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

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

- During all drilling phases, the use of Loss Control Materials (LCMs) will be implemented upon detection of a LOC or indications of a potential IR are noted or an IR is observed. The use of LCMs, however, is less effective 70 ft-bgs. Accordingly, the preferred corrective action needed to address the presence of fractures or LOC at greater depths below ground will require grouting of the HDD annulus. Two types of grouting may be utilized for corrective actions to seal fractures. These are: 1) grouting using “neat cement”; and 2) grouting using a sand/cement mix. Neat cement grout is a slurry of Portland cement and water which is highly reactive to bentonite and induces solidification. The sand/cement grout mix is a slurry of mostly sand with a small percentage of Portland cement and activators that after setup results in a material having the competency of a friable sandstone or mortar. 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.

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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

5/28/2019
Date:

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

Pertaining to the practice of geology

5/28/19
Date:

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

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
RICHARD T. WARDROP
GEOLOGIST
PG-000157-G

Pertaining to the pipeline stress and HDD geometry

5/28/19
Date:

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

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
JEFFREY A. LOWY
ENGINEER
PE082759
5/28/19

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ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

HDD HYDROGEOLOGIC REEVALUATION REPORT

Mariner East II
Spread 6
HDD S3-0290-20
Milford Rd/Little Conestoga Rd
Upper Uwchlan Township, Chester County, Pennsylvania

Prepared for:

Sunoco Pipeline, L.P.

Prepared by:

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

May 2019

HDD HYDROGEOLOGIC REEVALUTION REPORT

Mariner East II
Spread 6
HDD S3-0290-20
Milford Rd/Little Conestoga Rd
Upper Uwchlan Township, Chester County, Pennsylvania

May 2019

Prepared for:

Sunoco Pipeline, L.P.
535 Fritztown Road
Sinking Spring, Pennsylvania 19608

Prepared by:

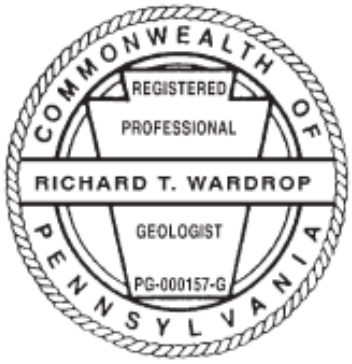
Steven L. Tanen, P.G.
Principal Hydrogeologist

Reviewed by:

Richard T. Wardrop
Lead Hydrogeologist

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.



May 27, 2019

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

Date

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FIGURES

ATTACHMENTS

1.0 INTRODUCTION

Sunoco Pipeline, L.P, (SPLP) retained Groundwater & Environmental Services, Inc. (GES) to prepare horizontal directional drill (HDD) Hydrogeologic Reevaluation Reports (HRRs) for certain HDDs associated with the Mariner East II pipeline project. This HRR has been prepared for HDD S3-0290 (the 20-inch HDD for this location), that is listed in Exhibit 3 of Stipulated Order EHB Docket No. 2017-009-L signed August 10, 2017.

The 16-inch pipeline at HDD-S3-0290 was pulled on November 21, 2017 without incident. It should be noted that the 16-inch line was installed along the originally planned alignment for the 20-inch line. The changeover for all active drilling locations in Spread 6, from the 20-inch line to the 16-inch line, was on November 1, 2017. The discussion presented in this report is based on a permitted plan and profile (P & P) developed by Tetra Tech/Rooney (Tetra Tech), revised on February 10, 2017 as compared to a proposed P & P revised March 14, 2019 (see **Attachment A**).

Figure 1 shows the location of the alignment for the 20-inch line at HDD S3-0290-16, with topographic information for the surrounding area.

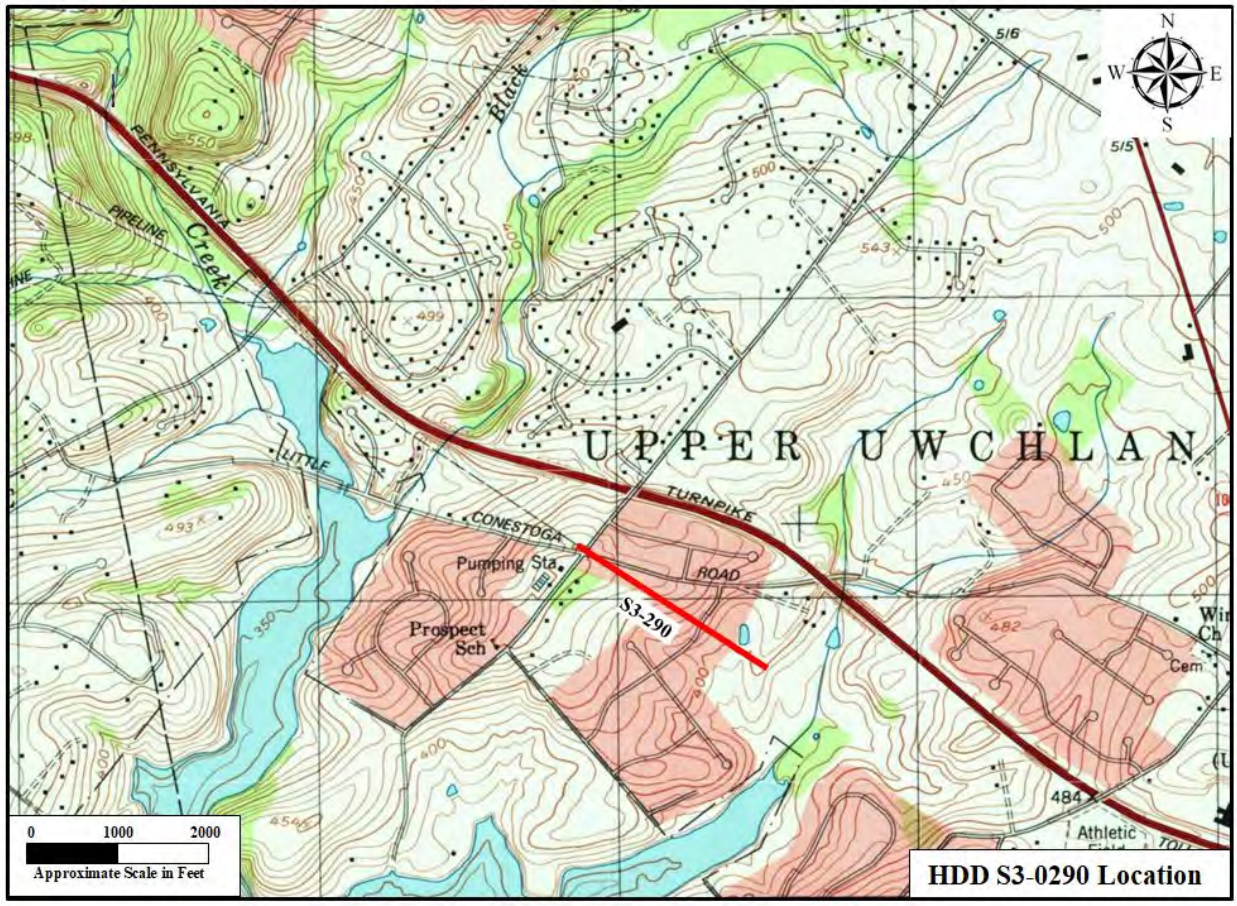


Figure 1. Site Location Map (modified from USGS, revised 1999)

The 20-inch HDD will run from the undeveloped lot located on the west-northwest side of Milford Road to the southeast crossing the intersection of Milford Road and Little Conestoga Road, then cross under several residential properties, until exiting in cultivated fields to the southeast of Highview Road.

Drilling for the 16-inch line at HDD S3-0290 started at the northwest entry/exit on May 27, 2017, initially for the 20-inch pipeline. On November 1, 2017, a decision was made by SPLP to complete the bore for the installation of the 16-inch pipeline using the 20-inch profile. On June 24, 2017 while advancing the pilot, inadvertent returns (IRs) were observed in two general locations at P & P Station 22+57 between a pond and the wetland on a slope leading up to the pond, and a small spot in an unnamed stream within the wetlands (see **Attachment A,** proposed P & P). The IR was estimated to be 50 to 100 gallons. Drilling activity resumed on August 29, 2017 after a project-wide suspension of activity. Subsequently, a 40 to 50 gallon IR occurred in the wetlands along stream SH-11 at approximately Station 22+90 while mud was being circulated prior to enlarging the pilot hole with a reamer.

This HRR is based on geotechnical boring reports; field observations during HDD drilling for the installation of the 16-inch pipe; a geophysical survey, and the interpretation of published information. Tetra Tech in May 2015 and Terracon in September 2017 advanced geotechnical borings to facilitate HDD design. Note that GES did not oversee or direct either of the geotechnical boring programs, including but not limited to, the selection of the number and location of borings, the determination of surface elevations and target depths, observations of rock cores during drilling operations and the preparation of boring logs. In addition, GES did not provide any input to a geophysical study performed by Rettew & Associates (Rettew) in January 2019. GES relied on these reports and incorporated the information presented therein into the general geologic and hydrogeologic framework for this HRR.

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

This report presents the following information:

- Geologic and hydrogeologic characteristics in the area of the 20-inch line at HDD S3-0290;
- Summaries of studies performed pertinent to reevaluation, including fracture trace analysis, geotechnical borings; and the geophysical survey;
- A site conceptual model; and
- A reevaluation summary with conclusions and recommendations.

2.0 HDD GEOLOGY / HYDROGEOLOGY

2.1 Physiography

HDD S3-0290 is located in southeastern Pennsylvania within the Piedmont Physiographic Province, Piedmont Upland Section. Broad, rounded to flat-topped hills and shallow valleys with low to moderate topographic relief, characterizes the Piedmont Uplands Section. The geology of this region is generally comprised of meta-igneous and metasedimentary rocks (gneiss and schist) of Proterozoic to Early- to Mid-Paleozoic age that have been severely folded and fractured. Rolling rounded and flat-topped hills and shallow valleys characterize the area of HDD S3-0290. The area along the HDD bore alignment is comprised of a mix of residential properties and agricultural land.

2.1.1 Topography

Figure 1 shows the area around HDD S3-0290 to generally slope to the west-southwest with local lows (relatively shallow valleys) to the northwest and southeast that contain unnamed tributaries to Marsh Creek. The profile of the land surface over HDD S3-0290 slopes to the southeast with elevations decreasing from the northwest entry/exit, northwest of the intersection of Milford Road and Little Conestoga Road, to the southeast entry/exit point in cultivated land. The as-built profile for the 16-inch pipeline (provided in **Attachment A**) shows the northwest entry/exit point to be at elevation 493 feet above mean sea level (ft amsl), and the southeast entry/exit point at elevation 393 ft amsl. Therefore there is a 100 foot difference in elevation between the two entry / exit points.

2.1.2 Hydrology

HDD S3-0290 is located within the Marsh Creek Watershed that is part of the Brandywine Creek East Branch Watershed, all of which are located in the Delaware River Basin. The area defined by Marsh Creek Lake and surrounding tributaries is a regional groundwater discharge zone. The water table in the area is a subtle reflection of the surface topography and as such, groundwater flow is to the lake and south.

Starting at the southeast entry/exit the permitted P & P for S3-0290 (see **Attachment A)** shows the profile passing below a wetland (between Stations 21+95 and 23+50) and two small (less than six inches deep) branches to an unnamed tributary to Marsh Creek (Stations 22+75 and 23+20). A small pond is present approximately 50 feet northeast of the alignment in the area of HDD Station 22+00.

Similar to the permitted profile, on the proposed profile there is approximately 113 feet of surface elevation difference between the northwest entry/exit and the southeast entry/exit indicating the potential for a groundwater discharge at the southeast entry/exit when a pilot hole is drilled (see **Attachment A)**.

2.2 Geology

2.2.1 Surface Soils

Surface soils along the HDD bore alignment were researched on the United States Department of Agriculture Natural Resources Conservation Service Web Soil Survey Site (USDA NRC WSS). At the northwest entry/exit, surficial soils have been mapped as the Gladstone gravelly loam on 3 to 8-percent slopes. The Gladstone-Parker gravelly loam on 15 to 25-percent slopes is mapped across the central portion of the HDD bore alignment. The surficial soils along the southeastern portion of the alignment consist of the Califon loam on 3 to 8-percent slopes and the Cokesbury silt loam on 0 to 3-percent slopes. The Califon loam and the Cokesbury silt loam are located in the area of the wetlands along the southeast part of the HDD alignment. Minor components of the Califon loam and the Cokesbury silt loam have been classified as hydric soils.

Ground surface elevations then increase after the HDD bore alignment passes through the wetlands and approach the southeast entry/exit. The entry/exit at the southeast end of the bore is located in cultivated land mapped as the Gladstone gravelly loam on 8 to 15-percent slopes and the Gladstone gravelly loam on 25 to 35-percent slopes.

Soils along HDD S3-0290 were characterized by five geotechnical borings, three drilled by Tetra Tech and two drilled by Terracon (see locations in **Attachment A**). The Tetra Tech borings were located near each entry/exit location with one additional boring was located approximately mid-way along the alignment. The Terracon borings were located at each of the entry/exit locations. Both Terracon borings were drilled well into bedrock, while one of the Tetra Tech (SB-02) was drilled five feet into bedrock.

Based on the geotechnical boring logs, topsoil thicknesses ranged from three-inches (at the northwest entry/exit) to twelve-inches (in the wetlands area approaching the southeast end of the alignment). The Tetra Tech borings were drilled to 30 feet below ground surface (ft bgs) in both the northwest and southeast borings, with soils from 8.0 ft bgs to boring completion being classified as decomposed rock. In the boring located near the center of the HDD bore alignment (SB-02), auger refusal was encountered at 7 ft bgs and then the bore was cored five additional feet into bedrock. The core consisted of decomposed rock described as a brown and gray silty, fine to medium, sand with gravel sized gneiss rock fragments.

2.2.2 Bedrock Lithology

Based on published mapping (see **Figure 2** and **Attachment A**, proposed profile), the majority of the HDD bore profile passes through graphitic gneiss (referred to as the Pickering Gneiss), with the northwest end of the HDD passing through a metadiabase (PaGEODE).

The geologic formations associated with HDD S3-0290 are described, as follow:

- **metadiabase (md):** a dark-greenish-gray to almost black diabase. Grain size is generally 0.5 to 1 mm. The rock consists of augite, feldspar, and magnetite. Much of it has been extensively altered. Feldspar is altered to sericite, and augite has been replaced by epidote and chlorite. It occurs as mostly thin dikes, but a few may be greater than 100 feet thick. It exhibits no banding (Geyer and Wilshusen, 1982).

- **graphitic gneiss (gg):** The graphitic felsic gneiss includes quartz, orthoclase, hornblende, biotite, graphite, and small areas of marble. It is light to medium gray. The graphite occurs as flakes 1 to 2 mm in diameter, somewhat larger than the usual grain size of the rock, and is disseminated throughout the gneiss. The unit is also referred to as the Pickering Gneiss (Hall, 1934). It has distinct and very common flaggy banding and is of sedimentary origin. Its thickness is unknown (Berg et al., 1980; Geyer and Wilshusen, 1982).

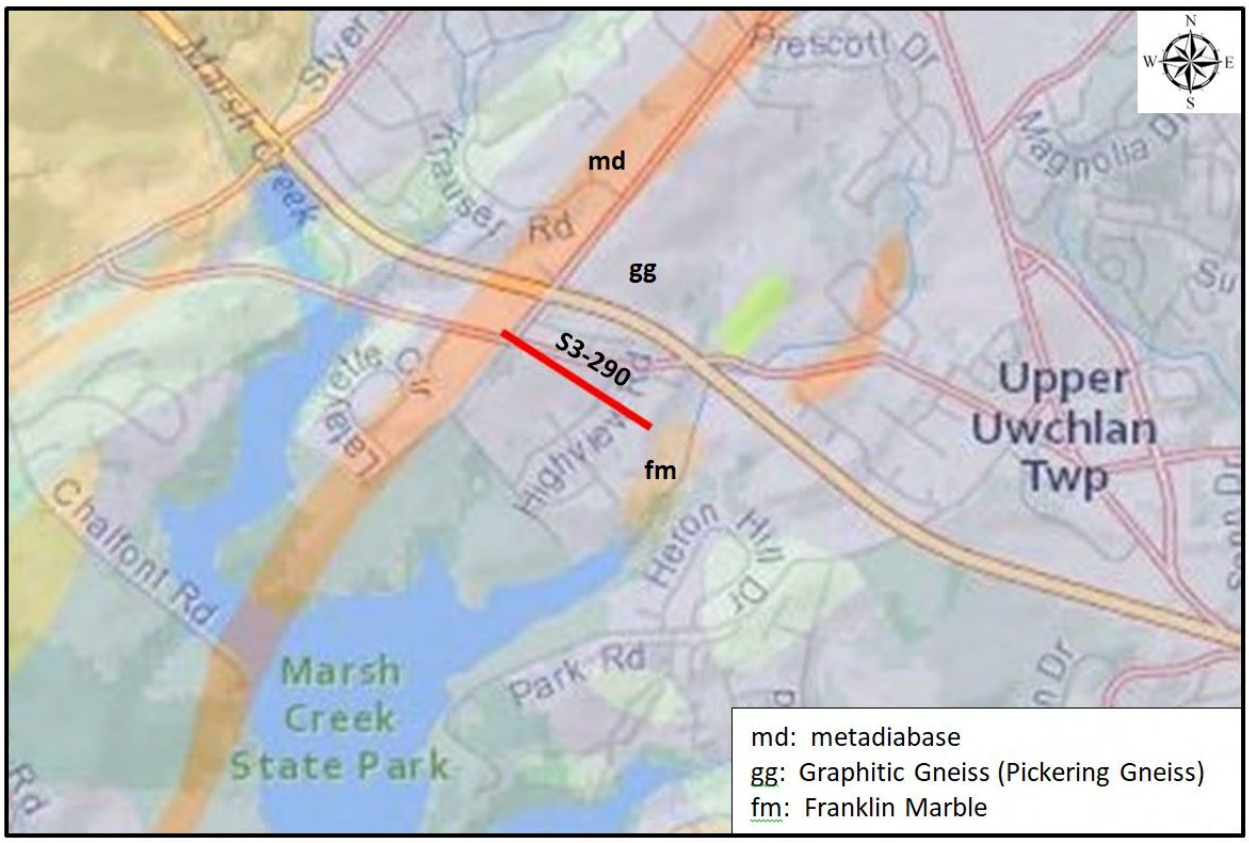


Figure 2. Local Bedrock Geology (from PaGEODE)

2.2.3 Structure

As a result of tectonic processes (folding with some diabase intrusions), the metamorphic rocks of Chester County are fractured and jointed, with some regional faulting. The geologic maps reviewed for this evaluation did not identify any mapped fault zones or other significant structural features along the HDD bore alignment, other than two geologic contacts; one within the alignment near the northwest entry/exit (the metadiabase / graphitic gneiss contact) and one southeast of the southeast entry/exit (the graphitic gneiss / Franklin Marble contact).

Statewide maps prepared by Berg et. al. (1980) show a northeast trending regional structural fabric across northern Chester County. Associated cross sections show the mapped formations steeply dipping to the southeast. Bedding orientations described for two historic graphite mines in the area indicate local bedrock trends N 85^{o} E and dips 45^{o} S (see Section 2.2.6).

Deformational fracture and jointing systems are prevalent throughout Pennsylvania. They can typically be orthogonal (90^{0}) sets or conjugate (60^{0}) sets which are systematic patterns usually related to folding and faulting. Commonly there are non-systematic orientations that are curviplanar and hook and fork into the systematic systems.

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) are 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.

The baseline photography used for this Fracture Trace Analysis consisted of historic photographic stereo pairs from the US Department of Agriculture (USDA and US Geological Survey (USGS), available through the Pennsylvania Imagery Navigator web site. The fracture trace analysis was based on a composite of interpretations for several 1937-1942 USDA (1-20,000) aerial photograph stereo pairs viewed with a Topcon MS-3 Stereo Scope and the traces observed were transferred to a single photo for further evaluation.

Figures 3 presents the fracture trace map prepared from the analysis. While the analysis identified several fracture traces in the area of the HDD, none intersected the HDD bore alignment.

