HORIZONTAL DIRECTIONAL DRILL ANALYSIS
EXTON BYPASS CROSSING
PADEP SECTION 105 PERMIT NO.: E15-862
PA-CH-0256.0000-RR
(SPLP HDD No. S3-0400)

EXTON BYPASS CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0256-0000-RR
(SPLP HDD No. S3-0400)

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

The installation of the 16-inch diameter pipeline 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 20-inch pipe HDD is referred to herein as HDD S3-0400.

SPLP has completed additional geotechnical and geophysical investigations of the drilling area to assess if the HDD could be redesigned to pass through better bedrock conditions; however, the data revealed inconsistencies in rock quality and other problematic geologic factors at depths through and below the HDD design limitations. Therefore, SPLP has elected to abandon any future HDD attempts to install the pipeline through this area and has developed an alternate construction plan using a combination of open trench construction method in uplands, and a Direct Pipe bore underneath aquatic resources, U.S. 30 Exton Bypass, an abandoned Norfolk rail line, and the active Amtrak/SEPTA rail lines.

PIPE INFORMATION

20-Inch: 0.456 wall thickness; X-65

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 2,200 foot (ft)
- Entry/Exit angle: 10-16 degrees
- Maximum Depth of cover: 117 ft
- Pipe design radius: 2,200 – 2,400 ft

Pipe stress allowances are an integral part of the design calculations performed for each HDD. The 20-inch HDD profile was intended to pass under public transportation infrastructure and a residential area adjacent to the existing SPLP pipeline easement, thereby avoiding surface disturbances where residences are immediately adjacent to the existing easement. The difference in elevation between the northwest HDD entry point and exit point allowed for a low angle of entry, but did result in an exit that exceeded the pipe free stress radius “breakover” allowance, which requires either ramping out the exit side ditch line before tie-in to the conventional laid pipe, or installing a custom pipe bend at the tie-in point. The entry and exit radius to the horizontal run at 2,000 – 2,400 ft is below pipe stress allowances and would have allowed for a clean pull through of the HDD pipe segment.

INADVERTENT RETURN DISCUSSION

During the pilot phase drilling for the S3-0400 16-inch, the first pilot drill was terminated after 909 feet of progress due to losses of returns and borehole collapse, and was abandoned by grouting. The HDD was

redesigned and the second pilot drill experienced similar issues; however, approved LCM products were used to improve circulation until completion of the pilot.

A 20-inch ream commenced from northwest to southeast and at approximately 940 feet from the northwest entry/exit a 50-gallon IR occurred. This IR location corresponds approximately with the projected location of the Marctic Thrust Fault zone. The IR was cleaned up and a 30-inch reamer was added behind the 20-inch reamer to improve circulation and reduce drilling fluid pressure through completion of the 20-inch ream. A 24-inch ream commenced from northwest to southeast and at 1,763 ft of progress a 500-gallon IR occurred, at the same location of the previous IR. Crews removed the bentonite drilling fluid and fenced off the area to prevent access. The next day a circular subsidence feature, initially 3 feet in diameter and 2 feet deep, was visible at the land surface, which subsequently expanded to a 9.0 ft by 9.5 ft circular area.

The cause of the IR during the reaming phase was due to a build-up of cuttings that clogged the annulus and caused the drilling fluids to migrate vertically through highly weathered and fractured bedrock to ground surface. The 24-inch reaming tool was located approximately 800 feet past the IR location and was at a higher elevation which assisted in the vertical movement of the drilling fluids.

The subsidence feature that developed was most likely caused by soil flowing downward along foliation planes within the saprolite horizon, weakened by drilling activity, into the subsurface fault zone. The Marctic Thrust Fault zone is characteristically filled with broken and weathered rock allowing this material to slowly collapse into the HDD annulus, causing subsidence at the ground surface.

Figures 1 and 2 in Attachment 2 provide a plan and cross section view of the HDD bore hole and locations of the IRs. Additional written description of the IR events during the drilling of HDD S3-0400 is provided in Section 3.0 of the Hydrogeologic Analysis Report provided in Attachment 1. SPLP utilized all the foregoing information obtained during installation of the 16-inch pipe in the assessment of construction alternatives and re-routes at this location.

GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

HDD S3-0400 transects the contact between the Piedmont Lowland Section to the north and Piedmont Upland Section to the south, both of the Piedmont Physiographic Province. The Marctic Thrust Fault marks the change from lowlands to uplands. The Lowland Section is characterized by broad moderately dissected, karst valleys separated by broad low hills. The Upland Section is characterized by broad rounded hilltops.

The mapped bedrock units crossed by the HDD alignment include; mica schist and phyllite of the Octoraro Formation; the calcareous phyllite upper unit of the Conestoga Formation; and carbonaceous limestone of lower unit of the Conestoga Formation. These lithologies correspond with the latest geologic map of Chester Valley.

The revised construction plans are for 2,114 ft of open trench construction, and an 816 ft Direct Pipe bore. The Direct Pipe bore method is cased, and has a closed fluid control system. The planned bore will pass through overburden or highly weathered and weak bedrock with low RQD values. The geology at this location presents no IR or subsidence risks to the construction methods planned in replacement of the HDD.

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

EXTON BYPASS CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0256-0000-RR
(SPLP HDD No. S3-0400)

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

The most basic conceptual model for groundwater flow in the area of HDD S3-0400 is to depict the uplands underlain by the Octorara Formation as the groundwater recharge zone and the lowland underlain by units of the Conestoga Formation as a groundwater discharge zone. As such, ground water is expected to move southeast to northwest at the HDD. Both formations have components of primary porosity and secondary porosity.

Primary porosity best supports the basic conceptual model of groundwater flow from recharge areas in uplands to discharge areas in lowlands. Secondary porosity created by openings in foliations, fractures and faults can impart anisotropies on the groundwater flow system altering the basic directions of groundwater flow.

Groundwater levels recorded during the geotechnical borings show groundwater depths ranging from 5.5 to 28 feet (ft) below ground surface (bgs).

A search of the Pennsylvania Groundwater Information System (PaGWIS) database produced twelve residential wells with 0.5 miles of the HDD S3-0400 alignment. Five of the wells were in the Conestoga Formation and seven of the wells are within the boundaries of the mapped Octoraro Formation. The water levels for the Conestoga Formation wells ranged from 17 to 40 ft bgs with a mean of 24 ft bgs. The water levels for the Octoraro wells ranged from 9 to 45 ft bgs with a mean of 30 ft bgs.

The revised construction plans are for 2,114 ft of open trench construction, and an 816 ft Direct Pipe bore. The Direct Pipe bore method is cased, and has a closed fluid control system. The planned bore will pass through overburden or highly weathered and weak bedrock with low RQD values. The hydrogeology at this location presents no IR or subsidence risks to the construction methods planned in replacement of the HDD.

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

ADJACENT FEATURES ANALYSIS

This HDD location is located on the southeast of the Town of Exton, West Whiteland Township, in Chester County, Pennsylvania. The HDD alignment crosses under U.S. 30 Exton Bypass; two (2) wetlands; an abandoned Norfolk rail line and active Amtrak/SEPTA rail line, and Lynetree Drive. This HDD location is set within urban residential developments for the majority of its length.

The pipeline route follows an existing SPLP utility easement with one or more existing pipelines for the entire length of the HDD alignment.

Aquatic resources along the HDD alignment include wetlands W-K18, and W-K21.

SPLP's public outreach conducted in October of 2017 resulted in no private water wells being identified within 450 ft of the HDD alignment. A water well map is provided as Figure 5 in the Hydrogeologic Reevaluation Report provided in Attachment 1. Landowner responses and available information indicates the properties adjacent to the HDD alignment are served by public water.

SPLP will transmit a copy of this HDD analysis to all landowners having a property line within 450 ft of any direction of this HDD location.

EXTON BYPASS CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0256.0000-RR-16
(SPLP HDD No. S3-0400)

ALTERNATIVES ANALYSIS

As required by the Order, the reanalysis of HDD S3-0400 includes an evaluation of open cut alternatives and a re-route analysis. As part of the PADEP Chapter 105 permit process for the Mariner II East Project, SPLP developed and submitted for review a project-wide Alternatives Analysis. During the development and siting of the Project, SPLP considered several different routings, locations, and designs to determine whether there was a practicable alternative to the proposed impact. SPLP performed this determination through a sequential review of routes and design techniques, which concluded with an alternative that has the least environmental impacts, taking into consideration cost, existing technology, and logistics. The baseline route provided for the pipeline construction was to cross every wetland and stream on the project by open cut construction procedures.

Re-Route Analysis

The pipeline route as currently permitted follows an existing SPLP easement through urban development southeast of the Town of Exton. The general route of the Mariner II project in this area of the state is from northwest to the southeast.

There is an existing Texas Eastern Pipeline easement 700 ft to the southwest of the SPLP easement. This easement originates in near vicinity to the SPLP, north of Exton Bypass, then proceeds through larger areas of wetlands and a stream which are not present on the SPLP easement. This easement is set within the same geologic setting; crosses under the same transportation infrastructure; crosses through the same residential area as the SPLP easement, and ultimately this easement proceeds in a southern direction deviating away from the general direction of the Mariner Pipeline project. Therefore, this alternative route presents no advantages over the existing SPLP easement.

There are no existing utility corridors to the east-northeast that provide a practical alternative route. Any alternate route considered to the east-northeast would require the clearing of a new “greenfield” corridor through existing woodlands, increase the number of stream crossings, and possibly encroach on additional private residences before it could rejoin the current route.

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

Open-cut Analysis

In this area of the Mariner II Pipeline project, the use of an HDD construction method was selected to be employed in many instances due to the infrastructure and amount of residential and commercial development adjacent to and encroaching upon the existing SPLP easement, since the HDD method generally avoids direct disturbance of lands between the points of entry and exit. However, as previously discussed, SPLP performed additional geologic investigations and has determined from this data that a revised HDD design will not be able to avoid the subsurface geologic conditions that resulted in the problems that occurred during installation of the 16-inch pipeline.

SPLP evaluated the select use of open cut construction of the existing permitted right-of-way and determined this would have the least impact, and most effective means, for installing the pipeline and restoring the properties where adequate space exists to employ conventional construction methods. As discussed previously, SPLP’s revised construction plans are for 2,114 ft of open trench construction.

EXTON BYPASS CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0256-0000-RR
(SPLP HDD No. S3-0400)

Use of Conventional Auger Bore

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

Based on the track record of installations during construction of this pipeline project, conventional auger bores should be limited to approximately 200 linear feet or less, varying by the underlying substrate at a proposed bore location. Conventional auger bores for the 20-inch pipeline, 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, and there is one existing in service pipeline within the existing SPLP easement and the already installed 16-inch ME II pipeline.

The length of crossing to pass under the aquatic resources; U.S. 30 Exton Bypass; the abandoned Norfolk rail line, and the active Amtrak/SEPTA rail line is beyond the capabilities of this technology. Subset conventional auger bores of the Exton Bypass and abandoned and active railroads was considered and rejected due to difficulty of accessing the alignment and resulting impacts to the public.

Use of FlexBor

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.

Use of Direct Pipe Bore

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 50-inch outside diameter bore 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. Once the bore pipe is installed, the 16-inch product pipeline will have spider gaskets and spacers installed to prevent coating damage and cathodic protection short circuits, and then will be pulled through the bore pipe.

SPLP evaluated the use of Direct Pipe bore to pass by difficult crossing features within the alignment of HDD S3-0400. The construction specialists who operate this boring equipment identified an 816 ft segment of this alignment to employ this method of construction; which is incorporated into SPLP's revised construction plan.

CONCLUSION

As stated previously, SPLP has evaluated the events which occurred during the S3-0400 16-inch HDD, and performed additional geotechnical investigations and a geophysical investigation of the alignment. This data revealed inconsistencies in rock quality and other problematic geologic factors at depths through and below the HDD design limitations. Therefore, SPLP has elected to abandon any future HDD attempts to install a pipeline through this area and has developed an alternate construction plan using a combination of open trench construction method in uplands, and a Direct Pipe bore underneath aquatic resources, U.S. 30 Exton Bypass, an abandoned Norfolk rail line, and the active Amtrak/SEPTA rail lines.

The revised construction plan will avoid impacts to public infrastructure and natural resources, and accelerate the completion of the pipeline installation and restoration while adjacent to residential areas.

Attachment 2 contains the HDD plan and profile with the 16-inch HDD IR location data, and the plan and profile views of the direct bore discussed above.

To address the additional impacts associated with these proposed changes in construction methods, a Chapter 102 & Chapter 105 permit modification package has been submitted to the PADEP.

EXTON BYPASS CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0256.0000-RR
(SPLP HDD No. S3-0400)

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 alternative construction plans presented within this re-revaluation report will minimize the risk of IRs and impacts to public and private water supplies during the construction phases for this segment of the Mariner II Pipeline Project.

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

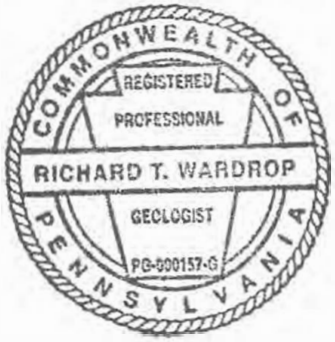
Larry J. Gremminger, CWB
Geotechnical Evaluation Leader
Mariner East 2 Pipeline Project

5/30/2019
Date

Pertaining to the practice of geology

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

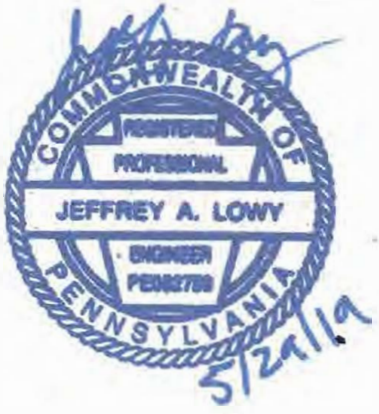
5/29/19
Date



Pertaining to the pipeline stress and geometry

Jeffery A. Lowy, P.E.
Lic. No. PE082759
Rooney Engineering, Inc.
Civil Engineer

5/29/19
Date



EXTON BYPASS CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0256.0000-RR-16
(SPLP HDD No. S3-0400)

ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

HDD HYDROGEOLOGIC REEVALUATION REPORT

Mariner East II
Spread 6
HDD S3-0400
Exton Bypass
West Whiteland 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
S3-0400
Exton Bypass
West Whiteland Township, Chester County, Pennsylvania

May 2019

Prepared for:

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

Prepared by:

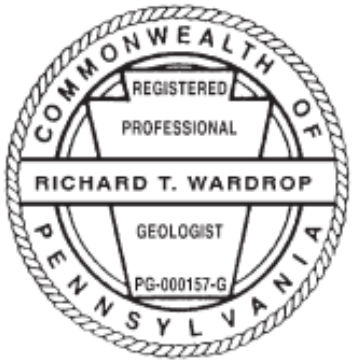
Richard T Wardrop, P.G.
Lead Hydrogeologist

Reviewed by:

David J. Demko, P.G.
V.P., Principal 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 29, 2019

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

Date

TABLE OF CONTENTS

FIGURES

ATTACHMENTS

1.0 INTRODUCTION

Sunoco Pipeline, L.P., (SPLP) retained Groundwater & Environmental Services, Inc. (GES) to prepare a horizontal directional drill (HDD) Hydrogeologic Reevaluation Reports (HRRs) for the Mariner East II pipeline project. This HRR is for the 20-inch pipe installation at Exton Bypass, PA-CH-00249.0000-RR (HDD S3-0400) in West Whiteland Township, Chester County, Pennsylvania. The alignment for HDD S3-0400 runs northwest to southeast along an alignment crossing the US 30 Exton Bypass, an abandoned Norfolk rail line, the active Amtrak/SEPTA rail lines, and two residential neighborhoods (**see Figure 1**). An HRR is required for this HDD in accordance with Exhibit 3 of Stipulated Order EHB Docket No. 2017-009-L signed August 10, 2017 (Stipulated Order). In November 2017, SPLP converted all of the approved, Spread 6, 20-inch profiles for installation of the 16-inch line, which was completed at HDD S3-0400 on March 2, 2018. Due to the conversion, installation of the 20-inch line became the second pipe to be installed at S3-0400 and became the de facto drill requiring an HRR, as per Exhibit 2 of the Order.

SPLP is submitting a major permit modification package to construct the 20-inch pipe at this location, which includes converting the HDD into a combination of open trench and a single direct pipe bore. This HRR provides a comparison between the permitted HDD plan and profile (P & P) and the proposed combination of open trench and direct pipe methods for completing installation of the 20-inch pipe along the S3-0400 alignment.

The direct pipe construction method uses a hydraulically jacked tunneling drill head to advance and steer excavation of the pipeline borehole along the design profile. A 42-inch diameter steel casing, slightly smaller than the cutter, will be advanced directly behind the drill head such that the bore is simultaneously and continuously cased during completion. A relatively small volume of drilling fluid (water and bentonite), compared to HDD drilling, is conveyed to the drill head where it lubricates the cutter and entrains cuttings. The drilling fluid, laden with cuttings, is conveyed back to entry along lines that lay within the steel casing providing for total containment of the drilling fluids. As such, direct pipe installations eliminate the risk of inadvertent returns (IRs) through total control of the drilling fluids and greatly reduces the risk of affecting local water tables, or causing subsurface voids and surface subsidence.

There is a potential for groundwater discharge and lowering of the local water table, along the drill path, during HDD installations where 1) the entry/exit elevation differences are large, 2) the profile intercepts the water table, and 3) where the annulus between the drill stem and bore hole wall is relatively large. The risk of lowering the water table is minimized using the direct pipe construction method because the profile can be constructed shallower (and still prevent IRs and subsidence) and, the annular space between the 42-inch casing is small (two inches or less).

Along this drill path there is a risk of creating surface subsidence during HDD drilling and/or in completion of the final pipe pull. The overburden/unconsolidated material and saprolite may become weakened (as multiple reamer and swab passes are completed, at depth, to keep the bore open prior to the final pulling of the pipe, creating open areas to where soil material can migrate downward generating surface subsidence features. The risk of creating these surface subsidence is greatly reduced using the direct pipe method as only enough subsurface material is removed to accommodate the casing and the casing is installed continuously and simultaneously behind the drill head.

The permit modification proposes to install approximately 816 feet of 20-inch line, from the a northwest entry point (proximal to the permitted HDD entry/exit point), through approximately 589 feet of the lower unit of the Conestoga Formation and approximately 227 feet of the upper unit Conestoga Formation, eliminating IR risk, and greatly reducing groundwater discharge and subsidence risk.

The permit modification proposes to install approximately 1,250 feet (horizontal distance) of the 20-inch line over the Octoraro formation by trenching, eliminating IR risk, eliminating groundwater discharge risk, and eliminating the risk of creating subsurface voids and surface subsidence along that section of the alignment.