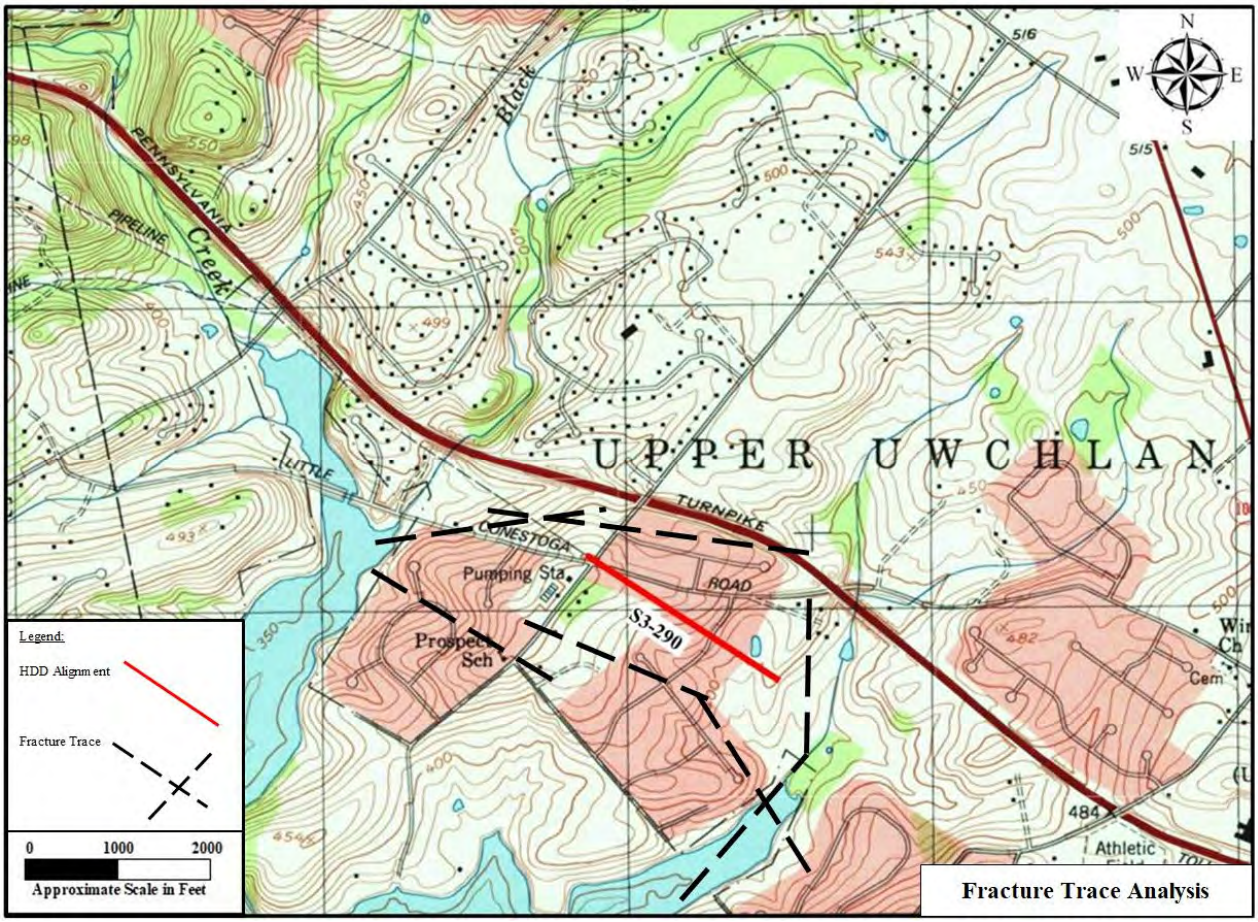


Figure 3. Fracture Trace Map (mod. USGS rev. 1999)

2.2.5 Karst

Geologic maps show the Franklin Marble to occur due southeast of the southeast entry/exit for HDD S3-0290. However, based on published geologic data, there are no known or mapped sinkholes in the area of the drill path (Kochanov, 1993; Kochanov and Reese, 2003), which is consistent with the mapped bedrock in the area directly under the alignment.

2.2.6 Mining

Based on a review of the Pennsylvania Mine Map Atlas and PADEP eMap PA web sites, there are no active subsurface mining or surface mining operations, or mining limits, at, or near, the HDD S3-0290 alignment.

Sloto (2009) discusses a series of historical graphite mines in Upper Uwchlan Township, as noted below:

- The Pettino Brothers graphite mine located approximately 1.9 miles to the east-southeast from the S3-290 southeast entry/exit. This mine operated in the 1880s until operations ceased in 1920. The mine included both open-pits and mine shafts.

- The Pennsylvania Graphite Company Mine located approximately 1.6 miles east of the S3-290 southeast entry/exit and operated from the late 1870s until circa 1920. Sloto notes that the graphite bearing beds were in a coarsely crystalline calcareous gneiss, micaceous gneiss, and marble striking N 85° E and dipping 45° SE, and the beds were reportedly cut by faults.

- The Acme Graphite Company Mine was located approximately one mile east-southeast from the S3-290 southeast entry/exit. The mine operated from the mid-1870s until 1910. The strike and dip of the beds in the mine were reported as N 85° E and 45° S. The mine included both open-pits and mine shafts.

In addition to the graphite mines, Sloto (2009) also discusses an open-pit iron mine located 200 feet west of Pennsylvania State Route 100 approximately one mile east-northeast from the S3-290 southeast entry/exit – the Beerbower Mine. The pit was filled in 2007 during local housing development activities.

The geologic map prepared by Bascom and Strose (1938) indicates that the mapped section of the Franklin Marble located southeast of the southeast entry/exit of the S3-0290 HDD bore alignment was once mined. However, additional research (review of Sloto, 2009 and historical aerial photographs), produced no information that would suggest any mining near the southeast entry/exit of the HDD bore alignment.

Since none of the mines listed above intersect or otherwise cross the S3-0290 20-inch HDD bore alignment, it is expected that historical mining features will not affect the installation of the 20-inch pipeline.

2.2.7 Rock Engineering Properties

Geyer and Wilshusen (1982) report the following with respect to the graphitic gneiss and metadiabase (diabase):

<u>Graphitic gneiss</u>

- Bedding: Banding is distinct and very common; bands are flaggy in thickness.
- Fracturing: 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.
- Weathering: Moderately resistant; deeply weathered; sometimes results in disintegration into very small rectangular fragments; overlying mantle is thick.
- Ease of excavation: Weathered portion may be excavated moderately easily; moderate drilling rate.

Diabase

- No bedding
- Joints / fractures are well developed in a blocky pattern, of moderate abundance, regularly spaced, with moderate spacing, open and steeply dipping.
- Difficult to excavate, large boulders can create difficulty, slow drilling rate.

2.2.8 Results of Geotechnical Borings

The locations of the geotechnical borings advanced for characterization of HDD S3-0290 are shown on the P & Ps in **Attachment A** and boring logs are provided in **Attachment B**.

Original Geotechnical Borings (Tetra Tech)

The Tetra Tech borings encountered a decomposed rock at depths of 8.0 ft bgs (SB-01), 7.0 ft bgs (SB-02) and 6.5 ft bgs (SB-03). The decomposed rock horizon (a completely weathered zone) consisted of a light brown, white and gray silty medium to fine sand with gravel sized gneiss rock fragments. A mottled brown and gray fine sandy silty clay was encountered between 1.0 and 6.5 ft bgs in SB-03 (located in the area of the wetlands and streams). Bedrock was cored at SB-02 from 7 to 12 ft bgs. The recovered core had an RQD of 20-percent and was described as a moderately to intensely fractured gray gneiss. The Rock Quality Designations (RQDs) indicated very poor rock quality (as defined by ASTM STP 984). Soil conditions regarding these borings was previously discussed in **Section 2.2.1**.

Recent Geotechnical Borings

Terracon drilled two (2) borings, one at each HDD S3-0290 entry/exit point in September 2017. The borings were generally located within 50 feet of the entry/exit points with B-21W located at the northwest entry/exit and B-21E located at the southeast entry/exit. Bedrock core recovery and RQD values with depth for each boring are presented on **Figure 4.**

Boring B-21W had a total depth of 237.5 feet. The bedrock cores consisted of felsic gneiss to approximately 150 ft bgs, after which it was described as being a mica gneiss. RQD and recovery values at B-21W indicated highly weathered and fractured (or poor rock quality) from approximately 15 to 35 ft bgs. The rock then became more competent with depth as recoveries were almost entirely 100 percent. However, RQD was highly variable, ranging from 20 to 100 percent, and higher RQD did not correlate with depth.

B-21E had a total depth of 145.5 feet. The bedrock cores consisted of highly fractured felsic gneiss, with a pegmatite intrusion between the depths of 75 ft bgs and 94.1 ft bgs, at which point the rock transitioned into more competent graphitic felsic gneiss. Recovery was poor until a depth of approximately 75 feet, after which the values were all 100 percent. RQD values indicated very poor rock quality to approximately 70 ft bgs, after which the rock quality was generally poor to fair, with the most competent bedrock zone (or good as described by ASTM) being from 80.5 ft bgs to 115.5 ft bgs; however, the RQD decreased again from 115.5 to the total depth of 145.5 feet.

2.3 Hydrogeology

In general, groundwater flow proximal to HDD S3-0290 moves along gradients established by a water table surface that is a subdued reflection of the local topography. The alignment of HDD S3-0290 passes from the northwest to the southeast in the Marsh Creek Watershed with groundwater flow in the area of the HDD bore alignment being towards Marsh Creek/Marsh Lake to the south and southwest.

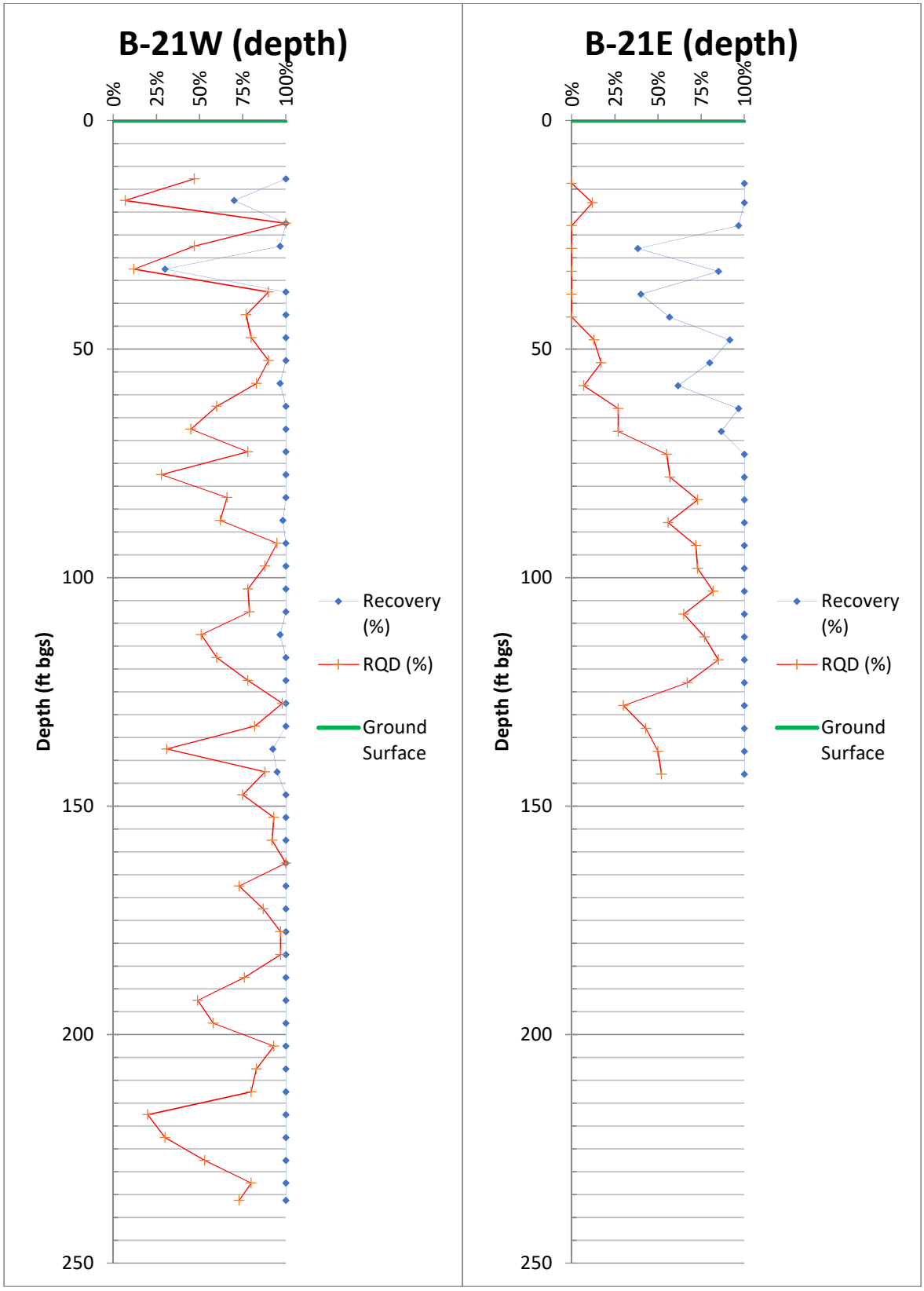


Figure 4. Recovery and RQD with Depth for Borings B-21W and B-21E

2.3.1 Occurrence of Groundwater

Based on soil borings and borings advanced into bedrock, groundwater has been encountered in both the soil/weathered bedrock zone and 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.

2.3.2 Groundwater Levels and HDD entry/exit elevations

A PAGWIS search of wells completed in gneissic bedrock in Uwchland and Upper Uwchlan Townships in Chester County. The wells listed with recorded static water levels had water levels ranging from 4 to 170 ft bgs with an average of 36 ft bgs. Groundwater level observations for the geotechnical borings are presented below:

- SB-03 (22+95 on proposed P & P): Groundwater was encountered at 16 ft bgs in a weathered silty medium to fine sand with gravel gneiss fragments classified as decomposed rock.
- B6-21W (located in the area of the northwest of northwest entry/exit): A water level measurement was recorded at 38 ft bgs in unweathered bedrock.
- B6-21E (located in the area of the southeast entry/exit): It was reported that groundwater was encountered from 15.0 to at 18.1 ft bgs in moderately to severely weathered bedrock.

The ground surface elevations decreases by approximately 107 feet from the highest point along the northwestern portion of the alignment to the southeast entry/exit. Given local water table depths as high as 15 ft bgs there is a potential for a groundwater discharge at the southeast entry/exit once the pilot bore is complete. During the drilling for the 16-inch line, there was no groundwater discharge observed at either entry/exit; however, following the installation of the 16-inch pipeline, an ongoing groundwater seep was observed at the southeast entry/exit, which flows at approximately one gpm or less. Due to the minimal discharge rate, no impact to the local water table was observed or reported by private well owners.

2.3.3 Well Yields

The published median well yield for the graphitic gneiss is typically ten gallons per minute (gpm) or less; wells can have potential yields of 35 gpm from wells properly sited and developed (Geyer and Wilshusen, 1982). The above referenced PAGWIS search indicated a range in well yields from 0 to 200 gallons per minute with an average of 21 gallons per minute.

2.3.4 SPLP Water Supply Surveys

SPLP performed a preconstruction survey of landowners with entire or part of their parcels falling within 450-feet of the HDD S3-0290 alignments. The HDD alignment with the 450-foot zone is presented on **Figure 5**. One landowner responded positively to SPLPs offer for baseline sampling. The well was identified within the 450-foot search zone (Well ID WL-01192018-628-01), approximately 172 feet northeast of the HDD alignment. A second well (WL-09052017-613-02) was located beyond the 450-foot search zone, at 565 feet from the alignment. Neither of these two well locations were impacted during the installation of the 16-inch pipeline, therefore, it is expected that neither will be impacted by the installation of the 20-inch pipeline.

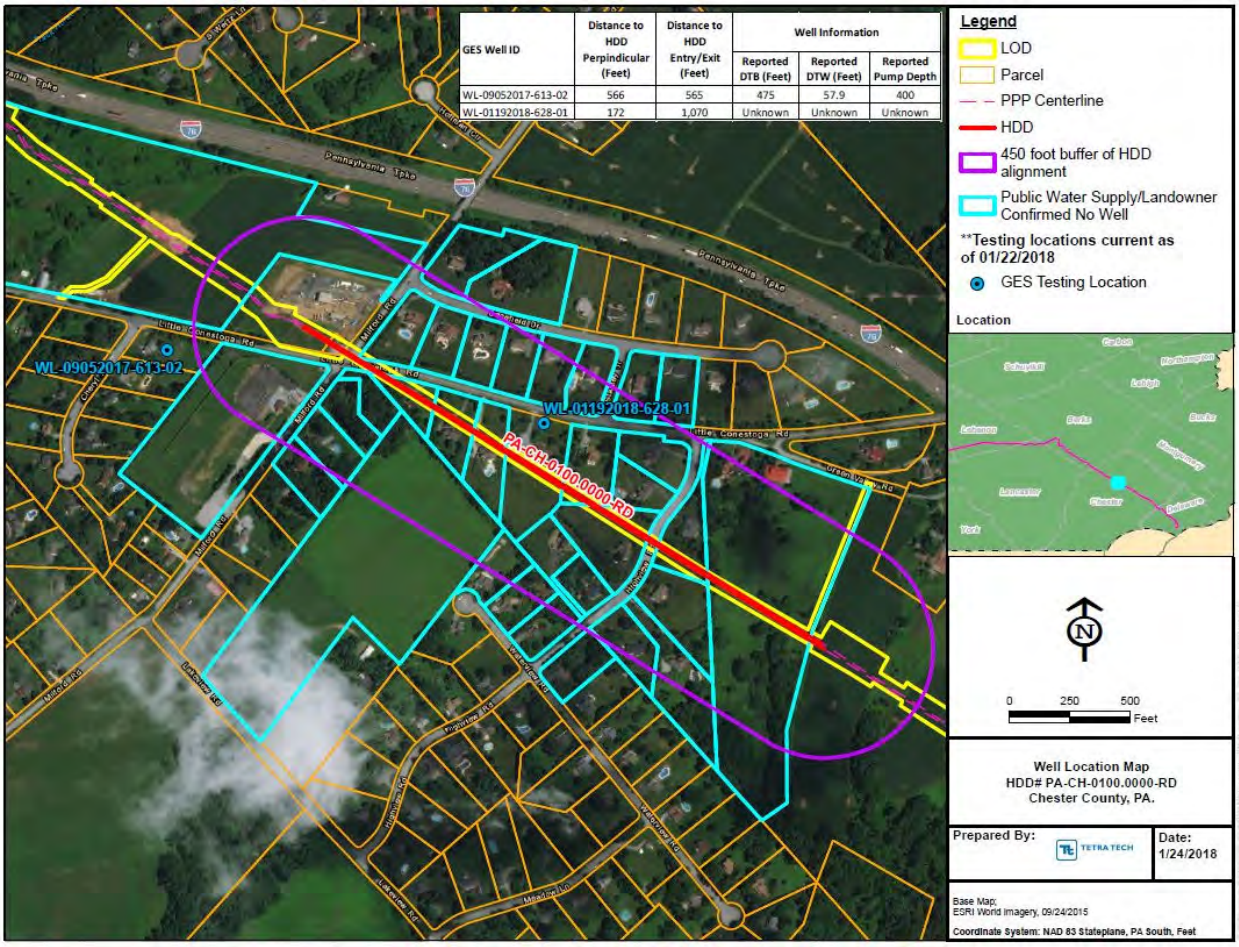


Figure 5. Well Search Map - Properties within 450 feet of HDD Alignment

2.4 Summary of Geophysical Studies

RETTEW Associates, Inc. completed a multi-method geophysical survey at the S3-0290 Milford Road/Little Conestoga Road HDD site in January 2019. The stated purpose of the survey was to detect and delineate subsurface fracture zones that could contribute to potential IRs and/or losses of circulation (LOCs), and to determine the rock profile and rock rippability as it relates to HDD drilling rates. The results of the survey are provided in **Attachment C.**

Seismic refraction, multi-spectral analysis of surface waves (MASW), and electrical resistivity methods were used to identify potential fracture zones and approximate the depth of competent bedrock along the profile. As shown on the figures in **Attachment C**, the combined methods identified potential fracture zones crossing the alignment at a frequency of approximately one every 100 to 200 feet in the northwestern part of the alignment, with a greater density (generally one every 50 to 100 feet in the southeastern part of the alignment. The highest density of potential fracture zones (approximately one every 10 to 25 feet) occurred in the wetlands area in the southeastern part of the alignment that includes the two branches to the unnamed tributary to Marsh Creek between P & P Stations 21+50 to 23+20 (proposed P & P). The two IRs described in Section 3.0 occurred adjacent to Stations 22+57 and 22+90. At these locations, both the seismic refraction data profile and the electrical resistivity profile indicate a fracture zone.

3.0 HDD OBSERVATIONS TO DATE

3.1 On This HDD Alignment

Drilling commenced for S3-0290-20 on May 27, 2017 with the 16-pipeline being pulled on November 21, 2017. Two IRs occurred during drilling activities, once during advancement of the pilot and once at the start of reaming (see locations on proposed P & P in **Attachment A**).

During pilot drilling on June 19, 2017, the HDD bore cuttings indicated a change in lithology that was observed between Stations 19+04 and 19+67 (proposed P & P) where the bedrock went from a felsic gneiss to a metadiabase, after which the felsic gneiss was once again encountered. While drilling through the metadiabase, a loss of circulation (LOC) totaling 1,500 gallons occurred; however, no IRs occurred. Based on discussion with the driller, a pressure lost was observed and drilling became notably quicker/softer at approximately P & P Station 19+52. Upon recognition of the LOC the crew began tripping the tooling out of the bore.

On June 20, 2017, the crew continued to trip out with minimal drilling fluid returns and it was estimated 20,000 gallons of drilling fluids were lost with no IRs occurring.

On June 21, 2017, as the crew continued to trip in, there was a LOC with estimated loss of 22,113 gallons of drilling fluid; however, no IRs observed. While inspecting the area of the drill bit and along the pond to the east-southeast, a local groundwater discharge from a springhouse was observed, approximately 225 feet from the HDD bore alignment. No drilling fluids were observed in the springhouse discharge.