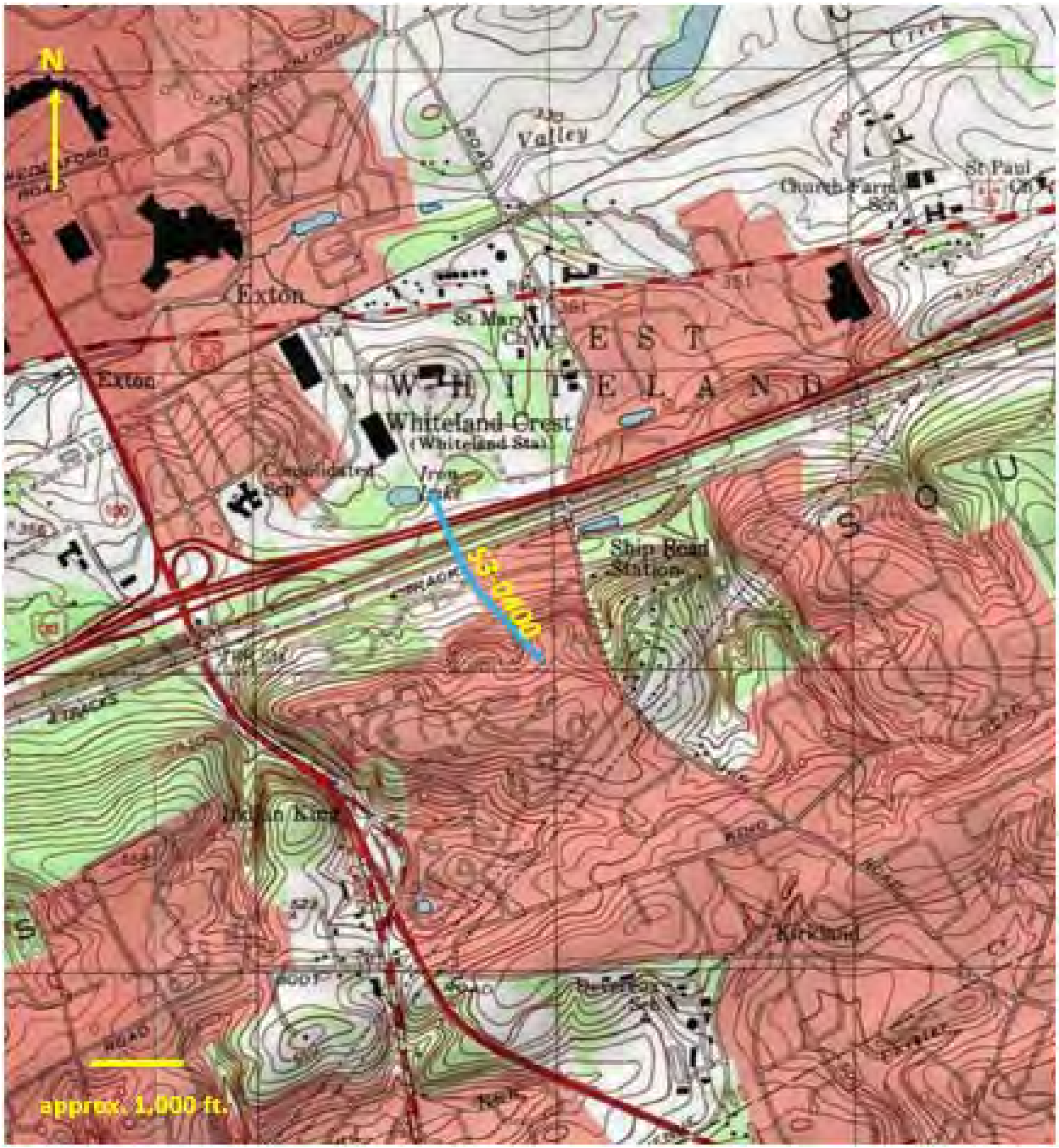


Figure 1. Site Location Map (modified from PaGEODE)**.**

This HRR provides a comparison of the permitted HDD S3-0400 (P & P revised 4/6/17) to the construction methods presented in the proposed permit modification, one direct pipe and conventional open trench construction for installation of the 20-inch pipe.

This report presents the following information:

- Geologic and hydrogeologic characteristics in the area of HDD S3-0400;
- Summaries of studies performed pertinent to reevaluation, including fracture trace analysis, geotechnical borings, and geophysical surveys;
- An updated site conceptual model; and
- A reevaluation summary with conclusions.

The contents of this report were developed from the review of published information and field observations acquired from installation of the 16-inch line installation, and related field studies. Site geotechnical boring programs were conducted by Tetra Tech in June 2015, by Terracon Consultants, Inc. (Terracon) in September 2017, and by Intertek/PSI in April 2017. Note that GES did not oversee or direct the Tetra Tech's, Terracon's, or Intertek/PSI's geotechnical drilling programs, including, but not limited to, the selection of number and location of borings, determination of surface elevations, target depths, observations of rock cores during drilling operations, or preparation of boring logs. The three SPLP contractors generated the geotechnical reports, boring logs, and any core photographs that resulted from these programs. GES did oversee the advance of borings by Parratt-Wolff, for the installation of five monitoring well nests, in April and May 2019. GES relied on the reports and well logs from all four drilling events and incorporated thee data into the general geologic and hydrogeologic framework for this HRR.

Additionally, this HRR incorporates the results of a geophysical study performed by Quantum Geophysics in September 2017.

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 trenchless construction operations. HRRs are not intended to evaluate potential adverse effects of trenchless construction on nearby man-made structures, including pipe lines, other than the ME II pipes, within local pipeline right-of-way.

2.0 HDD GEOLOGY / HYDROGEOLOGY

2.1 Physiography

HDD S3-0400 transects the contact between the Piedmont Lowland Section to the north and Piedmont Upland Section to the south of the Piedmont Physiographic Province. The Marctic Thrust Fault marks the change from lowlands to uplands. The Lowland Section is characterized by broad moderately dissected, karst valleys separated by broad low hills. The Upland Section is characterized by broad rounded hilltops. (PaGEODE).

2.1.1 Topography

The alignment of the original permitted drill profile for HDD S3-0400 trends northwest to southeast with a horizontal distance of approximately 2,200 feet (see **Attachment A**). The topography slopes northwest from the southeast entry/exit in an upland at an elevation of 537 feet above mean sea level (ft amsl) to the northwest entry/exit, due north of the Exton Bypass, at an elevation of 365 ft amsl.

2.1.2 Hydrology

HDD S3-0400 is located within the East Branch Brandywine Creek drainage basin. Local tributaries flow northwest, roughly parallel to the alignment, 0.5 miles west and 0.4 miles east of the alignment. A third stream originates in Iron Lake (a former ironstone quarry) due west of the northwest entry/exit and flows similarly to the northwest, away from the alignment. All three northwest flowing tributaries enter Valley Creek, which then flows southwest to a confluence with the East Branch Brandywine Creek, approximately 4.7 miles southwest of the HDD. The HDD S3-0400 easement limits cross two small PEM wetlands located between the Exton Bypass and abandoned Norfolk rail line (W-K18 and W-K21). Two other small PEM wetlands (W-K19 and W-K20) were mapped in the same setting, due west of the easement limits (see **Attachment A**). The ME II easement limits do not cross any other water resources.

2.2 Geology

2.2.1 Soils

The United States Department of Agriculture, National Resource Conservation, Web Soil Survey (NRCS WSS) site produced a local soils map showing Conestoga silt loam on 3 to 8 percent slopes at the northwest entry/exit; Glenelg silt loam on 3 to 8 percent slopes over the Exton Bypass, abandoned Norfolk rail line and active Amtrack/Septa rail lines; and, Urban land-Udorthents on 8 to 25 percent slopes from the active Amtrack/Septa rail lines to the southeast entry/exit. All three soils are primarily well-drained silt and clay loams. The Conestoga soil is reported to have a channery loam from 38 to 75 inches before encountering more competent bedrock and is derived from limestone and schist. The Glenelg is reported to have a channery loam from 54 to 76 inches before top of more competent bedrock is encountered and is derived from mica-schist. The Urban land-Udorthents is reported to have 40 inches of silt and clay loam above competent schist or gneiss that was graded for development. The water table is reported to be greater than 6.7 feet below ground surface (ft bgs) for the Conestoga and Glenelg, and approximately 5 feet for the Urban land-Udorthents.

2.2.2 Bedrock Lithology

A geologic map of the HDD S3-0400 area is provided as **Figure 2.** Note the inset depicts the southeast end of cross section A-A' published in Kochanov (2016) along a southeast trending line approximately 3.5 miles southwest of the S3-0400 alignment. The inset shows the general structural relationships between the Formations that the pipe line construction crosses and the Marctic Thrust Fault.

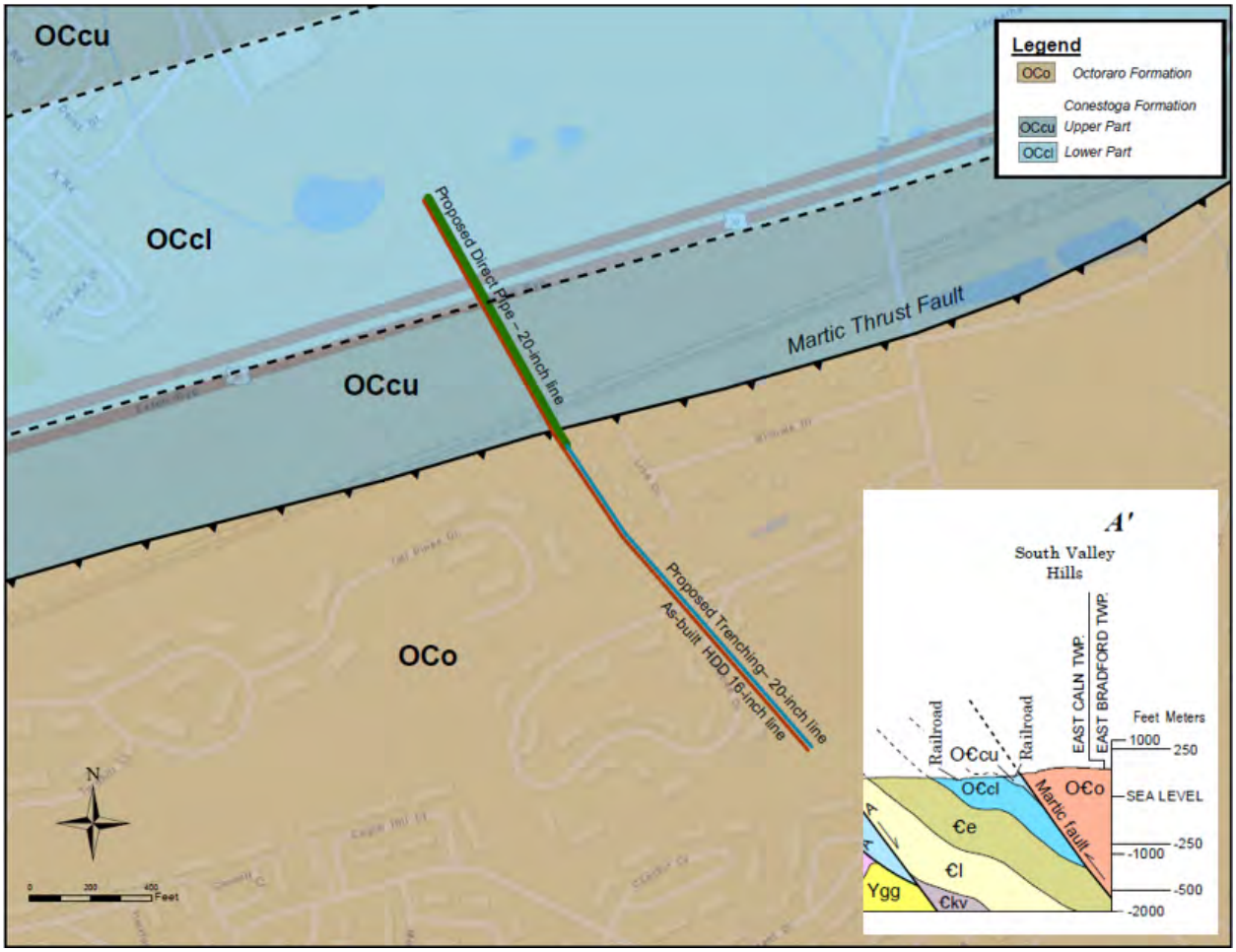


Figure 2. S3-0400 Geologic Map (mod. from Kochanov, 2016).