The drill string reached bottom on June 22, 2017 and the pilot hole continued with little to no loss of drilling fluid. On June 24, 2017, an IR occurred at approximately Station 22+57 (proposed P & P), due east and off the right-of-way. The IR was located on an embankment between the wetlands and the pond. The IR volume was estimated to be 50 to 100 gallons and the area of the wetlands was affected, including the two small streams that flow into the unnamed tributary to Marsh Creek. Drilling was stopped and the area was cleaned up. Drilling then resumed with the pilot punching out later in the afternoon of June 24, 2017 at the southeast entry/exit. .

The second IR occurred on August 29, 2017 after a month of project-wide suspended activity. Shortly after restart, while drilling fluid was being circulated, an IR occurred. The cause of the IR was likely due to groundwater entering the bore during the time of suspension, removing the drilling fluid caked on the borehole walls, allowing drilling fluid to migrate beyond the borehole walls when circulation was initiated. This IR occurred due west of the alignment at approximately Station 22+90.

Both IRs occurred near the southeast entry/exit where the overburden is thinning and the profile is rising to the surface. The as-built profile indicates approximately 50 to 60 feet of overburden in this zone. The geophysical survey indicates a zone of bedrock fracturing here with 20 to 25 feet of less competent weathered bedrock. The geotechnical boring logs suggest the zone of weathered bedrock could be greater than 50 feet here. In a very general sense, drilling fluid pressures tend to increase at the end of HDD profiles as they approach exit, especially for longer HDDs. To summarize, it is believed that the IRs occurred during drilling for the 16-inch line at HDD S3-0290 because the overburden was thinning as the profile rose to the surface and the overburden was comprised of a large percentage of weaker heavily weathered gneiss.

3.2 On Other HDD Alignments in Similar Hydrogeologic Settings

ME II HDDs in the same geologic setting of S3-0290 (metamorphic bedrock in Chester County) include S3-0280 to the northwest and S3-0310, S3-320 and S3-0331 (to the southeast). IRs have occurred during drilling of at S3-0320 and S3-0331. These IRs have typically occurred where bedrock is 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 overburden soil and weathered bedrock thins and there is less overburden strength to contain drilling fluid pressures. In some cases, IRs have occurred at the end of a pilot bore when annular pressure is increasing to maintain circulation back to the entry as distance increases and the profile is rising to exit causing overburden to thin and have a higher proportion of unconsolidated materials.

4.0 SUMMARY AND RECOMMENDATIONS

4.1 HDD Site Conceptual Model

HDD S3-0290 is located within the headwater drainage of Marsh Creek, Marsh Creek Lake and the East Branch of the Brandywine Creek within gneissic bedrock with a relatively thick covering of saprolite and heavily weathered bedrock. Examination of geotechnical boring data and results of a geophysical study indicate the thickness of the saprolite developed on gneissic bedrock could be greater than 50 feet. Below that, fractured bedrock of variable strength occurs to 235 ft bgs or greater. The geophysical study reports a saprolitic zone from 15 to 32 feet deep and potential fracture zones along the profile. The potential fracture zones were indicated at a frequency of approximately one every 100 to 200 feet in the northwestern part of the alignment and approximately one every 50 to 100 feet in the southeastern part of the alignment. The highest density of potential fracture zones (approximately one every 10 to 25 feet) occurred in the wetland area in the southeast part of the alignment that includes two branches to the unnamed tributary to Marsh Creek between P & P Stations 21+50 to 23+20. Fracture trace analysis did not identify any photo linears crossing the alignment

The current permitted P & P shows a profile that ranges from 0 to approximately 158 ft bgs. The overburden in the area of the wetland and IRs that occurred during installation of the 16-inch line is approximately 38 to 48 ft bgs. The proposed P & P for installation of the 20-inch line shows a profile that is generally 25 feet deeper with maximum overburden thickness of 200 feet and overburden thickness of 85 to 90 feet where the former IRs occurred. Assuming a depth for highly weathered bedrock of 100 feet, it is estimated the proposed profile will pass through highly weathered bedrock for approximately 300 feet on the northwest end and approximately 460 feet on the southeast end. In addition, as stated above, the geophysical study indicates bedrock fracture zones will be encountered at some frequency along the profile.

Due to the surface elevation difference between the northwest part of the alignment and the southeast entry/exit a groundwater discharge may be created at the southeast entry/exit by completing the pilot bore. This was the case for the 16-inch pipe installation when a relatively low flow (one gpm) discharge was created. Due to the minimal discharge rate, no impact to the local water table was observed or reported by private well owners.

To date IRs that have occurred at other drills in the gneissic bedrock of northern Chester County IRs tend to occur when the saprolite and highly weathered bedrock overburden materials are not strong enough to contain drilling fluid pressures. In most cases these have occurred as the path of the pilot bore is rising towards exit, overburden is thinning and the required annular pressure to move fluid and cuttings back to the entrance is increasing. Although the profile on the proposed P & P runs deeper than the as-built profile for the 16-inch line, drilling conditions similar to those encountered during installation of the 16-inch line should be anticipated. The zone under the wetlands between Stations 21+50 and 23+20 should be considered a zone of elevated IR risk during installation of the 20-inch line.

One private water supply well was identified within 450-feet of the S3-0290 alignment and is approximately 172 feet off the alignment. The depth of this well is unknown but it is assumed the profile on the proposed P & P for the 20-inch line passes through the zone of groundwater that is the source of water to the well. The landowner associated with this well is participating in SPLP's baseline sampling program. There were no water well impact complaints associated with the installation of the 16-inch line and similar results are anticipated for installation of the 20-inch line.

4.2 Conclusions and Recommendations

The synthesis of regional and local geologic data together with past drilling performance during drilling for the 16-inch pipeline indicate that installation of the 20-inch line at HDD S3-0290 has a moderate to high risk of drilling fluid loss and IRs. This statement is based on the depth of the profile on the proposed P & P and strength of overburden materials within zones of saprolite, highly weathered bedrock, low RQD bedrock and relatively high frequency of potential bedrock fracture zones. As such, drilling plans should account for these conditions identified in this HRR.

Specifically the location of the IRs that occurred in the wetland between Stations 21+50 and 23+20 during installation of the 16-inch line has been correlated with a relatively thin overburden comprised of highly weathered bedrock and potential bedrock fracture zone indicated by the geophysical survey. Although the profile on the proposed P & P runs 34 deeper at this location, area wide information indicates the depth of weathered bedrock can be over 100 feet deep and deepening the profile does not change the frequency of fracturing characteristic of the competent bedrock at depth.

In addition, contractors should be prepared to manage a groundwater discharge at the southeast entry/exit, even though the discharge that occurred during installation of the 16-inch line was only approximately one gpm.

One local private water well has been identified within 450 feet of the alignment. This well is included in SPLP's groundwater monitoring program and the landowner will be afforded a post-construction sampling event after installation of the 20-inch line. SPLP's standard procedures include an offer to landowners to provide a temporary water supply during construction of the 20-inch line. Even though no well impacts were indicated during installation of the 16-inch line, this offer will be reaffirmed prior to the start of construction of the 20-inch line to give the landowner the opportunity to assure no water supply impacts during construction.

Based on information provided by, and the expertise of, the HDD team, as well as our experience with the relevant hydrogeology and geology, GES believes that implementation of the profile on the proposed P & P for the 20-inch line at S3-0290 and best management practices inherent to the ME II construction project, including Station specific references to areas of concern identified in this HRR, will minimize the risk of IRs and LOCs and minimize the likelihood of an impact to the environment. Furthermore, based on such information, expertise and experience, GES believes that implementation of the profile on the proposed P & P for S3-0290, in conjunction with the SPLP's temporary water supply offer to private well owners within 450 feet of the HDD alignment, will minimize the risk of any impact to an active private water supply. In the event of an impact to a private water supply, SPLP will implement the procedures of the IR PPC Plan.

REFERENCES

ASTM, 1988. *Rock Classification Systems for Engineering Purposes*, ASTM International, ASTM STP 984, West Conshohocken, PA. 1988

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., et al, 1980. *Geologic Map of Pennsylvania.* Map 001, 1980.

Geyer, Alan R. and J. Peter Wilshusen (1982*). Engineering Characteristics of the Rocks of Pennsylvania*. Department of Environmental Resources, Office of Resources Management, Bureau of Topographic and Geologic Survey. Harrisburg, PA, Environmental Geology Report 1, 1982.

Hall, George M., 1934. *Ground Water in Southeastern Pennsylvania,* Pennsylvania Department of Internal Affairs, Bureau of Topographic and Geologic Survey, Groundwater Report W-2, 1934

Kochanov, W. E. 1993. Sinkholes and Karst-Related Features of Chester County, Pennsylvania. Pennsylvania Bureau of Topographic and Geologic Survey, Open File Report: 93-01, scale 1:24,000, 10 maps plus 9 page text.

Kochanov, W.E. and S. O. Reese, 2003. Density of Mapped Karst Features in South-Central and Southeastern Pennsylvania. Pennsylvania Bureau of Topographic and Geologic Survey, Map 68.

Sloto, Ronald, 2009. *The Mines and Minerals of Chester County, Pennsylvania.* 2009

USGS, 1995. *USGS Downingtown, PA*, 1:24,000 Topographic 7.5-minute series Quadrangle Map, United States Geological Survey, 1999.

Websites

Pennsylvania Department of Conservation & Natural Resources (PADCNR), NonFuel-Mineral Resources, http://maps.dcnr.pa.gov/topo/quarries/

Pennsylvania Department of Conservation & Natural Resources (PADCNR), Marsh Creek State Park, https://www.dcnr.pa.gov/StateParks/FindAPark/MarshCreekStatePark/Pages/History.aspx

Pennsylvania Department of Environmental Protection (PADEP) eMapPA, http://www.depgis.state.pa.us/emappa/

Pennsylvania Groundwater Information System (PAGWIS), http://www.docs.dcnr.pa.gov/topogeo/groundwater/pagwis/records/index.htm

The Penn State Pennsylvania Mine Map Atlas, http://www.minemaps.psu.edu/

Pennsylvania Imagery Navigator, http://maps.psiee.psu.edu/ImageryNavigator

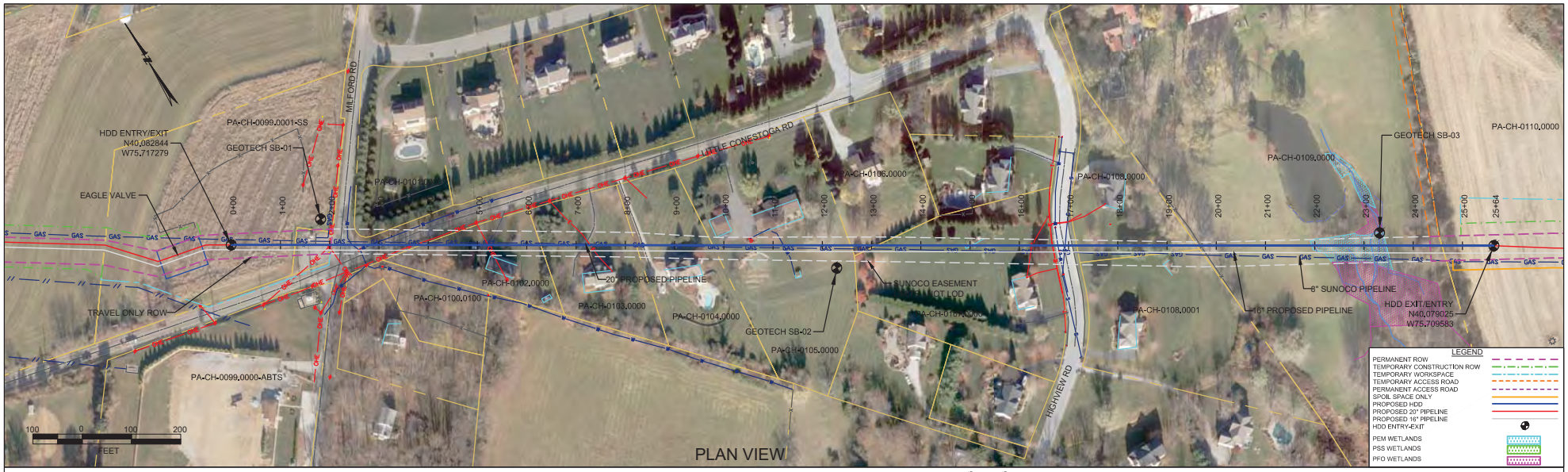
USDA, Natural Resources Conservation Service Web Soil Survey, https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Attachment A

Plan and Profiles

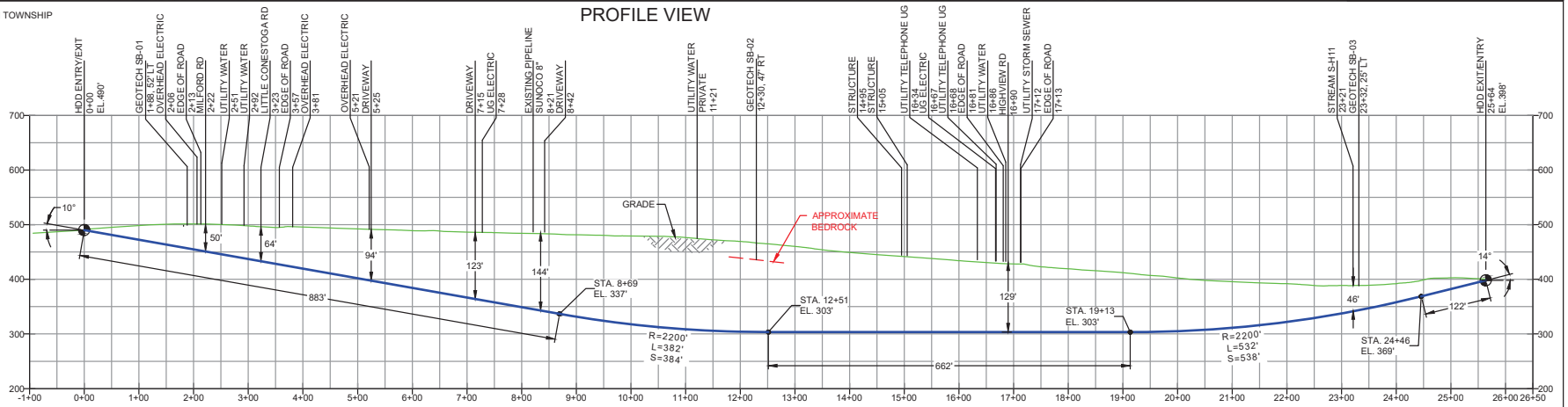
Permitted HDD S3-0290 Plan and Profile (rev. 2/10/17)

Proposed HDD S3-0290 Plan and Profile (rev. 3/14/19), showing IRs and geology



CHESTER COUNTY, PA - UWCHLAN TOWNSHIP
S3-0290

PROFILE VIEW



GEOTECH SB-01
- NG EL. 499'
- TOPSOIL (0' - 0.3')
- SM (0.3' - 30.0')
- COMPLETION DEPTH EL. 469'

GEOTECH SB-02
- NG EL. 460'
- TOPSOIL (0' - 0.7')
- SM (0.7' - 7.0')
- GNEISS (7.0' - 12.0')
- COMPLETION DEPTH EL. 448'

GEOTECH SB-03
- NG EL. 390'
- TOPSOIL (0' - 1.0')
- CL (1.0' - 6.5')
- SM (6.5' - 30.0')
- GROUNDWATER (16.0')
- COMPLETION DEPTH EL. 360'

NOTE: REFER TO TEST BORING LOG S3-0290 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=):2564'
   HDD PIPE LENGTH (S=):2589'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN 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.

NOTES

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

REVISIONS

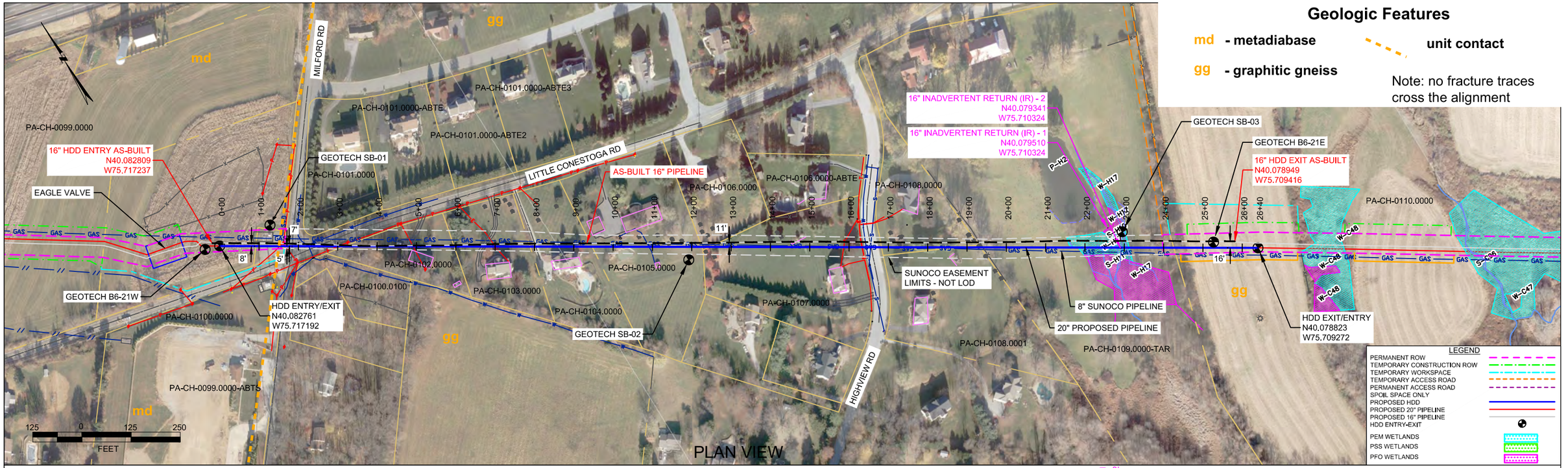
NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
5	REVISED PROFILE WITH 2017 LIDAR	DLM	02/10/17	RMB	02/10/17	AMC	02/10/17
5	DESIGN CHANGE (OZ HDD DESIGN RFI-0110)	MRS	01/31/17	RMB	01/31/17	AAW	01/31/17
4	REVISED PER ENGINEERING COMMENTS	MRS	08/12/16	RMB	08/12/16	AAW	08/12/16
3	DESIGN CHANGE	DLM	05/26/16	RMB	05/26/16	AAW	05/26/16
2	ADDED MLV LABEL	MRS	04/07/16	RMB	04/07/16	AAW	04/07/16
1	REVISED PER COMMENTS FROM REI REVIEW	MRS	03/03/16	RMB	03/03/16	AWW	03/03/16

Sunoco Logistics Partners L.P.
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

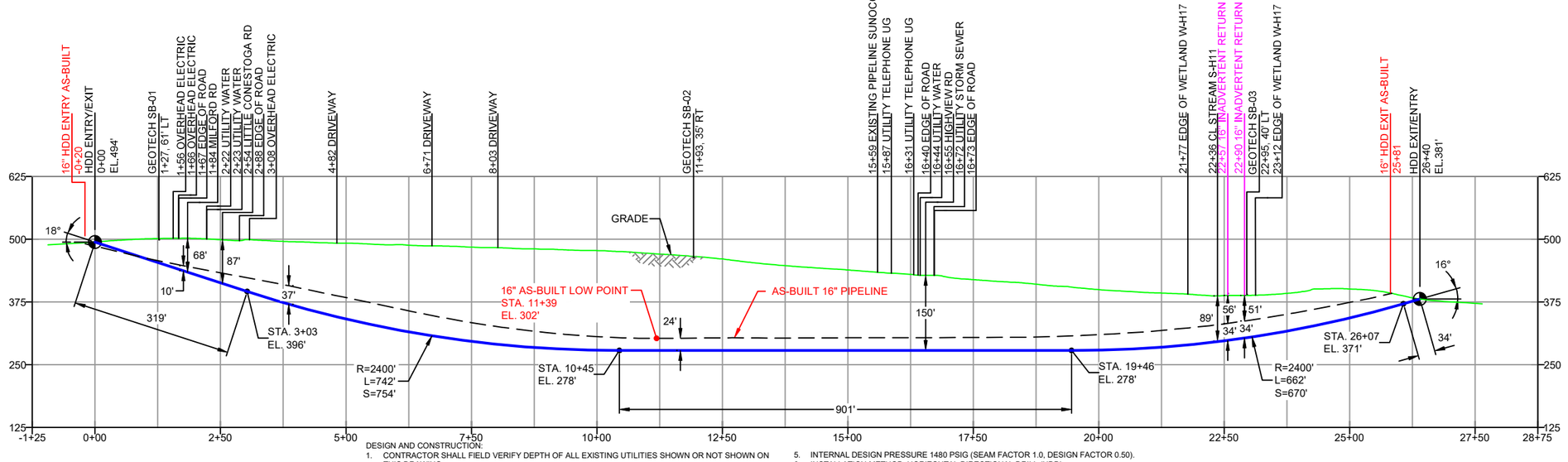
HORIZONTAL DIRECTIONAL DRILL
LITTLE CONESTOGA ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' | DWG. NUMBER: PA-CH-0100.0000-RD

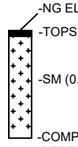


CHESTER COUNTY, PA - UWCHLAN TOWNSHIP
S3-0290

PROFILE VIEW

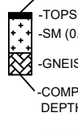


GEOTECH SB-01



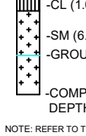
-NG EL. 499'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 30.0')
-COMPLETION DEPTH EL. 469'

GEOTECH SB-02



-NG EL. 460'
-TOPSOIL (0' - 0.7)
-SM (0.7' - 7.0')
-GNEISS (7.0' - 12.0')
-COMPLETION DEPTH EL. 448'

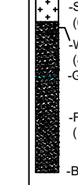
GEOTECH SB-03



-NG EL. 390'
-TOPSOIL (0' - 1.0')
-CL (1.0' - 6.5')
-SM (6.5' - 30.0')
-GROUNDWATER (16.0')
-COMPLETION DEPTH EL. 360'

NOTE: REFER TO TEST BORING LOG S3-0290 FOR COMPLETE SOIL MATERIAL DESCRIPTION

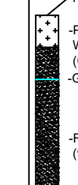
GEOTECH B6-21W



-NG EL. 490'
-SILTY SAND W/ GRAVEL SM (0.0' - 8.5')
-WEATHERED ROCK (8.5' - 10.5')
-GROUNDWATER (38.0')
-FELSIC GNEISS (10.5' - 237.5')
-BORING TERMINATED EL.252.5'

NOTE: REFER TO TEST BORING LOG B6-21W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B6-21E



-NG EL. 398'
-POORLY GRADED SAND W/ GRAVEL SP-SM (0.0' - 9.3')
-GROUNDWATER (15.0')
-FELSIC GNEISS (9.3' - 145.5')
-BORING TERMINATED EL.252.5'

NOTE: REFER TO TEST BORING LOG B6-21E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:
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3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2640'
   HDD PIPE LENGTH (S=):2678'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN 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.
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NOTES

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5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

ES-6.27	TO	ES-6.29	EROSION & SEDIMENT PLAN	
SHEET 16	TO	SHEET 17	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	SWITCHED 20" CENTERLINE LOCATION, INCREASED DEPTH OF DRILL AND ADDED GEOTECH INFORMATION	MRS	03/14/19	RMB	03/14/19	AMC	03/14/19
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/09/16	RMB	05/09/16	AAW	05/09/16
EP		MRS	12/07/15	RMB	09/25/15	AAW	12/07/15
D	ADDED GEOTECH INFO	MRS	09/25/15	RMB	09/25/15	AAW	09/25/15
C	ISSUED FOR BID	DLM	08/21/15	RMB	08/21/15	AAW	08/21/15

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
LITTLE CONESTOGA ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' | DWG. NO: PA-CH-0100.0000-RD

Attachment B

Geotechnical Boring Logs

Tetra Tech, May 2015

Terracon, September 2017

LEGEND:

Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S3-0290
CHESTER COUNTY, UPPER UWCHLAN TOWNSHIP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	MILFORD AND LITTLE CONESTOGA ROADS, DOWNINGTOWN, PA		Page 1 of 1
HDD No.:	S3-0290	Dates(s) Drilled: 05-20-15	Inspector: E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 4' 57.699" N	75° 42' 59.880" 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		19	SM	LIGHT BROWN AND WHITE FINE TO MEDIUM SAND WITH SOME	16	30	21	18	**51**
							SILT.					
2	8.0	9.5			13		VARI-COLORED FINE TO MEDIUM SAND WITH SOME SILT, TRACE	3	20	50		**70**
							FINE GRAVEL.					
3	13.0	14.9			22		VARI-COLORED FINE TO MEDIUM SAND WITH SOME SILT, TRACE	3	9	22	50/5"	**31**
							FINE GRAVEL.					
4	18.0	18.9			7		LIGHT BROWN AND WHITE FINE TO MEDIUM SAND WITH SOME	6	50/5"			**>50**
							SILT, AND A LITTLE FINE QUARTZ GRAVEL.					
5	23.0	23.8			8		LIGHT BROWN AND WHITE FINE TO MEDIUM SAND WITH SOME	28	50/3"			**>50**
							SILT, AND A LITTLE FINE QUARTZ GRAVEL. (USCS: SM).					
6	28.0	28.7			5		LIGHT BROWN AND WHITE FINE TO MEDIUM SAND WITH SOME	5	50/2"			**>50**
				30.0			SILT, AND A LITTLE FINE QUARTZ GRAVEL.					
							AUGERED TO 30'.					
							CAVED AND DRY AT 28.5'.					
							SAMPLES 2 THRU 6 ARE HIGHLY DECOMPOSED ROCK SOILS.					
							(SOILS THAT HAVE BEEN WEATHERED IN-PLACE FROM ROCK)					

Notes/Comments:
Pocket Pentrometer 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.

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:	465 LITTLE CONESTOGA ROAD, DOWNINGTOWN, PA		Page 1 of 1
HDD No.:	S3-0290	Dates(s) Drilled: 05-27-15	Inspector: E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 12.0
Boring Location Coordinates:		40° 4' 51.263" N	75° 42' 49.239" 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	0.7			TOPSOIL (8")					
1	3.0	5.0	0.7		16		BROWN AND GRAY FINE TO MEDIUM SAND AND SILT, WITH A LITTLE	13	22	28	23	**50**
						SM	FINE TO COARSE UNWEATHERED ROCK GRAVEL (GNEISS).					
				7.0			(USCS: SM).					
							AUGER REFUSAL AT 7'.					
							ROCK CORING					
RUN 1	7.0	12.0	7.0	11.0	60		VERY INTENSELY FRACTURED GRAY GNEISS, SOME OXIDATION.	TCR: 100%, SCR: 35%, RQD: 20%				
			11.0	11.9		ROCK	MODERATELY FRACTURED GRAY GNEISS.					
			11.9	12.0			VERY INTENSELY FRACTURED GRAY GNEISS.					
							CORE TESTING RESULTS (RUN 1, DEPTH 7.7'):					
							COMPRESSIVE STRENGTH: 5,690 PSI					
							UNIT WEIGHT: 172.8 PCF					
							CORE TESTING RESULTS (RUN 1, DEPTH 11.5'):					
							COMPRESSIVE STRENGTH: 3,360 PSI					
							UNIT WEIGHT: 160.8 PCF					
							OBSTRUCTION AT 9' PREVENTED ROCK CORE BARRELL FROM					
							BEING ADVANCED TO START RUN 2.					

Notes/Comments:
Pocket Pentrometer 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.

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:	CH-0109, DOWNINGTOWN, PA		Page 1 of 1
HDD No.:	S3-0290	Dates(s) Drilled: 05-27-15	Inspector: J. COSTELLO
Boring No.:	SB-03	Drilling Method: SPT - ASTM D1586	Driller: GREG
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 16.0	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 4' 45.950" N	75° 42' 36.827" 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	1.0			TOPSOIL (12")					
1	3.0	5.0	1.0		24	CL	MOTTLED BROWN AND GRAY SILTY CLAY WITH A LITTLE FINE	5	7	9	11	**16**
				6.5			SAND, TRACE FINE ROOTS. (USCS: CL).					
2	8.0	10.0	6.5		20		DR WEATHERED TO A VARI-COLORED FINE SAND AND SILT, TRACE	3	4	6	7	**10**
							FINE UNWEATHERED GRAVEL. (USCS: SM).					
3	13.0	15.0			23		DR WEATHERED TO A WHITE, GRAY, TAN FINE TO MEDIUM SAND AND	1	4	6	8	**10**
							SILT, TRACE TO A LITTLE UNWEATHERED FINE GRAVEL.					
4	18.0	20.0			24		DR WEATHERED TO A WHITE, GRAY, TAN FINE SAND AND SILT,	2	3	7	12	**10**
						SM	TRACE UNWEATHERED FINE GRAVEL.					
5	23.0	25.0			24		DR WEATHERED TO A WHITE, GRAY, TAN FINE SAND AND SILT,	1	4	6	10	**10**
							TRACE UNWEATHERED FINE GRAVEL.					
6	28.0	30.0			24		DR WEATHERED TO A WHITE, GRAY, TAN FINE SAND AND SILT,	1	1	6	4	**7**
				30.0			TRACE UNWEATHERED FINE GRAVEL. (USCS: SM).					
							WET ON SPOON AT 18'.					
							WATER LEVEL THROUGH AUGERS AT 16'.					
							DRY AND CAVED AT 14'.					

Notes/Comments:

Pocket Pentrometer Testing
S1: > 4TSF

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 S3-0290

HDD No.	Test Boring No.	Sample No.	Depth of Sample (ft.) From	Depth of Sample (ft.) To	Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318) Liquid Limit, %	Atterburg Limits (ASTM D4318) Plastic Limit, %	Atterburg Limits (ASTM D4318) Plasticity Index, %	USCS Classif. (ASTM D2487)
S3-0290	SB-01	1	3.0	5.0	11.7	27.8	-	-	-	-
		2	8.0	9.5	6.3	22.0	-	-	-	-
		4	18.0	18.9	7.4	31.5	-	-	-	-
		5	23.0	23.8	6.6	30.5	29	24	5	SM
		6	28.0	28.7	7.4	37.7	-	-	-	-
	SB-02	1	3.0	5.0	13.0	38.8	30	24	6	SM
	SB-03	1	3.0	5.0	20.3	83.0	41	23	18	CL
		2	8.0	10.0	21.5	48.0	36	26	10	SM
		3	13.0	15.0	23.9	42.1	-	-	-	-
		5	23.0	25.0	22.9	47.6	-	-	-	-
		6	28.0	30.0	22.9	47.6	55	37	18	SM

Rock Core Testing Results				
Boring No.	Core Run	Approximate Depth (ft)	Compressive Strength (psi)	Unit Weight (pcf)
SB-02	1	7.7	5,690	172.8
SB-02	1	11.5	3,360	160.8

Notes:

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

ROCK CORE DESCRIPTION SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0290

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					
S3-0290	SB-2	1	7	12	100	35	20	7	8	Moderate	Gneiss	Massive	Light gray	Fractures ranging from 0° to 45°, Avg. 29°
								8	10	Moderate	Metavolcanic inclusion	2	Gray, brown, black	Fractures ranging from 4° to 75°, Avg. 49°
								10	12	Moderate	Gneiss	Massive	Light gray	Fractures ranging from 30° to 75°, Avg. 51°

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0290

HDD No.	NAME	BORING NO.	REGIONAL GEOLOGY DESCRIPTION	GENERAL TOPOGRAPHIC SETTING	BEDROCK FORMATION	GENERAL ROCK TYPE	APPROX MAX FM THICKNESS (FT)	DEPTH TO ROCK (Ft bgs) based on nearby well drilling logs	NOTES / COMMENTS
S3-0290	Little Conestoga Road, Downingtown	SB-01	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.	Gently sloping to the north	Graphitic felsic gneiss (PreCambrian)	Graphitic gneiss	Unknown	Ranges from 4 to 50 ft bgs, Avg. 27 ft bgs (.25 mile radius)	
		SB-02		Generally level, slightly sloping to the south				Ranges from 10 to 50 ft bgs, Avg. 29 ft bgs (.25 mile radius)	
		SB-03		Generallly level				Ranges from 10 to 50 ft bgs, Avg. 31 ft bgs (.25 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.

October 17, 2017

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

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

Re: Geotechnical Site Characterization
Mariner East 2 Pipeline Project
Spread 6 – Little Conestoga Road
Commonwealth of Pennsylvania
Drawing # PA-CH-0100.0000-RD
PO # 20170908-1
Terracon Project No. J217P078

Dear Mr. Sessions:

This letter provides a summary of the bedrock characterization for the Mariner East 2 Pipeline Project crossing to be located at Little Conestoga Road (Drawing #PA-CH-0100.0000-RD) in the Commonwealth of Pennsylvania. Our services were performed in general accordance with our proposal number PJ2175108 dated July 28, 2017. Our scope of services included advancing two borings, designated as B6-21W and B6-21E, visual classification and photography of the rock core samples, and laboratory testing of representative rock samples.

Test borings, B6-21W and B6-21E were drilled between September 14 and 25, 2017 to depths of 237.5 and 145.5 feet, respectively as shown on the attached **Test Boring Location Plan**. Bedrock typically consisted of metamorphic rock primarily comprised of gneiss. Final test boring logs documenting overburden soil and bedrock conditions as well as photographs of the rock core samples are attached.

Rock compressive strength testing was performed on samples from approximately 20-foot intervals within the bedrock strata at each boring location. As an exception to the planned 20-foot intervals, rock samples from B9-21E near 35 feet and 85 feet were not tested due to highly fractured or weathered conditions. Unconfined compressive strength test results are shown on the attached reports.

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

Sincerely,
Terracon Consultants, Inc.

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

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

Attch:

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

TEST BORING LOCATION PLAN

N

APPROXIMATE BORING LOCATION

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

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

Terracon
Consulting Engineers & Scientists
201 Hammer Mill Road Rocky Hill, Ct 06067
PH. (860) 721-1900 FAX. (860) 721-1939

TEST BORING LOCATION PLAN

Little Conestoga Road HDD Core B6-21W and B6-21E
PA-CH-0100.0000-RD
Chester County, Pennsylvania

Exhibit

A-2

EXPLORATION RESULTS

BORING LOG NO. B6-21W Little Conestoga Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.082797° Longitude: -75.71732°
Approximate Surface Elev: 490 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)
		SILTY SAND WITH GRAVEL (SM), trace clay, red brown, medium dense	18	3-6-13 N=19		
8.5	481.5+/-					
		Weathered rock	4	50/5"		
10.5	479.5+/-					
		Run 1, Hard, slightly weathered, gray and brown, medium-grained FELSIC GNEISS, primary joint set, moderately dipping, very close spacing, rough, discolored, open	54		47	1 3 3 2 3
15.0	475+/-					
		Run 2, Moderately hard, moderately weathered, gray, white, and brown, medium-grained FELSIC GNEISS, primary joint set, high angle, very close spacing, rough, decomposed, open, highly fractured throughout	42		7	1 1 1 2 3
20.0	470+/-					
		Run 3, Hard, fresh, gray and brown, medium-grained FELSIC GNEISS, primary joint set, moderately dipping, moderately close spacing, rough, discolored, open	60		100	2 2 2 2 2
25.0	465+/-					
		Run 4, Similar to 27.2 feet At 27.2 feet: Moderately hard, moderately weathered, gray, white, and brown, medium-grained FELSIC GNEISS, primary joint set, high angle, very close spacing, rough, decomposed, open, highly fractured throughout	58		47	2 2 2 2 2
30.0	460+/-					

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

38' on 9/19/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-14-2017 | Boring Completed: 09-22-2017

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

Project No.: J217P078 | Exhibit: A-1

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 6.GPJ TERRACON_DATATEMPLATE.GDT 10/17/17

BORING LOG NO. B6-21W Little Conestoga Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.082797° Longitude: -75.71732°
Approximate Surface Elev: 490 (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 5, Similar									
35.0	455+/-	35			18		12	1 1 1 1 2	
Run 6, Hard, fresh, gray and white, medium-grained FELSIC GNEISS, primary joint set, high angle, close spacing, rough, discolored, open			▽		60		90	2 2 3 3 3	
40.0	450+/-	40							
Run 7, Hard, fresh, gray, medium to fine-grained, FELSIC GNEISS, primary foliation joints, high angle, close to moderately close spacing, smooth to rough, planar, fresh, open; secondary joint set, low angle, wide spacing, rough, slightly undulating to stepped, discolored to fresh, open to tight					60		77	4 4 3 4 4	
45.0	445+/-	45							
Run 8, Similar					60		80	3 3 3 3 3	
50.0	440+/-	50							
Run 9, Similar, no secondary joints encountered					60		90	2.5 2.5 2.5 2.5 3	
55.0	435+/-	55							
Run 10, Similar, single high angle (across foliation) secondary joint, from 56.1 to 57.3 feet, rough, undulating, slightly discolored, tight					58		83	2.5 2.5 2.5 2.5 1.5	
60.0	430+/-	60							

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

▽ *38' on 9/19/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-14-2017 | Boring Completed: 09-22-2017

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

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-21W Little Conestoga Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.082797° Longitude: -75.71732°
Approximate Surface Elev: 490 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
65.0	425+/-	65			60		60	2.5 2 3.5 3.5 2	
Run 11, Moderately hard to hard, slightly weathered,gray and olive gray with red brown, aphanitic to fine-grained, FELSIC GNEISS, primary foliation joint set, moderately dipping to high angle, close to moderately close spacing, rough, planar to undulating, discolored to slightly decomposed, open; secondary joint set, low angle across foliation, close to moderately close spacing,rough, planar to stepped, discolored to decomposed, open									
70.0	420+/-	70			60		45	1.5 1.5 2.5 2 2	
Run 12, Similar									
75.0	415+/-	75			60		78	2.5 3.5 4.5 4.5 4	
Run 13, Similar, slightly weathered to fresh, primary foliation joint set, moderately close spacing, discolored, open to tight; secondary joint set, moderately close spacing, discolored, open to tight									
80.0	410+/-	80			60		28	5 4 3.5 3 4.5	
Run 14, Similar, high angle to vertical (across foliation) tertiary joints from 76.1 to 79.3 feet, close spacing, rough, undulating, discolored, tight									
85.0	405+/-	85			60		66	4 3 1.5 2 2	
Run 15, Similar, no tertiary joints encountered									
90.0	400+/-	90			59		62	1.5 3 3 3 3	
Run 16, Similar, fresh with near vertical tertiary joint from 85 to 86.2 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

▽ *38' on 9/19/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-14-2017 | Boring Completed: 09-22-2017

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

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-21W Little Conestoga Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.082797° Longitude: -75.71732°
Approximate Surface Elev: 490 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
95.0	395+/-	95	60	95	3 3.5 3 3.5 4
100.0	390+/-	100	60	88	5 5.5 6 6.5 8
105.0	385+/-	105	60	78	9 4.5 6.5 4.5 4.5
110.0	380+/-	110	60	79	5.5 4 3.5 3 3
115.0	375+/-	115	58	51	3.5 3 3 4 3
120.0	370+/-	120	60	60	4 4.5 2.5 3 4

Run 17, Hard, slightly weathered, dark gray and white banded, FELSIC GNEISS, foliation moderately dipping to high angle, very thin, planar to slightly undulating; primary foliation joint set, moderately dipping to high angle, moderately close spacing, rough, planar, discolored, tight; secondary joint set, low angle across foliation, moderately close to wide spacing, rough, planar to stepped, discolored, tight

Run 18, Similar

Run 19, Similar

Run 20, Similar with moderately weathered zone from 107.0 to 107.8 feet

Run 21, Similar with moderately weathered zone from 114.3 to 115.0 feet

Run 22, Similar with moderately weathered zone from 116.5 to 117.2 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

38' on 9/19/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-14-2017 | Boring Completed: 09-22-2017

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

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-21W Little Conestoga Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.082797° Longitude: -75.71732°
Approximate Surface Elev: 490 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Run	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
125.0	365+/-	Run 23, Similar, no weathered zones encountered	125			60		78	4 5 4 5 5	
130.0	360+/-	Run 24, Similar, with vertical tertiary joint from 128.3 to 129.0 feet, rough, slightly undulating, discolored, open	130			60		98	4 4 4 4.5 4	
135.0	355+/-	Run 25, Similar, with vertical tertiary joints from 132.5 to 133.1 feet and 133.8 to 135.0 feet; frequent felsic migmatite seams along foliation	135			60		82	3.5 3.5 3.5 2.5 3	
140.0	350+/-	Run 26, Similar; primary and secondary joint sets closely spaced	140			55.5		31	3.5 3.5 4 4 3	
145.0	345+/-	Run 27, Hard, fresh, gray and white banded, FELSIC GNEISS; foliation moderately dipping, very thin, planar; primary foliation joint set, moderately dipping, wide spacing, smooth to rough, planar, discolored to fresh, tight; secondary joint set, low angle across foliation, wide spacing, rough, stepped, discolored to fresh, tight	145			57		88	4.5 3.5 3.5 3.5 3	
150.0	340+/-	Run 28, Similar	150			60		75	5 4 3 3.5 3	

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

▽ *38' on 9/19/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-14-2017 | Boring Completed: 09-22-2017

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

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-21W Little Conestoga Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.082797° Longitude: -75.71732°
Approximate Surface Elev: 490 (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 29, Very hard, fresh, dark gray and olive green, medium grained, hornblende mica GNEISS with quartzite bands, primary joint set, high angle, close spacing, rough, fresh, open									
155.0	335+/-	155			60		93	4.5 4.5 4.5 5 4.5	
Run 30, Similar, moderately close spacing, high angle joints									
160.0	330+/-	160			60		92	3 5.5 6 5.5 6	
Run 31, Very hard, fresh, dark gray and olive green, medium-grained, hornblende mica GNEISS with quartz and calcite banding, primary joint set, moderately dipping, wide spacing, rough, fresh, tight									
165.0	325+/-	165			60		100	5 5 4 4.5 4.5	
Run 32, Very hard, fresh, dark gray and olive green, medium-grained, hornblende mica GNEISS with quartz and calcite banding, primary joint set, moderately dipping, close spacing, rough, fresh, open; secondary joint set, high angle (across foliation) tertiary joints from 169 to 170 feet, very close spacing, polished/slickensided, fresh, tight									
170.0	320+/-	170			60		73	4 3.5 3.5 3 3.5	
Run 33, Similar, primary foliation joint set, high angle, rough, fresh, open									
175.0	315+/-	175			60		87	5.5 4.5 5.5 6 7	
Run 34, Similar, primary foliation joint set, tight									
180.0	310+/-	180			60		97	6 4 5.5 4.5 4	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Slightly reactive with hydrochloric acid from 160 to 190 feet

WATER LEVEL OBSERVATIONS

▽ *38' on 9/19/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-14-2017 | Boring Completed: 09-22-2017