Following the stationing of the permitted P & P for S3-0400, moving southeast to northwest, the mapped bedrock units encountered include:

- 0+00 to 12+95 mica schist and phyllite of the Octoraro Formation.
- 12+95 to 15+95 calcareous phyllite, upper unit of the Conestoga Formation;
- 15+95 to 22+00 carbonaceous limestone, lower unit of the Conestoga Formation;

These lithologies correspond with the latest geologic map of Chester Valley (Kochanov, 2016). The boundaries between the units were adjusted based on 1) inspection of HDD drill cuttings collected during drilling, 2) a geophysical survey conducted on the drill path in September 2017, and 3) field observations from daily inspections during drilling for the 16-inch HDD.

Kochanov (2016) describes the Octoraro Formation as a fine-grained, medium dark -gray to greenish-gray to silvery-gray fissile phyllite, with massive bedding, small-scale isoclinal folds and faults and thin to medium-sized (0.75 to 4.9 feet thick) quartz pods, stringers, and lenses running parallel to bedding. The contact with the underlying Conestoga Formation in the area of the S3-0400 is defined by the Marctic Thrust Fault zone along the base of the South Valley Hills.

The upper unit of the Conestoga Formation is primarily a very light gray to medium-gray, medium to coarsely crystalline, laminated limestone. The laminations are shaly to argillaceous in part and

carbonaceous in part; planar, thin to massively bedded with small-scale isoclinal folds. The fold axes run parallel to bedrock strike. The mica content is abundant, particularly where the rock is argillaceous, giving the rock a schistose appearance. Also present are thin quartz lenses and veins, and small pyrite cubes along bedding surfaces.

The lower unit of the Conestoga is described as a medium to light gray or bluish-gray, argillaceous to finely crystalline, laminated limestone. Weathered surface have a fine to medium, sandy texture; interlaminated with very light gray to white, fine to medium crystalline limestone or marble. Some of the medium-gray to sooty-gray laminations weather to an off white to light yellowish brown hue. The unit is very micaceous and pyritic where argillaceous, and medium to thick bedded. Small-scale isoclinal fold axes run parallel to bedding strike and there are thin quartz lenses and gash veins.

The proposed permit modification consists of one (1) direct pipe bore and open trench sections. The profile and location of the direct pipe are provided in **Attachment A**. The proposed direct pipe has a horizontal length of 806 feet and plots between Stations 13+13 and 21+29 on the permitted HDD profile. At that location, the northwest two-thirds of the direct drill bore profile will be within the lower unit of the Conestoga Formation and the southeast third will be within the upper unit of the Conestoga. The last approximate 70 feet at the southeast end will be south of the Amtrack Rail right-of–way (ROW) approaching or within the Marctic Fault zone.

2.2.3 Structure

The regional structural fabric of the bedrock proximal to S3-0400 is oriented east-northeast. Kochanov (2016) shows several geologic structure mapping symbols in the area of S3-0400. Within the Octoraro, the map shows three bedrock strike and dip measurements with strikes paralleling the regional fabric and dips between 62 to 67 degrees south. One additional measurement strikes northeast and dips 32 degrees south. Within the lower unit of the Conestoga Formation, the map shows three local strike and dip symbols trending east-northeast and dipping between 63 and 83 degrees south. Also shown is an inclined cleavage measurement with a similar trend, dipping 88 degrees north.

As previously mentioned the center of the Marctic Thrust Fault zone intersects the S3-0400 alignment at the surface at approximately Station 12+75 (on the permitted profile). Small-scale isoclinal folds are present in all three geologic units with axes trending parallel to bedrock strike. The foliated beds proximal to the Marctic Thrust Fault are highly contorted and dip directions vary widely from north to south.

2.2.4 Fracture Trace Analysis

Fracture trace analysis of high altitude aerial photography was performed for the area of interest to identify potential zones of bedrock weakness along the drill path. 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 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.

Aerial photographic images used to perform the fracture trace analysis were obtained through the Pennsylvania Imagery Navigator (PASDA). Stereo pair images at the 1:20,000-scale collected during flights contracted by the USDA in 1937 were viewed with a Topcon MS-3 Stereoscope. The observed traces were transferred onto the geologic map for further evaluation on **Figure 3**. As shown, three fracture traces south of the S3-0400 alignment are trending north-northeast. Due north of the northwest entry/exit, an east-west trending fracture trace has been mapped. None of the mapped fracture traces intersect or occur close to the S3-0400 alignment.

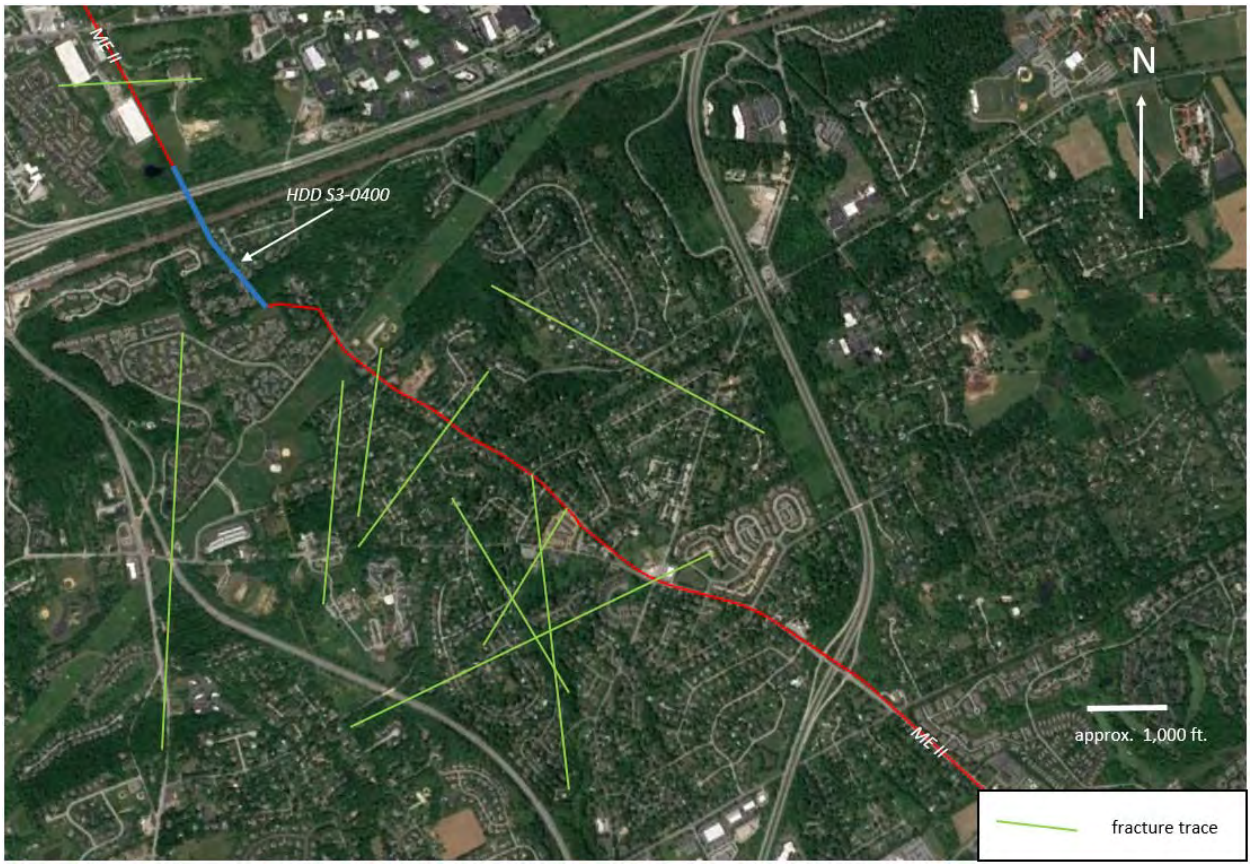


Figure 3. Fracture Trace Map (mod. from PaGEODE).

2.2.5 Karst

Kochanov (2016) describes the terrane associated with the undifferentiated upper and lower units of the Conestoga Formation carbonate rock as having an overall smooth appearance but the soil / bedrock surface is variable, sculpted and pinnacled. Small to medium-sized solution openings occur, usually along bedding planes. The terrane and subsurface is characterized as being prone to sink holes, surface depressions, irregular bedrock surfaces, subsurface voids, clay seams, and other carbonate bedrock dissolution features.

Dissolutioning of bedrock and void formation is not a characteristic of the Octoraro formation; however, local studies have shown the phyllite of the Octoraro to be highly weathered and fractured saprolitic material occurring to depths of over 150 feet in the area.

2.2.6 Mining

A local recreational feature, Iron Lake, is located approximately 200 feet west of the northwest entry/exit. This, and a similar, but smaller lake, east of the alignment are the locations of a historic iron ore pits. Sloto (2009) identifies the Iron Lake location as the former Hinter Mine. There is no active surface or subsurface mining operation in the vicinity of S3-0400.

2.2.7 Rock Engineering Properties

Engineering characteristics for the undifferentiated Conestoga Formation listed in Kochanov (2016) were previously included in Section 2.2.5. The material is considered a good source of road material, riprap, building stone and fill.

Geyer and Wilshusen (1982) noted the following with respect to the undifferentiated Conestoga Formation:

- Bedding: Crudely bedded to poorly bedded; thin; highly crumpled.
- Fracturing: Joints have an irregular pattern; poorly formed; moderately abundant; widely spaced having an uneven regularity; many are open but some are filled with quartz and calcite.
- Weathering: Moderately resistant; slightly weathered to a shallow depth; variably weathered (impure layers weather to a higher relief); large, irregularly shaped fragments result; mantle thickness is highly variable and may be extremely thick; interface between bedrock and mantle is pinnacled in most places.
- Ease of excavation: Difficult; bedrock pinnacles and numerous quartz veins are special problems; fast drilling rate; quartz veins can slow the drilling rate.

Kochanov (2016) describes the Octoraro Formation as moderately resistant to weathering, resulting in uneven, hackly, small sized rubble at the base of exposures. When exposed to water, weathering can be rapid producing unstable slopes that require maintenance. Weathered material is easy to excavate whereas fresh rock surfaces can be difficult to excavate. Foundations should be excavated to sound material which can be deeper than expected. Local studies have shown the high weathered and fractured saprolitic material can occur to depths of over 150 feet in the area. The Octoraro formation was not presented in Geyer and Wilshusen (1982).

2.2.8 Results of Geotechnical Borings

Several geotechnical boring programs have been conducted in the vicinity of S3-0400. The boring logs are provided in **Attachment B** and the boring locations are shown on **Figure 4.**

Tetra Tech Borings
Soil was described on logs for three soil boring advanced by Tetra Tech in 2015. SB-01 was located southeast of the northwest entry exit close to Station 20+54, SB-02 was located approximately 150 feet southwest of Station 11+32, and SB-03 was located approximately 50 feet east of the southeast entry/exit. SB-01 was advanced 30 ft bgs and the all of the material described on the drill log was listed as low blow count silt, fine sand, and trace limestone gravel increasing to little gravel in the last spoon. The log for SB-02 listed low blow count, degraded bedrock, schistose saprolite which had a texture of predominately silt with varying amounts of fine sand and gravel from the host bedrock. Split spoon refusal was logged at the total depth of 74.4 feet. SB-03 was drilled to a depth of 30 feet and the log describes a saprolite derived from schist for the entire boring. The texture of the material was a silty sand varying amounts of host bedrock gravel. At a depth of 13.0 feet blow counts changed from 3 to 12 blows to greater than 50 blows per six inches. At the same horizon, the material color transitioned from light grey to brown and gray.

The water levels recorded at SB-01 and SB-02 were 27 and 38 ft bgs; respectively, and no groundwater was encountered in SB-03.

Terracon Boring
In September 2017 Terracon advance a test boring (B6-18W), located approximately 680 feet east of the southeast entry/exit for S3-0400. The boring was drilled to a depth of 75.5 feet. The first 8.5 feet were described as light gray decomposed rock with a silty sand texture. A roller bit was advanced to 11.0 feet after which rock cores were taken. All rock cores to final depth were described as containing moderately hard, slightly weathered, gray-green to yellow-green schist with frequent seams of very hard gray and white quartzite. Foliations and a primary joint set were described as moderately dipping and a secondary joint set was described as having a high angle. All core recoveries were 80 percent or less,

Figure 4. **Boring Location Map** (mod. from Google Earth™).

ranging from 47 to 80 percent with no apparent increase in recovery with depth and Rock Quality Determinations (RQDs) were listed as ranging from 0 to 12 percent.

The water level in the boring was recorded at 8.1 ft bgs, 14 hours after completion, and at 14.5 ft bgs, 38 hours after completion.

GES/Parratt Wolff Borings

At the direction of GES, Parratt Wolff advanced five borings along the alignment, south of the Marctic Thrust Fault, to accommodate the deepest of three nested monitoring wells at each location. The borings were advanced using sonic drilling technology. The boring at MW-01 was drilled to a depth of 175 feet. The top 15 feet was described as silt and gravel. From at depth of 15 feet to the final depth of 175 feet the material was described as saprolite of variegated tan gray, brown, yellow, red and green color. The saprolite became graphitic after 110 ft bgs and stiffness was variable and often soft throughout the boring. The material was intermittently moist after a depth of 20 feet.

The boring at MW-02 was drilled to a depth of 180 feet. The top 9.5 feet was described as clayey silt with some gravel. From at depth of 9.5 feet to the final depth of 180 feet the material was described as a foliated saprolite of variegated gray tan, orange tan, brown tan, gray, and brown colors. The strength of the saprolite

varied between stiff, very stiff, soft, and friable. The material was intermittently moist, wet and dry after a depth of 20 feet.

The boring at MW-03 was drilled to a depth of 150 feet. The top one foot was described as brown clayey silt with gravel. From at depth of 1 to 135 ft bgs, the material was described as a foliated saprolite of variegated gray, orange, brown, and tan colors. The strength of the saprolite varied between stiff and very stiff, with occasional soft zones. At 135 ft bgs, the material changed to a gray limestone with some weathering. The material was intermittently moist and dry throughout the boring, with wet zones indicated at 100 ft bgs and 110 ft bgs.

The boring at MW-04 was drilled to a depth of 136 feet. The top 10.0 feet was described as brown clayey silt with some gravel. From at depth of 9.5 feet to 121 ft bgs, the material was described as a foliated saprolite of variegated tan gray, gray brown, and gray color. The strength of the saprolite varied between stiff, medium stiff, soft, and friable and was stronger (medium stiff to stiff) from 85 to 121 ft bgs. At 121 ft bgs, the material changed to a gray limestone with calcite veins and remained so until final depth at 135 feet. The material was intermittently moist, wet and dry after a depth of 20 feet.

The boring at MW-05 was drilled to a depth of 85 feet. The top 15.0 feet was described as brown gravelly silt with gravel and clay. From a depth of 15.0 to 40 ft bgs, the material was described as a foliated saprolite of orange brown and gray color. Starting at 40 ft bgs, the material changed to a gray competent limestone. Weathered limestone was logged from 40 to 41 ft bgs and from 60 to 65 ft bgs, and a fractured limestone layer was noted from 80 to 81 ft bgs. The competent limestone logged between 65 and 80 ft bgs was noted as having foliations dipping at 45 degrees. The material was intermittently moist, wet, and dry after a depth of 10 feet.

Intertek /PSI Borings

In April 2019, Intertek/PSI advanced three geotechnical borings proximal to the Exton Bypass at the northwest end of the S3-0400 alignment. G400-A was located on the shoulder of the north (west bound) lane, G400-B was located in the median strip between the east bound and west bound lanes, and G400-C was located on the shoulder of the south (east bound) lane. All three borings were drilled to a depth of 60 feet and the first five feet of each boring was excavated using an air knife for utility clearance.

Boring G400-A encountered varying amounts of sand, gravel and clay to a depth of 16.5 feet. From 16.5 to 60 feet, split-spoon and rock core samples were logged as grey, brown, dark gray and dark red brown, highly to completely weathered graphitic schist. Rock coring began at 29.5 ft bgs. No core recovery occurred for the first 5.5 feet of coring, after which recoveries ranged from 18 to 43 percent. All RQD was logged as zero percent. A large proportion of core samples were noted as being washed away during coring. Upon completion of the boring, a water level was recorded 7.0 ft bgs.

Boring G400-B encountered similar materials as G400-A. A sand, gravel and silt layer was present to a depth of 11.5 feet. From 11.5 to 60 feet, split-spoon and rock core samples were logged as highly to completely weathered, light gray, gray, brown, gray-brown, and dark gray-brown, highly to completely weathered graphitic schist. Rock coring began at 20.0 ft bgs. Core recoveries ranged from 7 to 72 percent and RQD ranged from 0 to 30 percent, with five of the eight values at zero percent. Again, a large proportion of core samples were noted as being washed away during coring. Groundwater was not encountered.

In Boring G400-C, the highly to completely weathered schist was encountered at a depth of 5.5 ft bgs and rock coring began at 16 ft bgs. From 16.5 to 60 feet, rock core samples were logged as dark grey, dark gray-brown, and dark red-brown, highly to completely weathered graphitic schist. Recoveries ranged from 18 to 77 percent. All RQD was logged as zero percent, except for one run at 8 percent and another run at

20 percent. Once more, a large proportion of core samples were noted as being washed away during coring. Upon completion of the boring, a water level was recorded 5.5 ft bgs.

2.3 Hydrogeology

The most basic conceptual model for groundwater flow in the area of HDD S3-0400 is to depict the upland underlain by the Octorara Formation as the groundwater recharge zone and the lowland underlain by units of the Conestoga Formation as a groundwater discharge zone. As such, ground water is expected to move southeast to northwest at the HDD. Both formations have components of primary porosity and secondary porosity. In the Conestoga, porosity that is more primary is in the residuum and in the highly weathered and fractured bedrock zone, and the secondary porosity is in the solution openings and fractures present in more competent bedrock, at depth. Similarly, in the Octoraro Formation, the more primary porosity is in the highly weathered and fractured saprolite near the surface. The saprolite has a measured thickness that can exceed 100 feet in the area of the HDD. Where the saprolite is thick, the materials display relic structural features (foliation and fractures) of the parent rock with depth, which provides a more secondary porosity for groundwater movement. The saprolite thins to the southeast along the alignment of the permitted HDD to the point where there is only approximately five feet of material above competent bedrock at the highest elevations on the ridgeline that is held up by more resistant bedrock.

Primary porosity best supports the basic conceptual model of groundwater flow from recharge areas in uplands to discharge areas in lowlands. Secondary porosity created by openings in foliations, fractures and faults can impart anisotropies on the groundwater flow system altering the basic directions of groundwater flow. The anisotropies are difficult to define without detailed field studies; however, it can be assumed that regional structural fabric causes a groundwater flow vector oriented west-southwest or east-northeast under the pressure head placed on the system in the upland where secondary porosity occurs. Most of the permitted profile for S3-0400 is within highly weathered and fractured bedrock / saprolite / residuum; therefore, the effects of anisotropy are likely less pronounced than would be present in more competent bedrock below.

The water table high underlying the ridge at the south end of the permitted profile is accentuated by two storm water retention basins oriented parallel to the ridgeline on the northern slope. These occur between Stations 7+00 and 8+00. These basins are designed to manage storm water by collecting runoff within the basins and allowing it to infiltrate into the subsurface over time. As such, they are considered enhanced recharge features within the site conceptual model.

2.3.1 Occurrence of Groundwater

Groundwater in the area of HDD S3-0400 occurs in both primary and secondary features as described above. The water level data presented in Section 2.3.2 illustrates that saturated conditions occur within saprolite / residuum and highly weathered and fractured bedrock capping more competent Conestoga and Octoraro Formation bedrock.

2.3.2 Water Level

The water levels recorded at Tetra-Tech borings SB-01 and SB-02 were 27 and 38 ft bgs; respectively, and no groundwater was encountered in SB-03.

The log from Terracon boring B6-18W, located 680 feet east of the southeast entry/exit indicates a groundwater level of 14.5 ft bgs after the boring was allowed to stand open for 38 hours.

Five nested monitoring well locations were constructed in April and May 2019 to evaluate local groundwater levels and flow paths in the area between the Marctic Thrust Fault and the storm water retention basins. Initial water level data indicate the water table is within 30 feet of the surface in this area.

In April 2019, Intertek PSI advanced three geotechnical borings proximal to the Exton Bypass at the northwest end of the S3-0400 alignment. Water levels from two of the borings were recorded at 5.5 and 7.0 ft bgs.

A search of the PaGWIS database produced twelve residential wells with 0.5 miles of the HDD S3-0400 alignment. Five of the wells were in the Conestoga Formation and seven of the wells were labeled as being drilled in albite chlorite schist-Wissahickon Formation; however, their locations place them within the boundaries of the mapped Octoraro Formation. Water levels in all wells ranged from 9 to 45 ft bgs. The water levels for the Conestoga Formation wells ranged from 17 to 40 ft bgs with a mean of 24 ft bgs. The water levels for the Octoraro wells ranged from 9 to 45 ft bgs with a mean of 30 ft bgs.