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

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-21W Little Conestoga Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.082797° Longitude: -75.71732°
Approximate Surface Elev: 490 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
185.0	305+/-	185	60	97	5 5 6 4 3
Run 35, Similar, primary foliation joint set, open					
190.0	300+/-	190	60	76	3 3 3 2 3
Run 36, Moderately hard, slightly weathered, dark gray and olive green, medium to coarse-grained, calcite hornblende mica GNEISS, primary joint set, moderately dipping, close spacing, rough, decomposed, open, vugs throughout, calcite veins					
195.0	295+/-	195	60	49	4 5 5 4 6
Run 37, Hard, fresh, dark gray and olive green, medium-grained, hornblende mica GNEISS, primary foliation joint set, high angle, close to very close spacing, rough, discolored, open; secondary mineralization (calcite) in-filling in joints, highly fractured from 193.5 to 195 feet					
200.0	290+/-	200	60	58	5 5 4 4 3
Run 38, Similar, fewer fractures					
205.0	285+/-	205	60	93	5 5 4 5 4
Run 39, SImilar, fewer fractures					
210.0	280+/-	210	60	83	3 5 5 4 4
Run 40, Hard, fresh, dark gray and olive green, medium-grained, hornblende mica GNEISS, primary foliation joint set, moderately dipping, close spacing, rough, fresh, open; secondary joint set, high angle, close spacing, rough, fresh, tight					

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:
Slightly reactive with hydrochloric acid from 160 to 190 feet

WATER LEVEL OBSERVATIONS

▽ *38' on 9/19/17*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-14-2017 | Boring Completed: 09-22-2017

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

Project No.: J217P078 | Exhibit: A-1

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL J217P078 - SPREAD 6.GPJ TERRACON_DATATEMPLATE.GDT 10/17/17

BORING LOG NO. B6-21W Little Conestoga Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.082797° Longitude: -75.71732°
Approximate Surface Elev: 490 (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 41, Similar, primary foliation joint set, moderately dipping to high angle, close to moderately close spacing, smooth to rough, planar to undulating, discolored to fresh, open to tight; secondary joint set, low angle across foliation, moderate to wide spacing, rough, stepped, decomposed to discolored, open					60		80	4 4 5 4 5	
215.0	275+/-	215							
Run 42, Similar, highly to completely weathered zones from 217.3 to 218.5 feet and 219.1 to 220 feet					47		20	6 26 4 3 3	
220.0	270+/-	220							
Run 43, Similar, no weathered zones, primary foliation joint set and secondary joint set, close to moderately close spacing					60		30	4 3 4 4 4	
225.0	265+/-	225							
Run 44, Similar					60		53	5 5 5 4 4	
230.0	260+/-	230							
Run 45, Similar, primary joint set, close to moderately close spacing, discolored to fresh, tight, secondary joint set, wide spacing, discolored to fresh, tight					60		80	4 5 5 6 4	
235.0	255+/-	235							
Run 46, Similar					30		73	3 3 2	
237.5	252.5+/-								
Boring Terminated at 237.5 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

38' on 9/19/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-14-2017 | Boring Completed: 09-22-2017

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

Project No.: J217P078 | Exhibit: A-1

BORING LOG NO. B6-21E Little Conestoga Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.079025° Longitude: -75.709583°
Approximate Surface Elev: 398 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	FIELD TEST RESULTS	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
		Surface soils stripped to approximately 3 feet with excavator to make pad for drill rig, depths are from bottom of pad				
		POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM), orange-brown to light brown, medium dense, (completely weathered rock)	7-10-11 N=21			
9.3	388.5+/-		44-50/4"			
		Completely weathered rock Boring advanced to 12 feet, roller bit refusal, begin rock core at 12 feet				
12.0	386+/-					
		Run 1, Medium hard, severely weathered, orange-brown to white banded, medium-grained, FELSIC GNEISS, very thin foliation, moderately dipping to high angle, planar; primary foliation joint set, moderately dipping to high angle, very close spacing, rough, planar, discolored to decomposed, open; secondary joint set, high angle across foliation, moderate to wide spacing, rough, stepped, discolored to decomposed, open, oxidation staining throughout		42	0	2.5 4.5 3 2
15.5	382.5+/-					
		Run 2, Similar to 18.6 feet At 18.6 feet: Similar, hard, moderately to severely weathered, green-gray and white		60	12	5.5 2.5 3 5 3.5
20.5	377.5+/-					
		Run 3, Similar to 24.6 feet At 24.6 feet: Similar, severely weathered, orange-brown oxidation staining throughout		58	0	2.5 2.5 2.5 4 2.5
25.5	372.5+/-					
		Run 4, Similar		23	0	2.5 2 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:
Approximately 50% loss of water circulation from 12 to 64 feet

WATER LEVEL OBSERVATIONS

18.1' on 9/23/17

15' on 9/25/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-22-2017 | Boring Completed: 09-25-2017

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

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-21E Little Conestoga Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.079025° Longitude: -75.709583°
Approximate Surface Elev: 398 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
30.5	367.5+/-				
Run 5, Similar			51	0	1.5 2.5 3 2.5 3.5
35.5	362.5+/-	35			
Run 6, Similar			24	0	2 2 2 2 1
40.5	357.5+/-	40			
Run 7, Similar			34	0	1.5 1.5 2.5 2.5 3.5
45.5	352.5+/-	45			
Run 8, Hard, slightly weathered, dark green-gray and white, medium-grained, FELSIC GNEISS, very thin, foliation, high angle, planar; primary foliation joint set, high angle, very close to close spacing, rough, planar, discolored to fresh, open to tight; secondary joint set, low angle to moderately dipping across foliation, rough, stepped, slightly decomposed, open, severely weathered zone from 49 to 51.5 feet			55	13	1.5 2 3.5 3 1.5
50.5	347.5+/-	50			
Run 9, Similar			48	17	2 2 2 2 2
55.5	342.5+/-	55			
Run 10, Similar, moderately weathered			37	7	2.5 3 2 2 2
		60			

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:
Approximately 50% loss of water circulation from 12 to 64 feet

WATER LEVEL OBSERVATIONS

18.1' on 9/23/17

15' on 9/25/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-22-2017 | Boring Completed: 09-25-2017

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

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-21E Little Conestoga Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.079025° Longitude: -75.709583°
Approximate Surface Elev: 398 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Run	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
60.5	337.5+/-				
		Run 11, Similar, slightly weathered	58	27	2.5 2.5 3 4 4
65.5	332.5+/-				
		Run 12, Similar	52	27	3 2.5 3 3 3
70.5	327.5+/-				
		Run 13, Similar, fresh, primary foliation joint set, fresh, open to tight; secondary joint set, fresh, open to tight, foliation poorly developed below 74.1 feet	60	55	3.5 3 4.5 4.5 3.5
75.5	322.5+/-				
		Run 14, Similar to 77.2 feet, poorly developed foliation At 77.2 feet: Very hard, fresh, blue-green and white, coarse-grained, anatectic, PEGMATITE, non-foliated; primary joint set, high angle, close to moderately close spacing, rough, slightly undulating, slightly decomposed, (sand and silt in-filling), to fresh, open to tight; secondary joint set, low angle to moderately dipping, moderately close to wide spacing, rough, planar, slightly decomposed to fresh, open to tight	60	57	3 3.5 4.5 4 5
80.5	317.5+/-				
		Complete loss of water circulation at 78.5 feet Run 15, Similar, fractured zones at joint set intersections from 85.9 to 86.1 feet and 88.4 to 88.9 feet, occasional pyrite on joint surfaces	60	73	5 3.5 4.5 4.5 4.5
85.5	312.5+/-				
		Run 16, Similar	60	56	6.5 5 5.5 6 6

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

18.1' on 9/23/17

15' on 9/25/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-22-2017 | Boring Completed: 09-25-2017

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

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-21E Little Conestoga Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.079025° Longitude: -75.709583°
Approximate Surface Elev: 398 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Run / Description	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
90.5	307.5+/-	Run 17, Similar to 94.1 feet At 94.1 feet: Hard to very hard, fresh, light green-gray to white banded, medium to coarse-grained, GRAPHITIC FELSIC GNEISS, very thin foliation high angle to near vertical, planar to slightly undulating; primary foliation joint set, high angle to near vertical, moderately close spacing, smooth to rough, planar to slightly undulating, slightly decomposed (sand and silt in-filling), to fresh, open to tight; secondary joint set, low angle, moderately close to wide spacing, rough, undulating to stepped, slightly decomposed to fresh, open to tight, numerous fractures healed by secondary mineralization	60	72	6 6 6 6 5
95.5	302.5+/-	Run 18, Similar, frequent pyrite on joint surfaces	60	73	5 6 6 5 4.5
100.5	297.5+/-	Run 19, Similar	60	82	6 5 6 6 6
105.5	292.5+/-	Run 20, Similar	60	65	4.5 5 5.5 5 5.5
110.5	287.5+/-	Run 21, Similar, primary foliation joint set very close to moderately close spacing; secondary joint set, close to moderately close spacing	60	77	4 3 3 4.5 4
115.5	282.5+/-	Run 22, Similar, poorly-foliated green-blue gray-white granitic zone from 120.2 to 122.1 feet	60	85	4.5 3.5 3.5 4 4

DEPTH (Ft.): 95, 100, 105, 110, 115, 120

WATER LEVEL OBSERVATIONS: SAMPLE TYPE

FIELD TEST RESULTS | Penetrometer Test (tsf)

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

18.1' on 9/23/17

15' on 9/25/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-22-2017 | Boring Completed: 09-25-2017

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

Project No.: J217P078 | Exhibit: A-2

BORING LOG NO. B6-21E Little Conestoga Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

LOCATION PA-CH-0100.0000-RD
20170908-1
Latitude: 40.079025° Longitude: -75.709583°
Approximate Surface Elev: 398 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Run	RECOVERY (In.)	RQD (%)	Core rate (min/ft)
120.5	277.5+/-				
		Run 23, Similar, poorly-foliated GNEISS	60	67	5 4 5 5 5
125.5	272.5+/-				
		Run 24, Similar to 125.9 feet At 129.5 feet: Very soft to medium hard, severely weathered, dark green to black, medium to fine-grained, serpentine GNEISS At 126.6 feet: Hard, slightly weathered to fresh, dark green to light green-gray, coarse to medium-grained, hornblende GNEISS, foliation high angle, poorly-developed; primary joint set, high angle to near vertical, moderately close spacing, rough, undulating, discolored, open to tight; secondary joint set, low angle, moderately close spacing, rough, undulating to stepped, open, joint set intersection forms highly-fractured zone from 129.7 to 130.5 feet	60	30	4.5 3.5 3.5 3.5 4.5
130.5	267.5+/-				
		Run 25, Similar, primary and secondary joint sets decomposed (sand and silt in-filling) to discolored, open to tight, small slickensides on primary joint at 134.7 feet	60	43	3.5 3.5 3.5 3.5 3.5
135.5	262.5+/-				
		Run 26, Similar	60	50	4 3.5 3 3 3
140.5	257.5+/-				
		Run 27, Similar	60	52	2.5 2 2.5 2.5 2
145.5	252.5+/-				
		Boring Terminated at 145.5 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

18.1' on 9/23/17

15' on 9/25/17

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 09-22-2017 | Boring Completed: 09-25-2017

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

Project No.: J217P078 | Exhibit: A-2

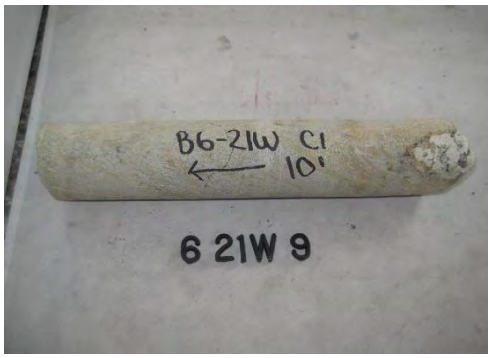
ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B6-21W	Lithology :	Gneiss
Sample No.:	9	Moisture Content :	As received
Sample Depth:	10 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	3 min

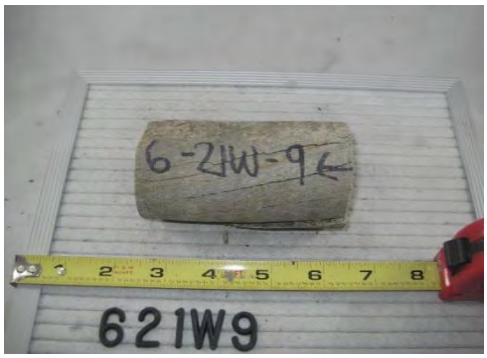
Diameter:	1.96 in	Maximum Axial Load at Failure:	8,670 lb
Length:	3.84 in	Compressive Strength:	2,874 psi
L/D:	1.96	Compressive Strength:	19.81 Mpa
End Area:	3.02 in^2	Unit Weight	163 pcf

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

Before the Test



After the Test



Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

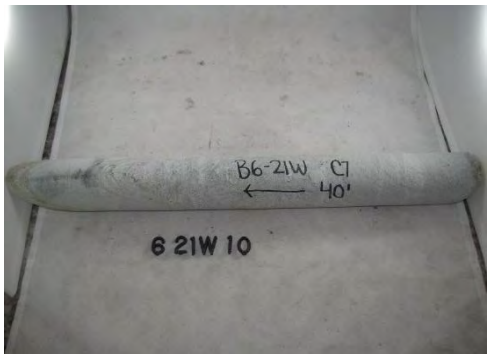
Project:	Mariner East Pipeline	Terracon		Performed by:	C. Santana
Project No.	J217P078			Test Date:	10/16/2017
Location:	Spread 6			Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire		Review Date :	10/16/2017

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

Boring No.:	B6-21W	Lithology :	Gneiss
Sample No.:	10	Moisture Content :	As received
Sample Depth:	40 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	3 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	11,260 lb
Length:	4.61 in	Compressive Strength:	3,657 psi
L/D:	2.33	Compressive Strength:	25.21 Mpa
End Area:	3.08 in^2	Unit Weight	173 pcf

Before the Test



After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	C. Santana
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

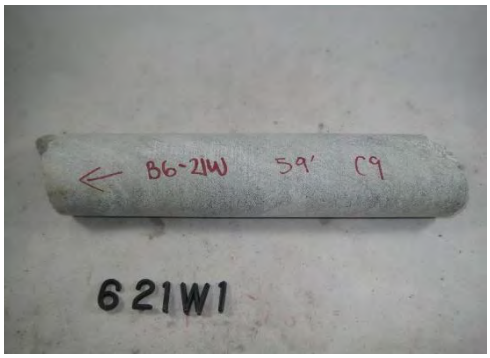
ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B6-21W	Lithology :	Gneiss
Sample No.:	1	Moisture Content :	As received
Sample Depth:	51 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	11 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	35,010 lb
Length:	4.49 in	Compressive Strength:	11,370 psi
L/D:	2.27	Compressive Strength:	78.40 Mpa
End Area:	3.08 in^2	Unit Weight	175 pcf

Photograph before the test mislabeled as 59 feet

Before the Test



After the Test

Drawing # :	PA-CH-0100.0000-RD
PO # :	20170908-1
Crossing :	Little Conestoga Road
Spread :	Spread 6

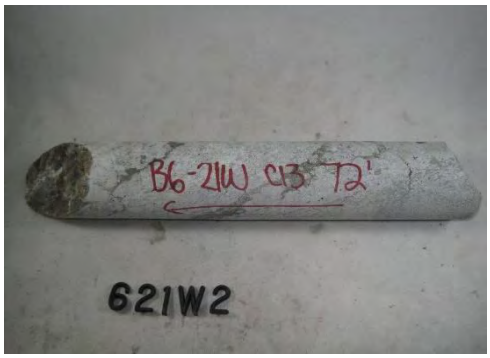
Project:	Mariner East Pipeline	Terracon	Performed by:	C. Santana
Project No.	J217P078		Test Date:	10/16/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/16/2017

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

Boring No.:	B6-21W	Lithology :	Gneiss
Sample No.:	2	Moisture Content :	As received
Sample Depth:	72 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	6 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	19,940 lb
Length:	4.66 in	Compressive Strength:	6,476 psi
L/D:	2.35	Compressive Strength:	44.65 Mpa
End Area:	3.08 in^2	Unit Weight	173 pcf

Before the Test



After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	C. Santana
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.:	B6-21W	Lithology :	Gneiss
Sample No.:	3	Moisture Content :	As received
Sample Depth:	93 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	11 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	37,800 lb
Length:	4.73 in	Compressive Strength:	12,276 psi
L/D:	2.39	Compressive Strength:	84.64 Mpa
End Area:	3.08 in^2	Unit Weight	175 pcf

Before the Test

After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

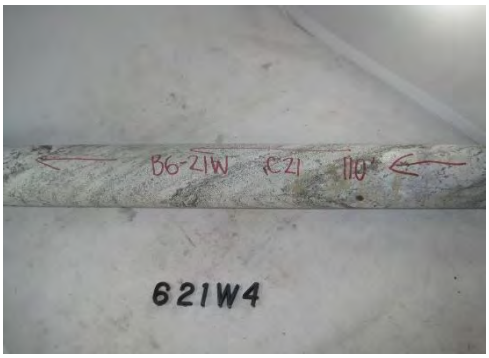
Project:	Mariner East Pipeline	Terracon		Performed by:	C. Santana
Project No.	J217P078			Test Date:	10/16/2017
Location:	Spread 6			Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire		Review Date :	10/16/2017

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

Boring No.:	B6-21W	Lithology :	Gneiss
Sample No.:	4	Moisture Content :	As received
Sample Depth:	110 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	4 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	14,430 lb
Length:	4.52 in	Compressive Strength:	4,639 psi
L/D:	2.27	Compressive Strength:	31.99 Mpa
End Area:	3.11 in^2	Unit Weight	172 pcf

Before the Test



After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

Project:	Mariner East Pipeline	Terracon		Performed by:	C. Santana
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.:	B6-21W	Lithology :	Gneiss
Sample No.:	5	Moisture Content :	As received
Sample Depth:	131 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	2 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	6,450 lb
Length:	4.19 in	Compressive Strength:	2,074 psi
L/D:	2.11	Compressive Strength:	14.30 Mpa
End Area:	3.11 in^2	Unit Weight	166 pcf

Before the Test

After the Test

Drawing # :	PA-CH-0100.0000-RD
PO # :	20170908-1
Crossing :	Little Conestoga Road
Spread :	Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	C. Santana
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.:	B6-21W	Lithology :	Gneiss
Sample No.:	6	Moisture Content :	As received
Sample Depth:	152 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	8 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	25,510 lb
Length:	4.60 in	Compressive Strength:	8,285 psi
L/D:	2.32	Compressive Strength:	57.12 Mpa
End Area:	3.08 in^2	Unit Weight	182 pcf

Before the Test

After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

Project:	Mariner East Pipeline	Terracon		Performed by:	C. Santana
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.:	B6-21W	Lithology :	Gneiss
Sample No.:	7	Moisture Content :	As received
Sample Depth:	175 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	7 min

Diameter:	1.95 in	Maximum Axial Load at Failure:	22,720 lb
Length:	4.66 in	Compressive Strength:	7,608 psi
L/D:	2.39	Compressive Strength:	52.45 Mpa
End Area:	2.99 in^2	Unit Weight	179 pcf

Before the Test

After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

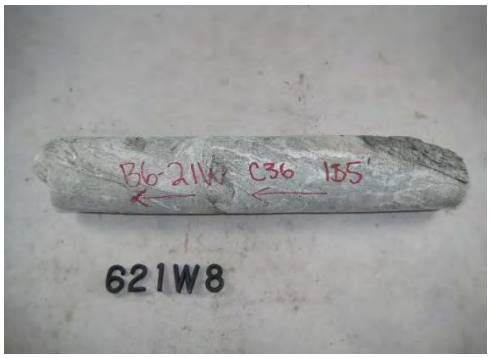
Project:	Mariner East Pipeline	Terracon	Performed by:	C. Santana
Project No.	J217P078		Test Date:	10/16/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/16/2017

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

Boring No.:	B6-21W	Lithology :	Gneiss
Sample No.:	8	Moisture Content :	As received
Sample Depth:	185 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	1 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	2,060 lb
Length:	4.65 in	Compressive Strength:	669 psi
L/D:	2.35	Compressive Strength:	4.61 Mpa
End Area:	3.08 in^2	Unit Weight	157 pcf

Before the Test



After the Test

Drawing # :	PA-CH-0100.0000-RD
PO # :	20170908-1
Crossing :	Little Conestoga Road
Spread :	Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	C. Santana
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

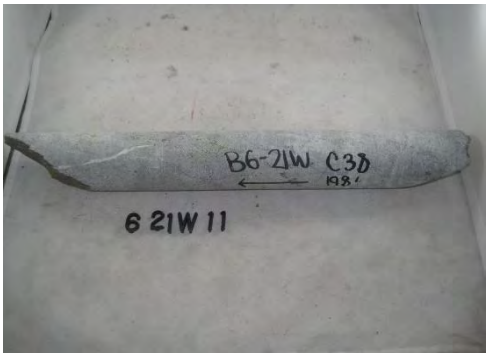
77 Sundial Ave., Suite 401 W
Manchester, New Hampshire

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

Boring No.:	B6-21W	Lithology :	Gneiss
Sample No.:	11	Moisture Content :	As received
Sample Depth:	198 feet	Lab Temperature :	70° F
Sampling Date:	9/14/17	Loading Rate:	55 psi/s
		Time to Failure:	10 min

Diameter:	1.98 in	Maximum Axial Load at Failure:	33,680 lb
Length:	4.48 in	Compressive Strength:	10,938 psi
L/D:	2.26	Compressive Strength:	75.42 Mpa
End Area:	3.08 in^2	Unit Weight	175 pcf

Before the Test



After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

Project:	Mariner East Pipeline	Terracon		Performed by:	C. Santana
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.:	B6-21E	Lithology :	Gneiss
Sample No.:	1	Moisture Content :	As received
Sample Depth:	18 feet	Lab Temperature :	70° F
Sampling Date:	9/22/17	Loading Rate:	55 psi/s
		Time to Failure:	13 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	43,140 lb
Length:	3.96 in	Compressive Strength:	13,870 psi
L/D:	1.99	Compressive Strength:	95.63 Mpa
End Area:	3.11 in^2	Unit Weight	169 pcf

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

Before the Test

Photographs are mislabeled as 6-21E-2

After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

Project:	Mariner East Pipeline	Terracon		Performed by:	C. Santana
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

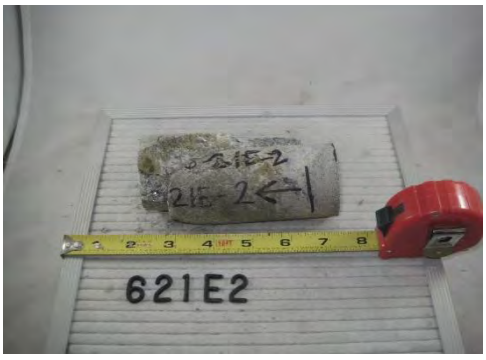
ASTM D7012 (Method C) Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Boring No.:	B6-21E	Lithology :	Gneiss
Sample No.:	2	Moisture Content :	As received
Sample Depth:	48 feet	Lab Temperature :	70° F
Sampling Date:	9/22/17	Loading Rate:	55 psi/s
		Time to Failure:	8 min

Diameter:	2.00 in	Maximum Axial Load at Failure:	27,070 lb
Length:	4.58 in	Compressive Strength:	8,617 psi
L/D:	2.29	Compressive Strength:	59.41 Mpa
End Area:	3.14 in^2	Unit Weight	164 pcf

Before the Test

After the Test



Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

Project:	Mariner East Pipeline	Terracon	Performed by:	C. Santana
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.:	B6-21E	Lithology :	Gneiss
Sample No.:	3	Moisture Content :	As received
Sample Depth:	75 feet	Lab Temperature :	70° F
Sampling Date:	9/22/17	Loading Rate:	55 psi/s
		Time to Failure:	14 min

Diameter:	2.00 in	Maximum Axial Load at Failure:	45,180 lb
Length:	3.36 in	Compressive Strength:	14,381 psi
L/D:	1.68	Compressive Strength:	99.15 Mpa
End Area:	3.14 in^2	Unit Weight	214 pcf

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

Before the Test

Photographs are mislabeled as 6-21E-1

After the Test

Drawing # :	PA-CH-0100.0000-RD
PO # :	20170908-1
Crossing :	Little Conestoga Road
Spread :	Spread 6

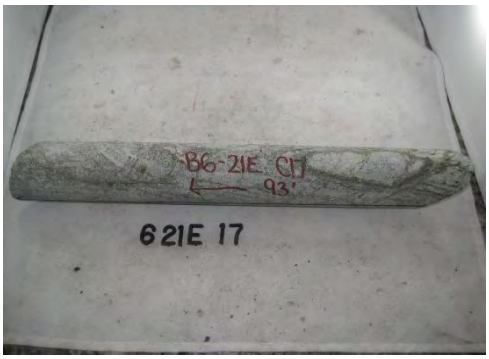
Project:	Mariner East Pipeline	Terracon	Performed by:	C. Santana
Project No.	J217P078		Test Date:	10/16/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/16/2017

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

Boring No.:	B6-21E	Lithology :	Pegmatite
Sample No.:	17	Moisture Content :	As received
Sample Depth:	93 feet	Lab Temperature :	70° F
Sampling Date:	9/22/17	Loading Rate:	55 psi/s
		Time to Failure:	6 min

Diameter:	2.01 in	Maximum Axial Load at Failure:	18,610 lb
Length:	4.59 in	Compressive Strength:	5,865 psi
L/D:	2.28	Compressive Strength:	40.44 Mpa
End Area:	3.17 in^2	Unit Weight	168 pcf

Before the Test



After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

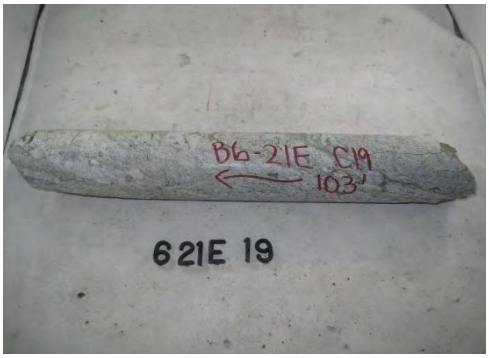
Project:	Mariner East Pipeline	Terracon	Performed by:	C. Santana
Project No.	J217P078		Test Date:	10/16/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.	77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Review Date :	10/16/2017

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

Boring No.:	B6-21E	Lithology :	Gneiss
Sample No.:	19	Moisture Content :	As received
Sample Depth:	103 feet	Lab Temperature :	70° F
Sampling Date:	9/22/17	Loading Rate:	55 psi/s
		Time to Failure:	4 min

Diameter:	1.99 in	Maximum Axial Load at Failure:	11,760 lb
Length:	4.51 in	Compressive Strength:	3,781 psi
L/D:	2.27	Compressive Strength:	26.07 Mpa
End Area:	3.11 in^2	Unit Weight	170 pcf

Before the Test



After the Test

Drawing # : PA-CH-0100.0000-RD
PO # : 20170908-1
Crossing : Little Conestoga Road
Spread : Spread 6

Project:	Mariner East Pipeline	Terracon		Performed by:	C. Santana
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: B6-21W, Samples C-1 to C-4 (10.5 to 30 feet)

Photograph 2: B6-21W, Samples C-5 to C-8 (30 to 50 feet)

Photograph 3: B6-21W, Samples C-9 to C-12 (50 to 70 feet)

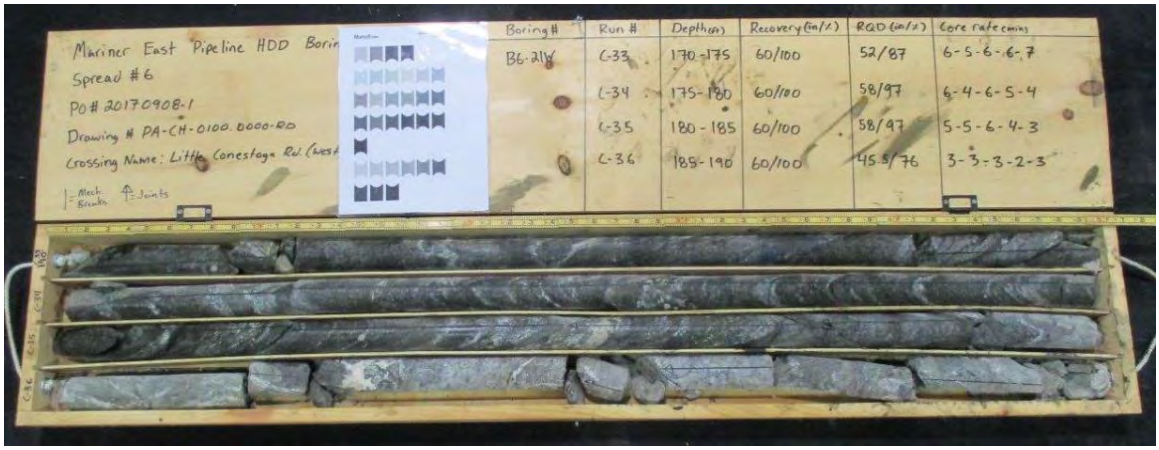
Photograph 4: B6-21W, Samples C-13 to C-16 (70 to 90 feet)

Photograph 5: B6-21W, Samples C-17 to C-20 (90 to 110 feet)

Photograph 6: B6-21W, Samples C-21 to C-24 (110 to 130 feet)

Photograph 7: B6-21W, Samples C-25 to C-28 (130 to 150 feet)

Photograph 8: B6-21W, Samples C-29 to C-32 (150 to 170 feet)

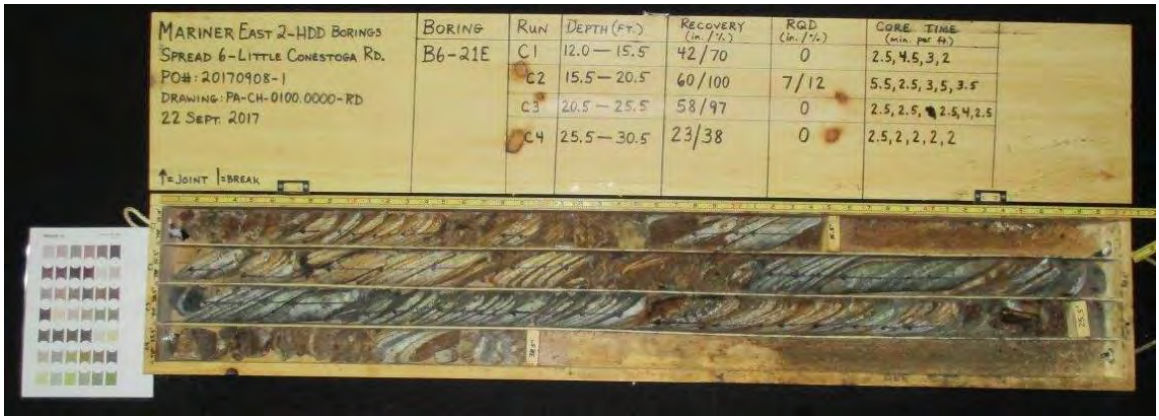


Photograph 9: B6-21W, Samples C-33 to C-36 (170 to 190 feet)

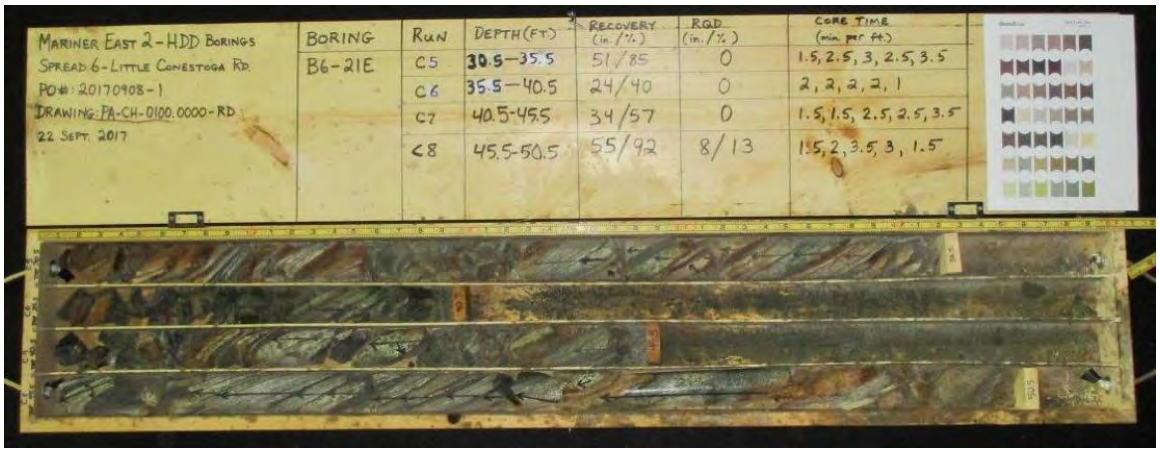
Photograph 10: B6-21W, Samples C-37 to C-40 (190 to 210 feet)

Photograph 11: B6-21W, Samples C-41 to C-44 (210 to 230 feet)

Photograph 12: B6-21W, Samples C-45 to C-46 (230 to 237.5 feet)



Photograph 1: B6-21E, Samples C-1 to C-4 (12 to 30.5 feet)



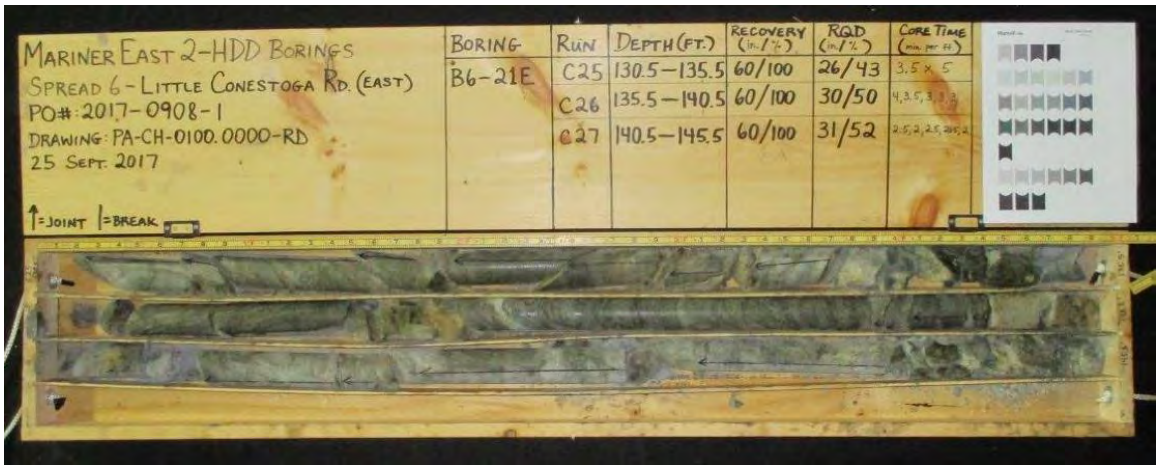
Photograph 2: B6-21E, Samples C-5 to C-8 (30.5 to 50.5 feet)

Photograph 3: B6-21E, Samples C-9 to C-12 (50.5 to 70.5 feet)

Photograph 4: B6-21E, Samples C-13 to C-16 (70.5 to 90.5 feet)

Photograph 5: B6-21E, Samples C-17 to C-20 (90.5 to 110.5 feet)

Photograph 6: B6-21E, Samples C-21 to C-24 (110.5 to 130.5 feet)



Photograph 7: B6-21E, Samples C-25 to C-27 (130.5 to 145.5 feet)

Attachment C

Geophysical Study Report

Rettew, May 2019

3020 Columbia Avenue, Lancaster, PA 17603 ● Phone: (800) 738-8395
E-mail: rettew@rettew.com ● Website: rettew.com

May 10, 2019

Mr. Larry J. Gremminger
Sunoco Logistics, L.P.
535 Fritztown Road
Sinking Spring, PA 19608

RE: Geophysical Survey
Sunoco Pipeline, L.P. Pipeline Project
Horizontal Directional Drill S3-0290 Little Conestoga Road
PA-CH-0100.0000-RD
Upper Uwchlan Township, Chester County, Pennsylvania
RETTEW Project No. 096302015

Dear Mr. Gremminger:

RETTEW Associates, Inc. completed a multi-technique geophysical survey at the S3-0290 Little Conestoga Road horizontal directional drill (HDD) site. The purpose of the survey was to detect and delineate subsurface fracture zones that could contribute to potential inadvertent returns (IRs) and/or a loss of circulation, and to determine the rock profile and rock rippability for ease-of-excavation along the HDD path. The following report, figures, and attachments describe the methods and results of the investigation.

EXECUTIVE SUMMARY

The multi-technique geophysical survey was completed on January 15, 2019. Two different geophysical techniques were utilized to detect and delineate subsurface features and provide a bedrock profile. These methods, and their general results, are as follows:

- Seismic refraction and multi-spectral analysis of surface waves (MASW) results confirmed the presence of low-velocity zones within the bedrock that could represent fracture zones
- Electrical resistivity imaging (ERI) identified a relatively conductive surface layer over a discontinuous mildly resistive layer, with the discontinuities possibly suggesting the presence of fracture zones.

Results from the geophysical techniques are consistent with each other, and with the geology as mapped by the PA Geological Survey; all suggesting that the local bedrock is mildly fractured, with a few potential anomalous zones of concern. The top-of-rock is expected to be slightly irregular with a weathered zone above competent rock and potential fractures within the bedrock formation.

SITE DESCRIPTION

The Little Conestoga Road HDD site is located east of Marsh Creek Reservoir in Upper Uwchlan Township, Chester County, Pennsylvania (see **Figure 1**). A geophysical survey was conducted over accessible areas of the path between the HDD exit/entry locations (**Figure 2**).

The site bedrock geology consists of Precambrian-aged Graphitic felsic gneiss (The Geologic Map of Pennsylvania, PA Department of Conservation and Natural Resources Geology Interactive Map, 2017 – see **Figure 2**). The graphitic felsic gneiss includes the Pickering Gneiss and small areas of marble and serpentinite. Outside the marble, it is dominantly quartz and feldspar with varying amounts of graphite and various metamorphic minerals. It can also be medium-grained, light to dark gray and greenish-gray, and is also of probable sedimentary origin prior to metamorphosis (Berg et al., 1980). The Geologic Map of Pennsylvania (PA Department of Conservation and Natural Resources Geology Interactive Map, 2017) shows several contacts and major faults within a mile of the survey area, as seen on the geologic inset on **Figure 2,** upper right (Ibid.).

SEISMIC MASW AND REFRACTION SURVEY

Seismic Multi-Spectral Analysis of Surface Waves (MASW) and refraction methods utilize the speed of seismic waves through various geologic layers and features to characterize the subsurface geologic conditions. The methods enable determination of the general material types, and the approximate depth to bedrock or rock profile. MASW can detect low velocities below the top of rock that might be associated with fracture zones. The principles of seismic refraction are summarized in **Appendix A**.

The seismic survey consisted of a single profile along the HDD center line between the exit/entry points (see blue triangles representing every 4th geophone, **Figure 2**). Color-contour velocity models of the seismic velocity for refraction and MASW are presented on **Figures 3** and **4,** respectively. On each, the vertical scale represents relative elevation in feet, and the horizontal axis represents an along-profile distance in feet. The color contours represent average seismic velocity variations (compressional or P-wave velocities for refraction, and shear or S-wave velocities for MASW), with increasing velocities from blue to yellow to orange to brown (refraction), and purple to grey to tan to brown (MASW). Please note that high- and low-velocity data along the first and last fifteen feet of any profile have higher uncertainty. Specific seismic refraction and MASW survey parameters are listed in **Appendix B**.

ERI SURVEY

Electrical resistivity measurements involve driving an electrical current into the ground using current electrodes at the ground surface. The apparent resistivity of the subsurface is determined by measuring the potential difference, or voltage, between two potential electrodes with a known separation and position/orientation relative to the current electrodes. The depth and volume of the subsurface zone represented by the measured apparent resistivity is a function of the geometry of the current and potential electrodes. Apparent resistivities are converted to model or true resistivities by performing a joint inversion of all the measured apparent resistivities along a profile.

The resistivity survey consisted of a single profile between the exit/entry points (see orange dots representing every 4th electrode, **Figure 2**). The apparent resistivity data were mathematically inverted using EarthImager 2D by AGI to provide a cross-sectional image. This is shown as successive segments (broken by roadways and other obstructions) in **Figure 5**. Specific ERI survey parameters are listed in **Appendix B**.

RESULTS

The seismic refraction data are presented as a cross-sectional profile on **Figure 3**. The data indicate a general three-layer stratigraphy consisting of a residual or sedimentary soil mantle, a weathered rock zone, and competent bedrock. The uppermost layer has average P-wave velocities generally less than

5,000 feet per second (fps) with a thickness of approximately 10-20 feet. This is consistent with a relatively compact soil mantle (shaded blue to yellow). The deepest layers have velocities over 10,000 fps (shaded orange to brown), consistent with competent bedrock (Carmichael, R. S., 1989). The seismic refraction results show multiple low-velocity zones indicative of fracture zones. The suspected fracture zones are highlighted in magenta on the seismic profiles.

The MASW seismic cross sections are presented on **Figure 4**. The MASW velocity models show lateral velocity changes within the soil and bedrock layers across the profiles, and are relatively consistent with the seismic refraction. Velocity lows below the bedrock surface could indicate fractures which might be potential pathways for inadvertent returns (IRs) and/or locations for loss of circulation.

The seismic velocity models from the ray-tracing method (not shown) were compared to standard ripping charts (see **Appendix C**, Caterpillar, Inc., 1995) using the inferred/assumed layer compositions to determine the general rippability of each stratum. In general, the surficial layer (bounded at depth by the wavy dashed contour) should be readily to marginally rippable with a D9 multi- or single-shank ripper doing open field ripping, based on a weighted average velocity of about less than 5,000 fps. Below the 5,000-fps contour, ripping will get more difficult with depth, with the transition zone expected to become non-rippable below the 10,000-fps contour (based on the average ray-trace velocity of over 13,990 fps and Caterpillar charts). The 5,000-fps contour represents the top of weathered rock. For trenching (as opposed to open field ripping), material below approximately the 3500-fps contour color (greenish blue) may become non-rippable (for a CAT-330 tracked excavator or equivalent). The selection of the contour cut-off for trenching is based on correlations between the ray-tracing models (not shown), material properties, and various excavation strategies investigated by Kirsten (1982). The Limitations section contains additional important information regarding rippability estimation by seismic and other means.