2.3.3 Ground Elevation Between HDD Entry/Exits

The permitted HDD profile drops 171 feet from the southeast entry/exit (elevation 536 ft amsl) to the northwestern entry/exit (elevation 365 ft amsl). The lowest topographic point along the alignment is the northwestern entry/exit. Water level data collected to date from the five monitoring well nests installed by GES indicates an average depth to groundwater within the Octoraro upland of approximately 25 ft bgs. The water level at MW-5, at the Marctic Thrust Fault zone has had an average elevation of 385 ft amsl. This represents a head difference of approximately 20 feet between the upland and the northwest entry/exit, indicating a high probability of creating a groundwater discharge at the northwest entry/exit upon completion of the pilot bore for the HDD. In fact, a groundwater discharge did occur at the northwest entry/exit during drilling of the pilot bore for the 16-inch line.

A recent test boring advanced at the Exton Bypass indicates a water table elevation of 371.1 ft amsl at approximately Station 18+00; therefore, there would be approximately 16 feet of head between the water table and the northwest direct pipe bore end point. Using an average water level elevation of 385 ft msl at MW-5 on the southeast side the Amtrack/Septa rail line, the approximate head difference with the northwest end of the direct pipe bore would be the same as the permitted HDD, or approximately 20 feet. Although head differences indicate the potential for a groundwater discharge, for the direct pipe bore the discharge rate would be much smaller and easier to mitigate than that for the permitted HDD profile. HDD drilling provides a relatively large annular space for groundwater flow between the drill pipe and borehole. The direct pipe method leaves a much smaller annular space (two inches or less) between the outside of the casing and borehole wall.

2.3.4 Well Yield

Results of the aforementioned PAGWIS survey revealed a range of yields for five local domestic wells in the Octoraro Formation from 6 to 120 gallons per minute (gpm) with a mean of 42 gpm. The PAGWIS search only produced well yield values for two domestic wells, 1 and 4 gpm. Kochanov (2016) lists mean yield values of 7.5 and 25 gpm for the Octoraro and Conestoga Formations, respectively.

2.3.5 Water Supply Wells within 450 of ROW

During the planning for advancement of the HDD S3-0400 drills, in October of 2017 a survey of landowner parcels within 450 feet of the HDD alignment was performed (see **Figure 5**). No landowners responded in the affirmative as to whether they had a residential well and wanted to become part of the project sampling program. Available information indicates that most residential parcel landowners adjacent to the S3-0400 alignment have public water service provided by Aqua PA.

Aqua America operates a municipal surface water intake on Chester Creek 170 ft southwest of the ROW, 216 feet upstream from where tributary S-I4 discharges to Chester Creek.

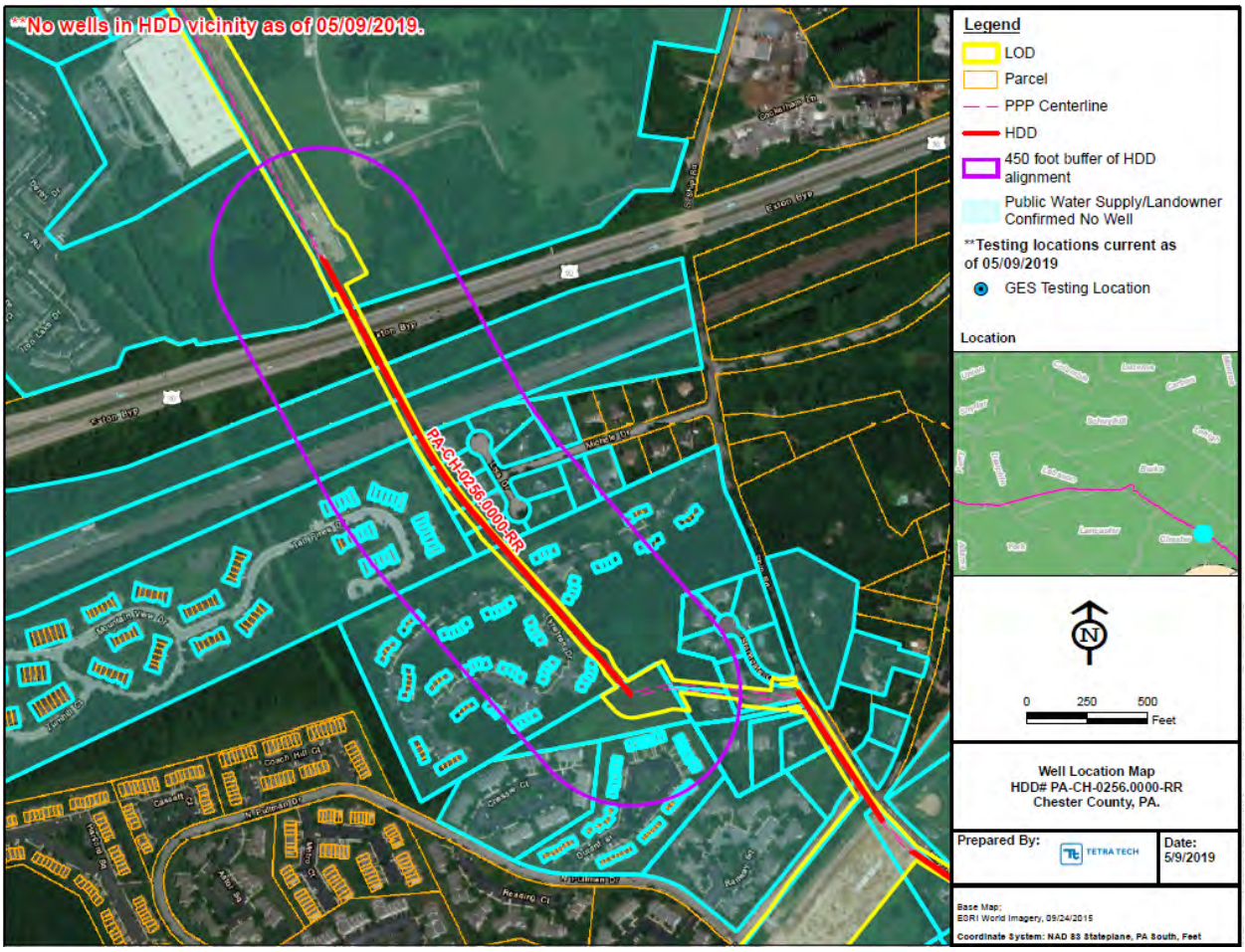


Figure 5. 450-ft Water Supply Survey Map.

2.4 Summary of Geophysical Studies

A geophysical survey was performed at the HDD S3-0400 site by Quantum Geophysics in September 2017, employing microgravity and seismic (MASW) techniques. The full report of the survey is provided in **Attachment C**. The study revealed the following detailed geologic information along the drill path:

- Karst features are present within the lower unit of the Conestoga Formation north of the Amtrak / Septa rail lines toward the northwest entry/exit point.
- A significant fracture zone was identified beneath the abandoned Norfolk rail line marking the boundary between the lower and upper units of the Conestoga Formation.
- Uniform microgravity within the upper unit of the Conestoga Formation, located south of the Amtrak / Septa rail lines, indicated the absence of karst geology,
- A significant fracture zone was identified 900 feet into the bore, corresponding to the area of 475 and 479 Lisa Drive, and confirming the presence of the mapped Marctic Thrust Fault zone, and
- Uniform microgravity results recorded within the investigated portion of the Octoraro Formation, along the HDD path, indicates the absence of karst geology south of the Marctic Fault zone to the southeast entry/exit.

3.0 OBSERVATIONS TO DATE

3.1 During Construction for 16-inch line

The following is a summary of events that occurred during installation of the 16-inch line at HDD S3-0400. HDD drilling for S3-0400-16 began on 4/14/2017 with entry at the northwest entry/exit, drilling towards the southeast, and the pilot bore was completed on 9/21/17. During drilling of the pilot bore, groundwater was produced beginning at approximately Station 15+81within the lower unit of the Conestoga Formation and continuing, off and on, until the pilot was completed. Due to losses of returns and borehole collapse, the first pilot bore was terminated after 909 feet, within the lower unit of the Conestoga approaching the Marctic Fault Zone, and was abandoned by grouting. The second pilot bore experienced similar issues; however, approved LCM products were used to improve circulation until completion of the pilot. A 20-inch ream from northwest to southeast was initiated on 9/21/17 and on 10/5/17, a 50-gallon IR occurred at 479 Lisa Drive., approximately 940 feet from the northwest entry/exit (see **Attachment A**), when the 20-inch reamer was 1,312 feet into the borehole, well within the Octoraro Formation. This IR location corresponds approximately with the projected location of the Marctic Thrust Fault zone. Crews cleaned up the bentonite spill and added a 30-inch reamer behind the 20-inch reamer to improve circulation and reduce drilling fluid pressure. On 11/4/2017, the 20-inch diameter ream was completed and a 24-inch ream was initiated drilling from northwest to southeast.

On 11/11/2017, a 500-gallon IR occurred, at the same location of the previous IR, when the 24-inch reamer was 1,763 feet into the borehole (approximately 431 feet remaining to complete the final ream) as drilling fluids flowed downhill toward the 475 Lisa Drive property. Crews removed the bentonite drilling fluid and fenced off the area to prevent access. A circular subsidence feature, initially 3 feet in diameter and 2 feet deep, was visible at the surface the following day. Drilling was halted pending Pennsylvania Department of Environmental Protection (Department) review. On 11/15/2017, the subsidence feature at 479 Lisa Drive expanded to 9.0 by 9.5 feet with the feature exhibiting water to a level 3.75 ft bgs. Before the 11/11/2017 IR was detected, the driller employed a number of actions to reduce IR risk, including:

- Swabbing the hole (tripping the reamer in and out of the borehole to remove excess cuttings) when reduction in return flow was noticed, and
- Positioning an observer at the former IR location

The driller shut down the mud pump when the observer reported drilling fluid daylighting, which limited the IR to 500 gallons.

The cause of the 11/11/2017 IR was due to a build-up of cuttings that made drilling fluids migrate through highly weathered and fractured bedrock to ground surface near 479 Lisa Drive. The driller noted a reduction in drilling fluid return flow just before the 11/11/17 IR and shutdown. The 24-inch reamer was located approximately 800 feet south of the IR location at an elevation of 400 ft amsl. Due to this relatively high elevation differential, drilling fluid pressure would have naturally built-up as mud flowed downhill toward the northwest HDD entry point by gravity.

The subsidence feature that developed at 479 Lisa Drive on 11/12/17 was most likely caused by soil flowing downward along foliation planes, within the saprolite horizon, weakened by drilling activity, into the subsurface the fault zone. The Marctic Thrust Fault zone is characteristically filled with broken and weathered rock allowing this material to slowly collapse into the HDD borehole, causing subsidence at the ground surface. Additionally, related excavation in the area, and a sanitary sewer line that crosses the alignment just north of the IR location which may convey movement of subsurface liquids.

3.2 On Other HDDs in Similar Hydrogeologic Settings

IRs have occurred during the drilling of other ME II HDDs in the metamorphic rocks of Chester and Delaware County. These IRs have typically occurred where bedrock is densely fractured (sometimes indicated by a fracture trace or fracture trace intersection) or where the profile approaches an entry/exit point, closer to the surface, where unconsolidated overburden material thins and there is less overburden strength to contain drilling fluid pressures. In some cases, overburden thickness is reduced where the deepest part of the profile passes under a stream occupying a section of the alignment with the lowest surface elevation along the profile. 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 CONCLUSIONS

4.1 HDD Site Conceptual Model

From northwest to southeast, the geologic formations within the hydrogeologic setting associated with the alignment for the original permitted S3-0400 20-inch pipe include the lower unit Conestoga Formation, upper unit Conestoga Formation and the Octoraro Formation. The Marctic Thrust Fault marks the boundary between the Octoraro and the upper unit Conestoga. The Octoraro Formation is a massively bedded, fissile phyllite, with small-scale isoclinal folds and faults; quartz pods, stringers, and lenses running parallel to bedding. The upper part of the Conestoga Formation is primarily a coarsely crystalline, laminated limestone. The laminations are shaly to argillaceous and carbonaceous, and bedding is thin to massive, with small-scale isoclinal folds, as well. The mica content is abundant, particularly where the rock is argillaceous, giving the rock a schistose appearance. The lower part of the Conestoga is an argillaceous to finely crystalline, laminated limestone. The unit is very micaceous and pyritic where argillaceous, and medium to thick bedded. Small-scale isoclinal fold axes run parallel to bedding strike and there are thin quartz lenses and gash veins.

The Octoraro is highly weathered and there is a deep (>100 feet) saprolite containing highly weathered and fractured material with low rock strength at its northern limit within the Marctic Thrust Fault zone and for a distance south along the alignment. The surface of more competent phyllite rises to the south and is close to the surface (within 5 feet) along the most southern part of the permitted profile. The upper and lower units of the Conestoga are highly fractured and weathered, as well, with an increasing effect of karst development (pinnacled bedrock surfaces and solution openings in bedrock) moving north from the Marctic Thrust Fault into more calcite rich rock. Three core borings, each drilled to a total depth of 60 feet, located at the contact between the lower and upper units near the Exton Bypass, produced rock core with low recoveries and very low RQDs to total depth.

The ME II 16-inch line was successfully installed at HDD S3-0400; however, a groundwater discharge, IRs and surface collapse occurred due, in part, to the high degree of bedrock fracturing and weathering over each bedrock unit, potential karst features in the Conestoga Formation, and relatively shallow water table. For installation of the 20-inch line, SPLP is proposing a combination of construction methods intended to eliminate IRs, void development, surface subsidence and groundwater discharge. The alternative methods include one direct pipe installation, from Station 13+13 to 21+29 on the permitted HDD profile, and conventional open trench installation for the remainder of the S3-0400 alignment. An approximate 17-foot deep construction pit will extend from Station 13+13 to 12+55 to facilitate the direct pipe bore. The direct pipe installation will travel under the Exton Bypass, wetlands W-K18 and W-K21, the abandoned Norfolk rail line, and the active Amtrack/Septa rail lines.

The direct pipe construction method uses a tunneling drill head to advance and steer excavation of the pipeline borehole along the design profile. A steel casing, slightly smaller than the cutter, is advanced directly behind the drill head such that the bore is continuously and simultaneously cased during completion. Electrical power and drilling fluid discharge and suction lines lay within the steel casing providing for total control of the drilling fluid pathway. The volume of drilling fluid required is much less than that required for standard HDD drilling and the annulus between the borehole wall and casing is two inches or less. As such, this method eliminates the risk of IRs. In addition, simultaneous and continuous installation of the casing and conveyance of drilling fluids and cuttings inside the casing, eliminates the need to swab the borehole, eliminating excess removal of unconsolidated material, preventing the development voids and associated ground subsidence features. For the direct pipe installation, SPLP will install a 42-inch casing. Once the direct pipe casing is in place, the 20-inch pipe will be installed inside the casing. Spacers will used to prevent the pipe from contacting the inside of the external casing during installation.

The northwest two-thirds of the direct drill pipe profile will be within the lower unit of the Conestoga Formation (approximately 589 feet horizontal distance) and the southeast third will be within the upper unit of the Conestoga (approximately 227 feet horizontal distance). The last approximate 70 feet at the southeast end will be south of the Amtrack/Septa rail line right-of-way approaching or within the Marctic Thrust Fault zone. It is estimated that there will be approximately a 16 to 35 feet of hydraulic head differential between sections of the direct pipe bore profile and the northwest entry point. Although head differences indicate a risk for a groundwater discharge for the direct drill bore, the risk is much smaller than that for the permitted HDD profile because the direct drill method leaves a much smaller annular space (two inches or less) between the outside of the casing and borehole wall.

Furthermore, the direct pipe method represents no risk for an IR because drilling fluids travel to the cutting head and back to the entry point within the outer casing. Lastly, there is a very small risk for ground subsidence as the bore created when drilling is immediately occupied by the outer casing and there are no ream or swab passes that potentially remove material beyond the dimensions of the drill bore and create voids.

As proposed, installation of the remainder of the 20-inch line along the originally permitted S3-0400 alignment will be accomplished by standard open trench construction to a depth of approximately four feet. These sections of the alignment do not pass through any water resources. Contractors will install both the open trench sections and direct pipe section in accordance with the methods outlined in the permit modification for pipe installation under review by the Department.

4.2 Conclusions and Recommendations

Hydrogeologic conditions encountered during installation of the 16-inch pipe at HDD S3-0400 presented difficulties leading to IRs, groundwater discharges and land subsidence. SPLP is proposing to greatly reduce the risk of these events during construction of the 20-inch line along the original permitted alignment using a combination of direct pipe and conventional open trench construction methods. Taking this approach IR risk is eliminated and the risk of subsidence is greatly reduced. Given the geometry and depth of the profile for the direct pipe bore, there is the potential for a groundwater discharge due to the elevation change along the profile. Contractors should plan to manage such a groundwater discharge, if one occurs.

5.0 REFERENCES

Geyer, Alan R. and J. Peter Wilshusen (1982*). Engineering Characteristics of the Rocks of Pennsylvania*. Pa. Geol. Surv., Environmental Geology Report 1.

Kochanov, W. E,, (2016). *Geology of Part of the Chester Valley Area, Chester, Delaware, Montgomery, and Philadelphia Counties, Pennsylvania,* Pa. Geol. Surv., 4th Ser., Open-File Geologic Atlas 16-01.0.

Sloto, R. A., (2009). *The Mines and Minerals of Chester County, Pennsylvania.*

Web Sites

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

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

PASDA, Pennsylvania Spatial Data Access, http://www.pasda.psu.edu/.

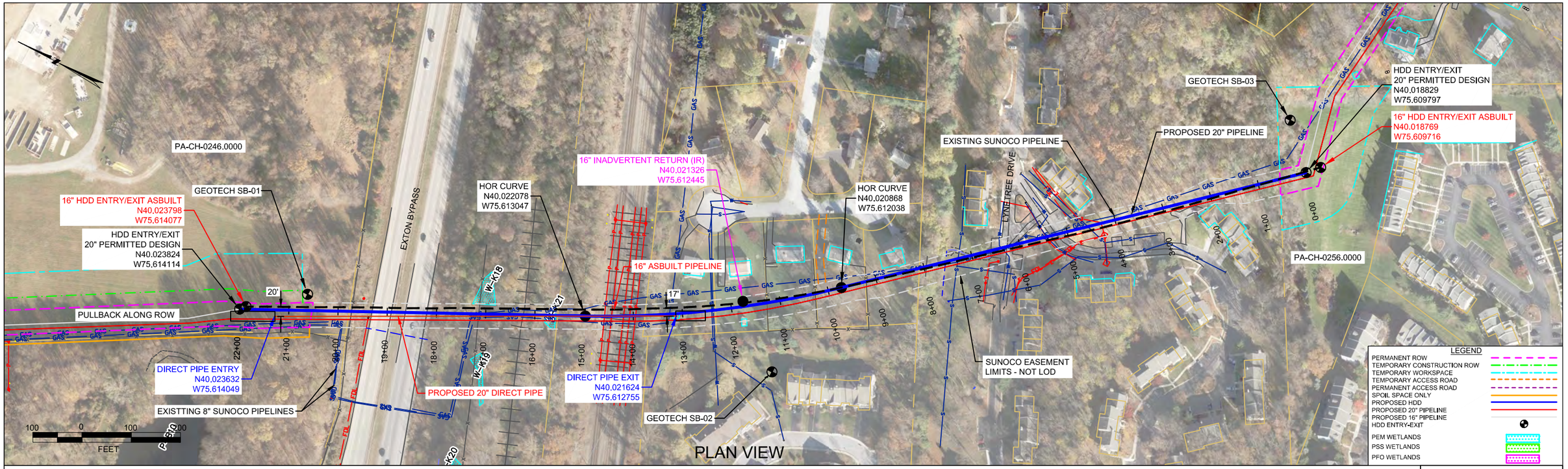
NRCS WSS, United States Department of Agriculture, Natural Resources and Conservation Services, Web Soil Survey, https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.asp.