The electrical resistivity results are shown on **Figure 5.** The electrical profiles show a general two-layer model with a relatively conductive surface layer over a discontinuous mildly resistive layer. The upper layer is relatively discontinuous, with irregularities that could represent near-surface disturbances given the site development history. The deep conductive (blue) anomalies below the inferred top-of-rock may represent fractures or weathered seams within bedrock. Note that access was limited in the western portion of the HDD due to driveways and roadways that shortened the profile lengths and locally limited the depth of investigation of the geophysical survey.

CONCLUSIONS

In general, the geophysical survey results display anomalies indicative of fractures that are possible locations for IRs and/or loss of circulation along most of the HDD alignment. **Figure 6** summarizes the anomalous areas with various colored double-arrows. Overlapping and/or adjacent arrows indicate the highest risk of IR, but any anomalous areas might have an enhanced risk.

LIMITATIONS

The survey described above was completed using standard and/or routinely accepted practices of the geophysical industry, and the equipment employed represents, in RETTEW's professional opinion, the best available technology. RETTEW does not accept responsibility for survey limitations due to inherent technological limitations or unforeseen site-specific conditions. We will notify you of such limitations or conditions, when they are identifiable.

Rippability, while historically closely-correlated with seismic P-wave velocity, also depends on geotechnical properties of the material, on the specific method of excavation, and on the variety and size of equipment employed. For mechanical excavation, the teeth or other cutting elements must be forced into discontinuities of competent rock masses, or penetrate the fabric of weak rocks. Thus, joint or fracture spacing, aperture, and infilling will all play a role in determining whether existing discontinuities in apparently-competent rock masses can allow mechanical excavation. The strength of the intact rock will also control whether fresh discontinuities can be induced during excavation activities. Therefore, while seismic data can provide reliable guidelines, RETTEW recommends that the rocks to be excavated be checked for these other geotechnical characteristics through examination of local outcrops, test pits, or boring logs.

We have enjoyed and appreciated the opportunity to have worked with you. If you have any questions, please do not hesitate to contact the undersigned.

Charles H. Rhine, MSc, PG
Senior Project Manager

Timothy D. Bechtel, PhD, PG
Senior Project Manager

Felicia Kegel Bechtel, MSc, PG
Director of Geophysics

Enclosures
Figure 1: Topographic Basemap
Figure 2: Data Coverage Map and Geologic Setting
Figure 3: Seismic Refraction Survey Results
Figure 4: Seismic MASW Survey Results
Figure 5: Electrical Resistivity Survey Results
Figure 6: Geophysical Results Summary
Appendix A: Introduction to Seismic Refraction
Appendix B: Geophysical Survey Parameters
Appendix C: Caterpillar Ripping Charts

References

Berg, T.M., Edmunds, W.E., Geyer, A.R., and others, 1980, Geologic Map of Pennsylvania, PA Geological Survey, 4th series.

Carmichael, R. S. (1989), Physical Properties of Rocks and Minerals, CRC Press.

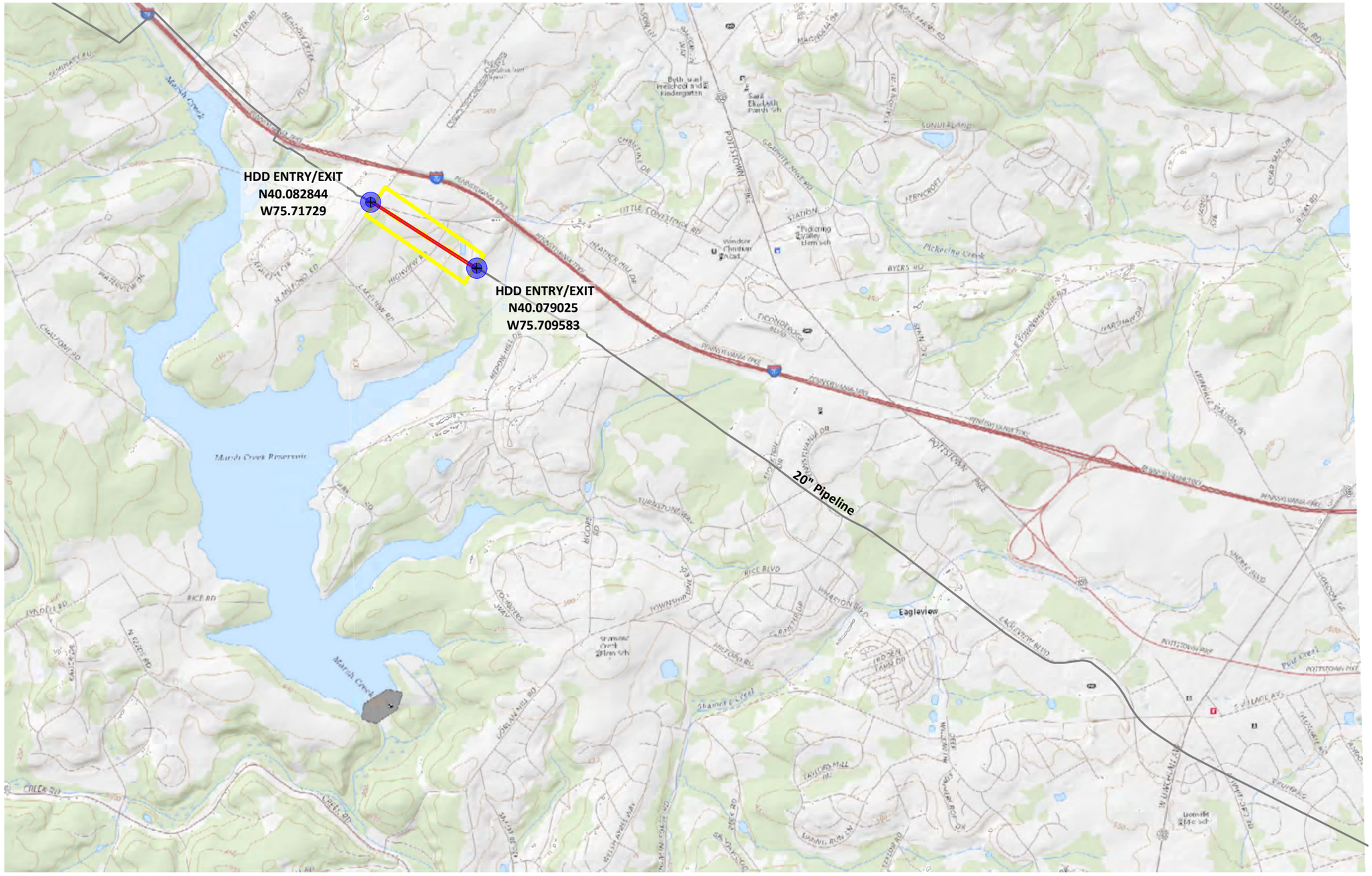
Caterpillar Tractor Company (1995), The Applicator, Caterpillar Tractor Company Marketing Division.

Kirsten, HAD (1982). A classification system for excavating in natural materials. Civil Engineering (Siviele Ingenieurswese), 24(7), 293-308.

PA Department of Conservation and Natural Resources Geology Interactive Map, (http://www.gis.dcnr.state.pa.us.html), 2017.

Z:\Shared\Projects\09630\096302015 - Spread 6 Eight Sites\GP\S3-0290 Little Conestoga Road\Report\Final\S3-0290 Little Conestoga Geophysic Final Report 5-10-19.docx

ENCLOSURES



Notes:

Basemap extracted from USGS Topographic WMS Server, extracted 01/2019.

SURVEY DATE: 01/15/2019
RETTEW No.: 096302015
REVIEWED BY: FKB
DRAWN BY: CHR
DATE: 02/08/2019
SCALE: 1" = 2000'
FIGURE NO. 1 of 6

RETTEW ENVIROSCAN

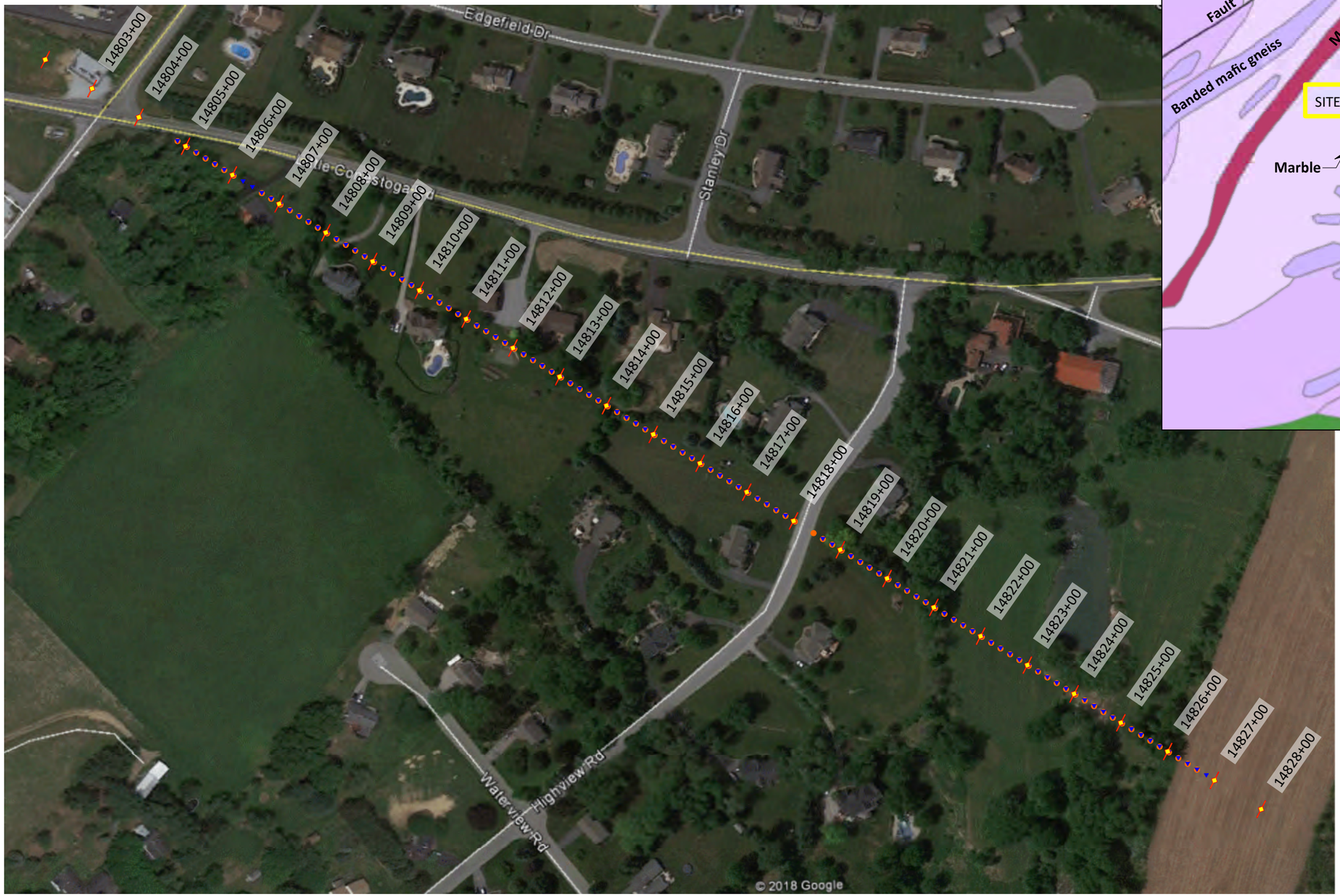
RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

Figure 1: Topographic Basemap

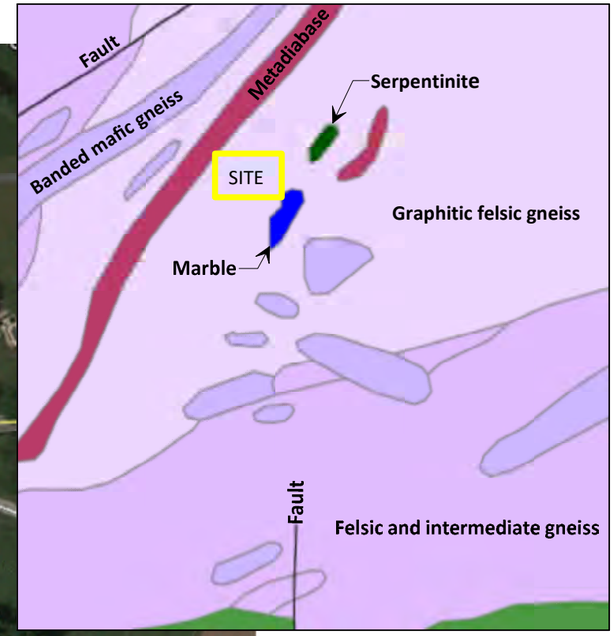
Little Conestoga Road
S3-0290
PA-CH-0100.0000-RD

CHESTER COUNTY, PA

UPPER UWCHLAN TOWNSHIP



Regional Geologic Map



Geophysical Survey Legend

- HDD Entry/Exit
- Electrical Resistivity Station (every 4th)
- Seismic Geophone Location (every 4th)
- 11256+00 — 20" Product Line with Station Number

Scale (ft)

0 100 200 300 400

Notes:

Basemap from Google Earth Pro, extracted 11/2018.

Survey profiles/stations from DGPS survey by RETTEW.

Geologic information from DCNR WMS Server, extracted 11/2018, and Wood (1980).

SURVEY DATE:	01/15/2019
RETTEW No.:	096302015
REVIEWED BY:	FKB
DRAWN BY:	CHR
DATE:	02/08/2019
SCALE:	1" = 200'
FIGURE NO.	2 of 6

RETTEW ENVIROSCAN
RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

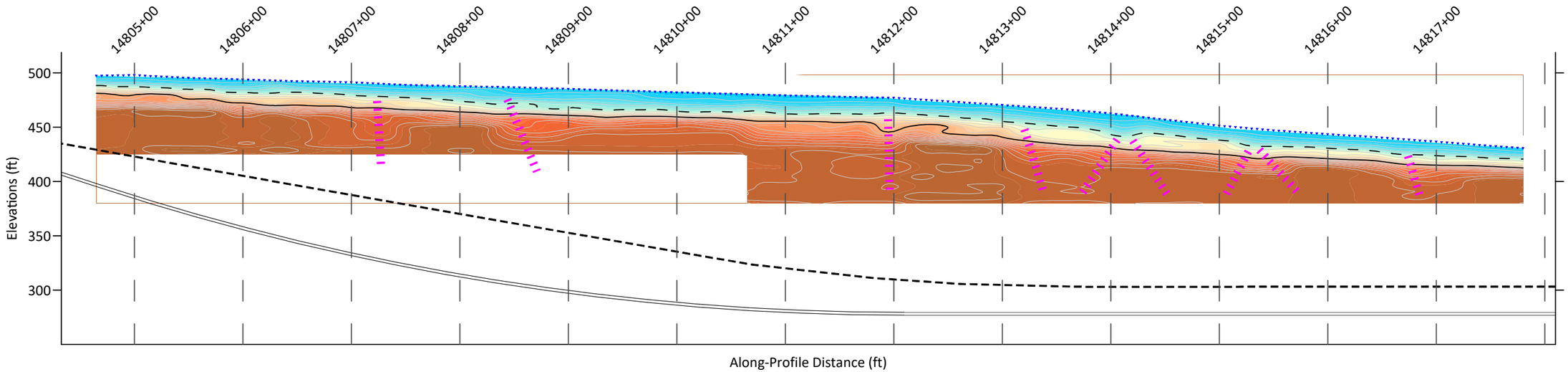
Figure 2: Data Coverage Map and Geologic Setting

Little Conestoga Road
S3-0290
PA-CH-0100.0000-RD

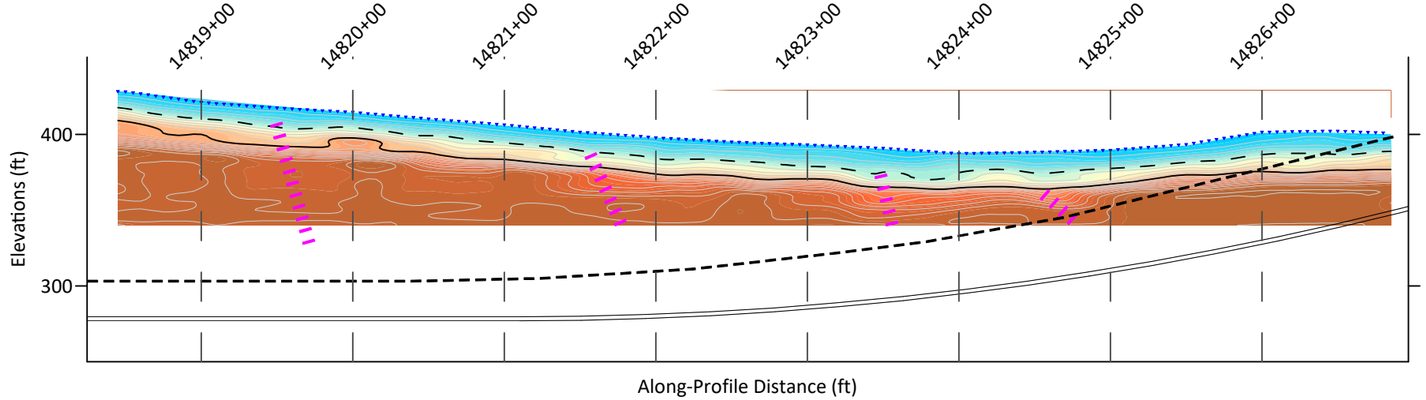
CHESTER COUNTY, PA

UPPER UWCHLAN TOWNSHIP

Seismic Refraction Profile

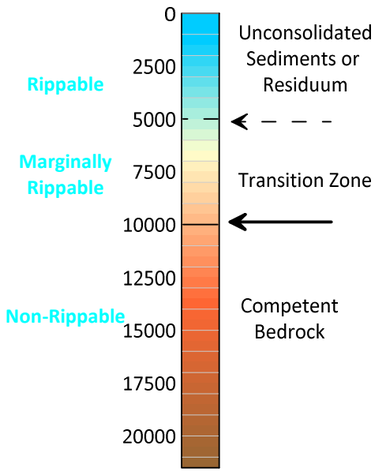


Seismic Refraction Profile



Relative P-Wave Velocity (fps)

Open Field Ripping (D9)



Weighted Average Velocity (Trg)

V_1 = 4,439 fps

V_2 = 13,990 fps

Geophysical Survey Legend

- Seismic Geophone Location
- Possible Fracture Zone
- Proposed 16" HDD
- AS-BUILT 16" HDD
- 11627+00 Station Number

Notes:

Seismic data from Geometrics 24-channel Geode with 4.0 Hz geophones.

Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic and ReMi inversions.

SURVEY DATE: 01/15/2019
RETTEW No.: 096302015
REVIEWED BY: FKB
DRAWN BY: CHR
DATE: 05/09/2019
SCALE: 1" = 100'
FIGURE NO. 3 of 6

ENVIROSCAN

RETTEW

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3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

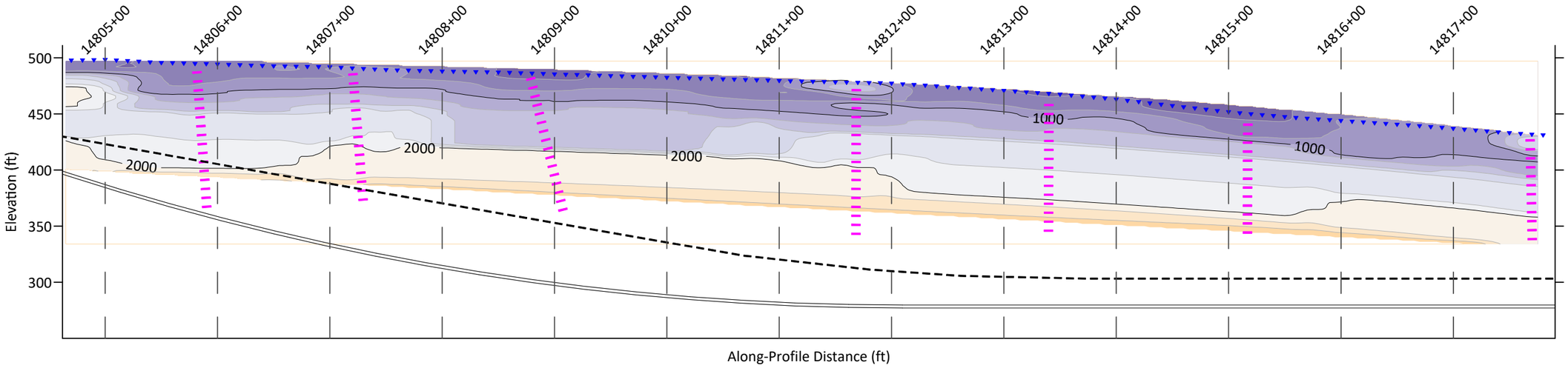
Figure 3: Seismic Refraction Survey Results

Little Conestoga Road
S3-0290
PA-CH-0100.0000-RD

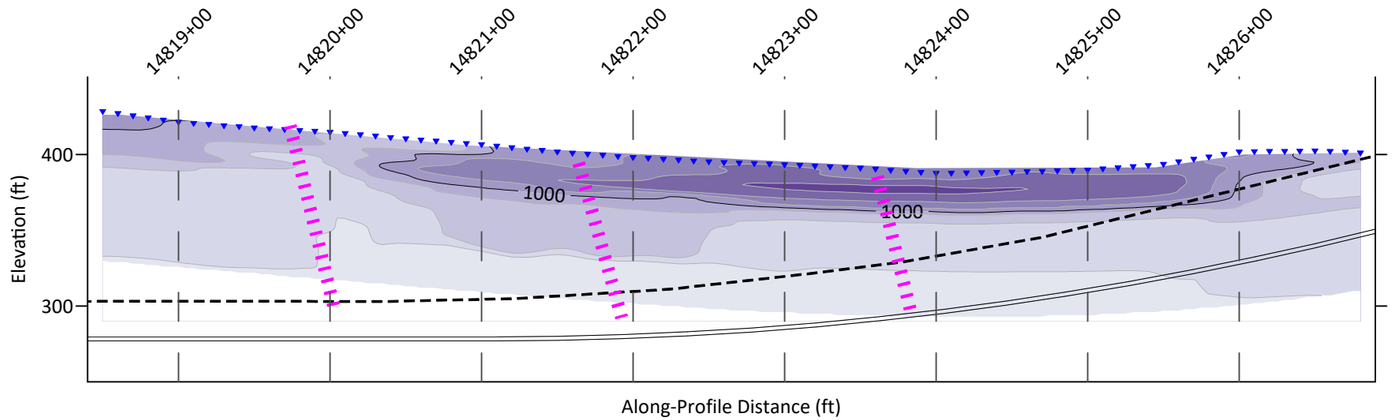
CHESTER COUNTY, PA

UPPER UWCHLAN TOWNSHIP

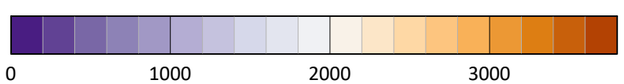
Seismic MASW Profile



Seismic MASW Profile



Relative S-Wave Velocity (fps)



Geophysical Survey Legend

- Seismic Geophone Location
- Possible Fracture Zone
- Proposed 16" HDD
- AS-BUILT 16" HDD
- 11627+00 Station Number

Notes:

Seismic data from Geometrics 24-channel Geode with 4.0 Hz geophones.

Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic and ReMi inversions.

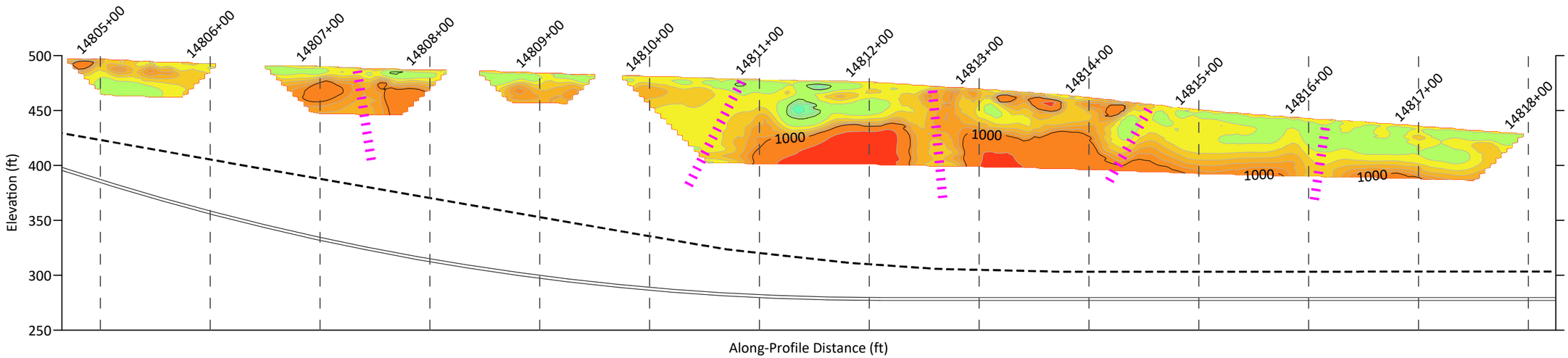
SURVEY DATE: 01/15/2019
RETTEW No.: 096302015
REVIEWED BY: FKB
DRAWN BY: CHR
DATE: 05/09/2019
SCALE: 1" = 100'
FIGURE NO. 4 of 6

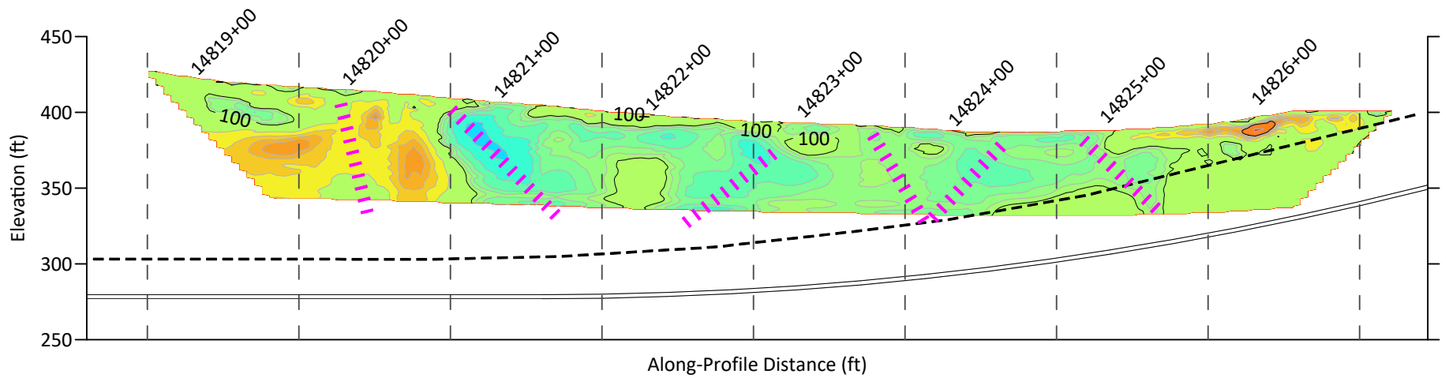
RETTEW ENVIROSCAN
RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

Figure 4: Seismic MASW Survey Results

Little Conestoga Road
S3-0290
PA-CH-0100.0000-RD

CHESTER COUNTY, PA
UPPER UWCHLAN TOWNSHIP





Geophysical Survey Legend

- Possible Fracture Zone
- Proposed 16" HDD
- AS-BUILT 16" HDD
- 11627+00 Station Number

Electrical Resistivity (ohm*m)

1 — 10 — 100 — 1000

Notes:

Resistivity data from AGI Super Sting R-8, 56 channels, 5-ft electrode spacing.

Resistivity models from EarthImager 2D (by AGI Corporation) inversions.

SURVEY DATE:	01/15/2019
RETTEW No.:	096302015
REVIEWED BY:	FKB
DRAWN BY:	CHR
DATE:	05/09/2019
SCALE:	1" = 100'
FIGURE NO.	5 of 6

ENVIROSCAN

RETTEW

RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

Figure 5: Electrical Resistivity Survey Results

Little Conestoga Road
S3-0290
PA-CH-0100.0000-RD

CHESTER COUNTY, PA

UPPER UWCHLAN TOWNSHIP

Geophysical Survey Legend

Possible Fracture Zone Detected By:

- Electrical Resistivity
- Seismic MASW
- Seismic Refraction

Proposed 16" HDD

11627+00 Station Number

Scale (ft)

0 100 200 300 400

Notes:

Basemap from Google Earth Pro, extracted 01/2019.

Geophysical results from previous figures.

SURVEY DATE:	01/15/2019
RETTEW No.:	096302015
REVIEWED BY:	FKB
DRAWN BY:	CHR
DATE:	02/08/2019
SCALE:	1" = 200'
FIGURE NO.	6 of 6

ENVIROSCAN

RETTEW

RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

Figure 6: Geophysical Results Summary

Little Conestoga Road
S3-0290
PA-CH-0100.0000-RD

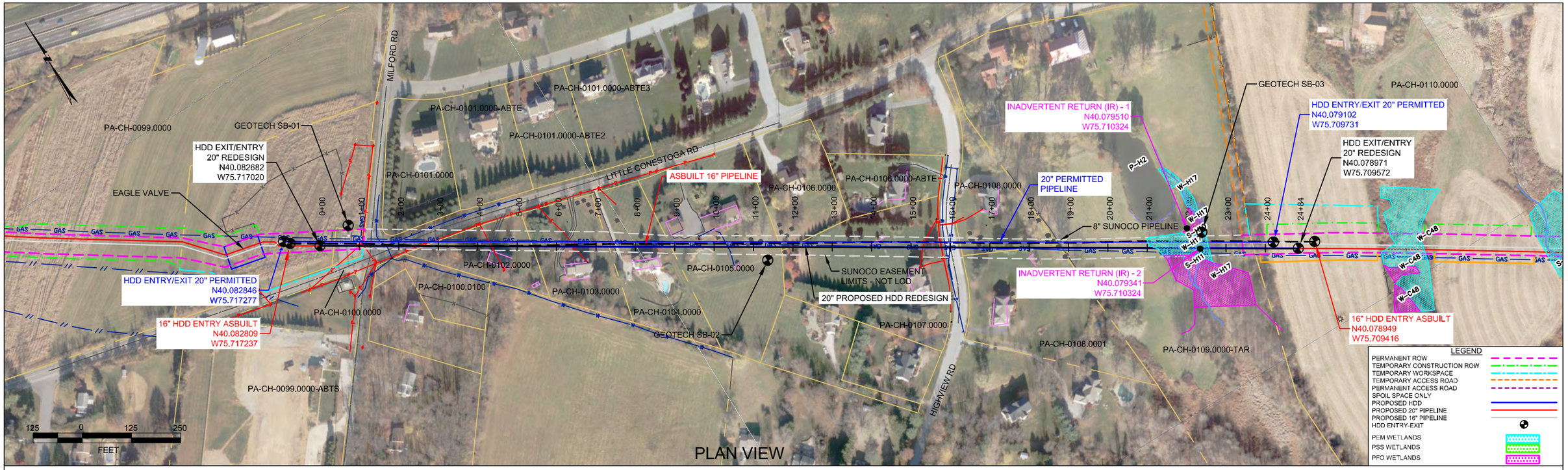
CHESTER COUNTY, PA

UPPER UWCHLAN TOWNSHIP

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
LITTLE CONESTOGA ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E15-862
PA-CH-0100.0000-RD
(SPLP HDD# S3-0290)

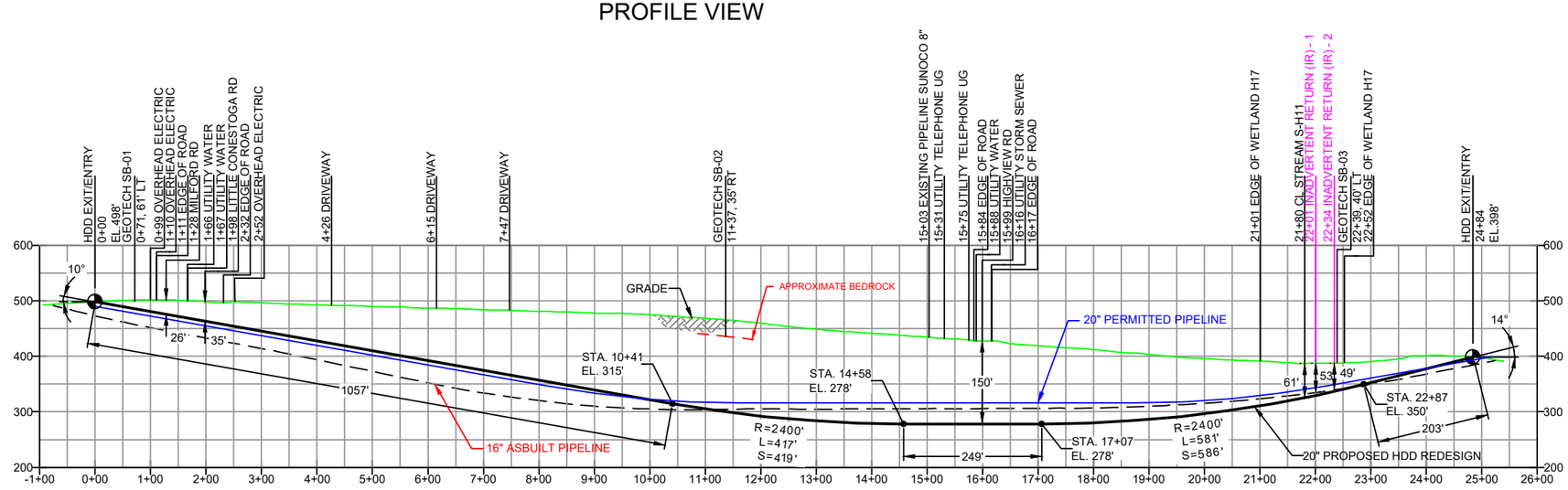
ATTACHMENT 2

HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES

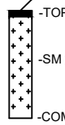


PLAN VIEW

PROFILE VIEW



GEOTECH SB-01



GEOTECH SB-02

GEOTECH SB-03

NOTE: REFER TO TEST BORING LOG S3-0290 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 HOR2. LENGTH (L=):2484'
   HDD PIPE LENGTH (S=):2514'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN 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.

Figure 1. Permitted 20-Inch HDD Plan and Profile with 16-Inch IR Data

CHESTER COUNTY, PA - UWCHLAN TOWNSHIP
S3-0290

NOTES

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

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
5	REVISED PROFILE WITH 2017 LIDAR	DLM	02/10/17	RMB	02/10/17	AMC	02/10/17
5	DESIGN CHANGE (OZ HDD DESIGN RFI-0110)	MRS	01/31/17	RMB	01/31/17	AAW	01/31/17
4	REVISED PER ENGINEERING COMMENTS	MRS	08/12/16	RMB	08/12/16	AAW	08/12/16
3	DESIGN CHANGE	DLM	05/26/16	RMB	05/26/16	AAW	05/26/16
2	ADDED MLV LABEL	MRS	04/07/16	RMB	04/07/16	AAW	04/07/16
1	REVISED PER COMMENTS FROM REI REVIEW	MRS	03/03/16	RMB	03/03/16	AWW	03/03/16

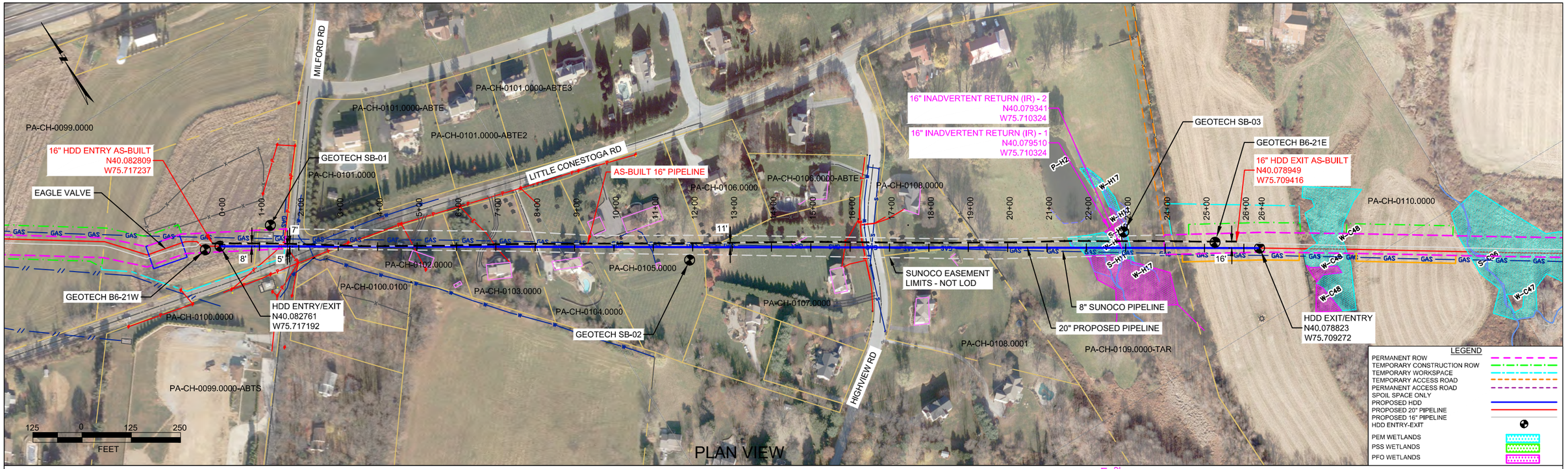
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
LITTLE CONESTOGA ROAD
PENNSYLVANIA PIPELINE PROJECT

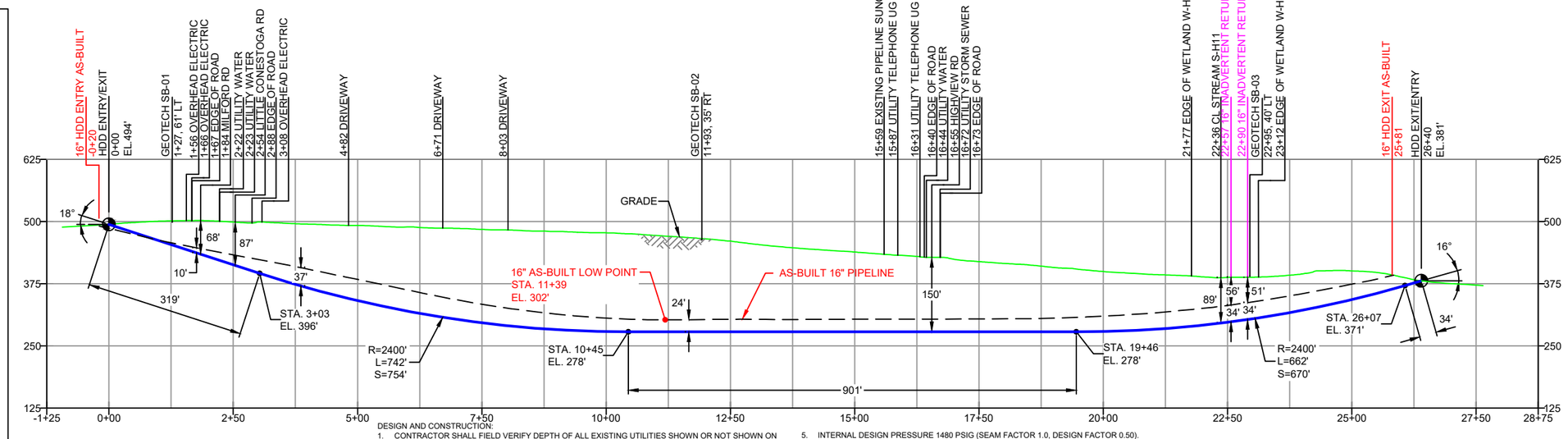
SCALE: 1"=200' | DWG. NO.: PA-CH-0100.0000-RD-20 IR EXI



PLAN VIEW

PROFILE VIEW

CHESTER COUNTY, PA - UWCHLAN TOWNSHIP
S3-0290



GEOTECH SB-01

-NG EL. 499'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 30.0')
-COMPLETION DEPTH EL. 469'

GEOTECH SB-02

-NG EL. 460'
-TOPSOIL (0' - 0.7)
-SM (0.7' - 7.0')
-GNEISS (7.0' - 12.0')
-COMPLETION DEPTH EL. 448'

GEOTECH SB-03

-NG EL. 390'
-TOPSOIL (0' - 1.0')
-CL (1.0' - 6.5')
-SM (6.5' - 30.0')
-GROUNDWATER (16.0')
-COMPLETION DEPTH EL. 360'

NOTE: REFER TO TEST BORING LOG S3-0290 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B6-21W

-NG EL. 490'
-SILTY SAND W/ GRAVEL SM (0.0' - 8.5')
-WEATHERED ROCK (8.5' - 10.5')
-GROUNDWATER (38.0')
-FELSIC GNEISS (10.5' - 237.5')
-BORING TERMINATED EL.252.5'

NOTE: REFER TO TEST BORING LOG B6-21W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B6-21E

-NG EL. 398'
-POORLY GRADED SAND W/ GRAVEL SP-SM (0.0' - 9.3')
-GROUNDWATER (15.0')
-FELSIC GNEISS (9.3' - 145.5')
-BORING TERMINATED EL.252.5'

NOTE: REFER TO TEST BORING LOG B6-21E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2640'
   HDD PIPE LENGTH (S=):2678'
   20" x 0.456" W.T., X-65, APISL, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN 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.

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-6.27	TO	ES-6.29	EROSION & SEDIMENT PLAN		
SHEET 16	TO	SHEET 17	AERIAL SITE PLAN		
DWG NO		DWG NO	DESCRIPTION		

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	SWITCHED 20" CENTERLINE LOCATION, INCREASED DEPTH OF DRILL AND ADDED GEOTECH INFORMATION	MRS	03/14/19	RMB	03/14/19	AMC	03/14/19
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/09/16	RMB	05/09/16	AAW	05/09/16
EP		MRS	12/07/15	RMB	09/25/15	AAW	12/07/15
D	ADDED GEOTECH INFO	MRS	09/25/15	RMB	09/25/15	AAW	09/25/15
C	ISSUED FOR BID	DLM	08/21/15	RMB	08/21/15	AAW	08/21/15

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TETRA TECH ROONEY (303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
LITTLE CONESTOGA ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' | DWG. NO: PA-CH-0100.0000-RD