Attachment A

Plan and Profiles

Permitted Plan and Profile (rev. 4/16/17),
showing IR, geology and proposed direct pipe

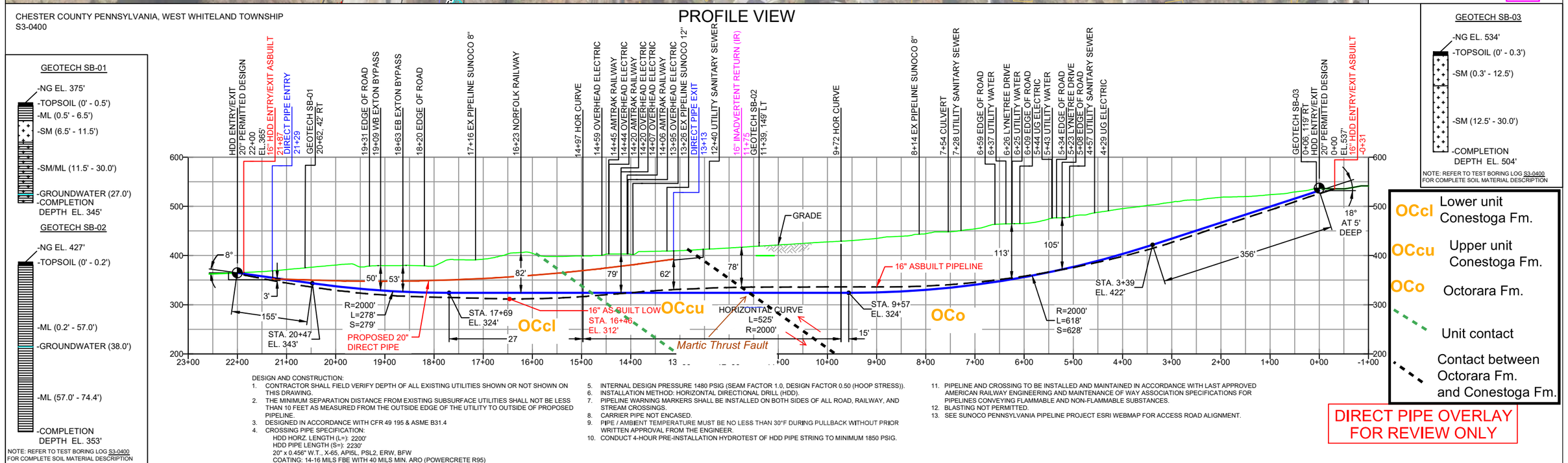
Proposed Direct Pipe Profile (rev. 5/3/19)



PLAN VIEW

PROFILE VIEW

CHESTER COUNTY PENNSYLVANIA, WEST WHITELAND TOWNSHIP
S3-0400



GEOTECH SB-01

GEOTECH SB-02

NOTE: REFER TO TEST BORING LOG S3-0400 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH SB-03

NOTE: REFER TO TEST BORING LOG S3-0400 FOR COMPLETE SOIL MATERIAL DESCRIPTION

OCcl Lower unit Conestoga Fm.
OCcu Upper unit Conestoga Fm.
OCo Octorara Fm.
Unit contact
Contact between Octorara Fm. and Conestoga Fm.

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=): 2200'
   HDD PIPE LENGTH (S=): 2230'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. PIPELINE AND CROSSING TO BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH LAST APPROVED AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION SPECIFICATIONS FOR PIPELINES CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES.
12. BLASTING NOT PERMITTED.
13. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

DIRECT PIPE OVERLAY FOR REVIEW ONLY

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	DESIGN CHANGE - ADJUSTED DRILL CENTERLINE ALIGNMENT - RFI 0140	MRS	04/06/17	RMB	04/06/17	AMC	04/06/17
4	DRILL ENTRY / EXIT LAT LONG UPDATE	MRS	03/31/17	RMB	03/31/17	AMC	03/31/17
3	REVISED PROFILE WITH 2017 LIDAR	MRS	02/15/17	RMB	02/15/17	AMC	02/15/17
2	REVISED PER ENGINEERING COMMENTS	MRS	08/12/16	RMB	08/12/16	AAW	08/12/16
1	REVISED PER COMMENTS FROM REI REVIEW	MRS	03/03/16	RMB	03/03/16	AAW	03/03/16
0	ISSUED FOR CONSTRUCTION	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16

Sunoco Logistics Partners L.P.

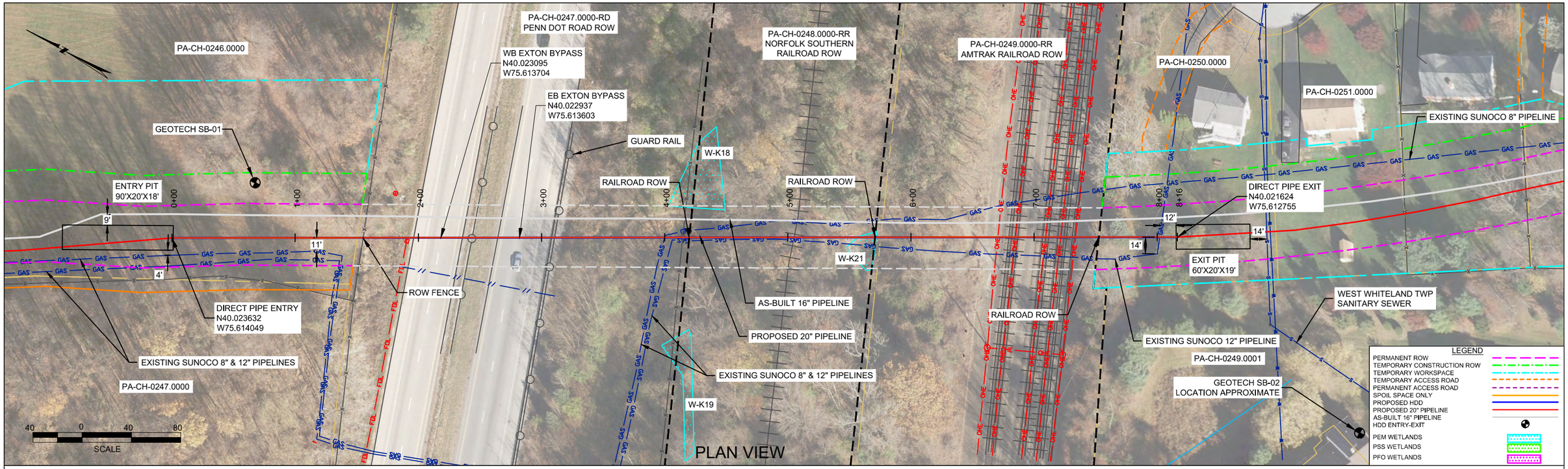
TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
EXTON BYPASS
PENNSYLVANIA PIPELINE PROJECT

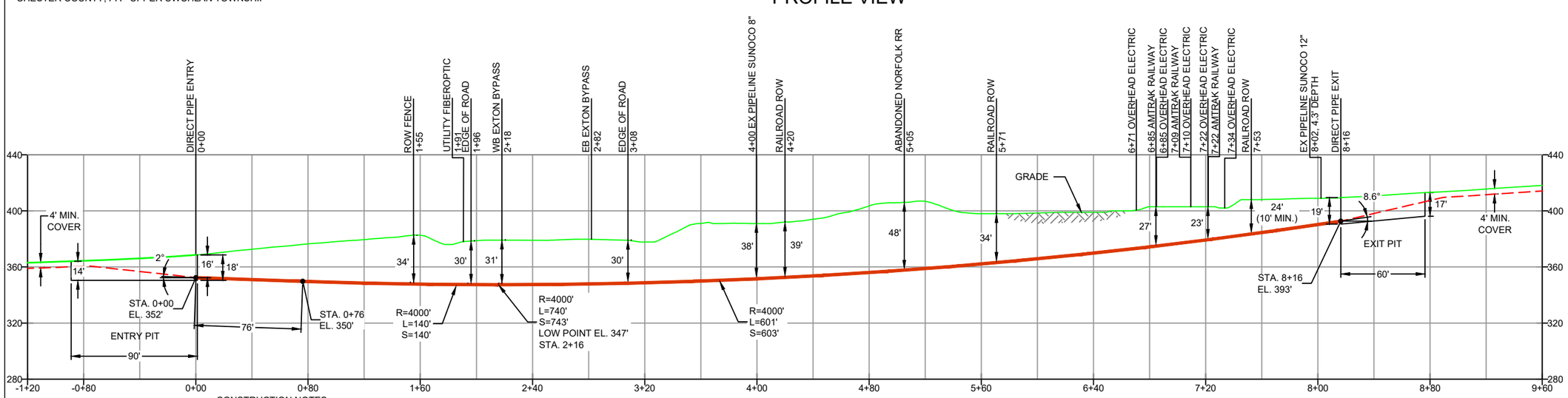
SCALE: 1"=200'

DWG. NUMBER: PA-CH-0249.0000-RR



CHESTER COUNTY, PA - UPPER UWCHLAN TOWNSHIP

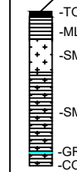
PROFILE VIEW



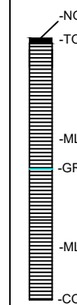
CONSTRUCTION NOTES

1. 20" PIPE WILL BE INSTALLED INTO A SINGLE WELDED STEEL CASING (48" OD, 0.750" WT, X-52) USING DIRECT PIPE METHOD.
2. 20" WELDED STEEL PIPE: 20" OD x 0.456" WT, X-65, API-5L, PSL2, ERW, BFW, DRL
   HORIZONTAL PIPE LENGTH (L) = 816'
   PIPE LENGTH (S) = 819'
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
3. 20" DESIGN PRESSURE: 1480 PSIG
   CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF PIPE STRING TO MINIMUM 1850 PSIG.
4. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
5. THE COATING ON THE CARRIER PIPE SHALL BE INSPECTED IMMEDIATELY PRIOR TO ITS INSTALLATION AND ALL DAMAGED COATING SHALL BE REPAIRED IN ACCORDANCE WITH SUNOCO'S PIPELINE COATING SPECIFICATIONS.
6. INSTALL CATHODIC PROTECTION TEST LEADS AS SPECIFIED ON THE ALIGNMENT SHEETS OR SUNOCO CORROSION TECHNICIAN.
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. WELDED JOINTS INSIDE R.O.W. SHALL BE 100% X-RAYED.
9. CONTRACTOR WILL MAINTAIN A MINIMUM 4' OF COVER TO THE TOP OF PIPE USING FIELD BENDS.
10. CONTRACTOR WILL MAINTAIN A MINIMUM 24" OF COVER FROM ALL EXISTING UTILITIES.
11. CONTRACTOR WILL MAINTAIN A MINIMUM 5' OF COVER FROM BOTTOM OF STREAMS.
12. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
13. IN ADDITION TO THE SITE-SPECIFIC INFORMATION PROVIDED IN THIS DRAWING, GENERAL REQUIREMENTS INCLUDED IN ALIGNMENT SHEETS, PERMITS AND APPROVAL FROM FEDERAL, STATE AND LOCAL AGENCIES ALSO APPLY.
14. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
15. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

GEOTECH SB-01



GEOTECH SB-02



NOTE: REFER TO TEST BORING LOG S3-0400 FOR COMPLETE SOIL MATERIAL DESCRIPTION

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-6.49	TO	ES-6.50	EROSION & SEDIMENT PLAN
SHEET 33	TO	SHEET 34	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
0	ISSUED FOR CONSTRUCTION	MRS	05/03/19	RMB	05/03/19	AMC	05/03/19

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

DIRECT PIPE
EXTON BYPASS / AMTRAK RAILWAY
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=80' | DWG. NO.: PA-CH-0249.0000-RR

Attachment B

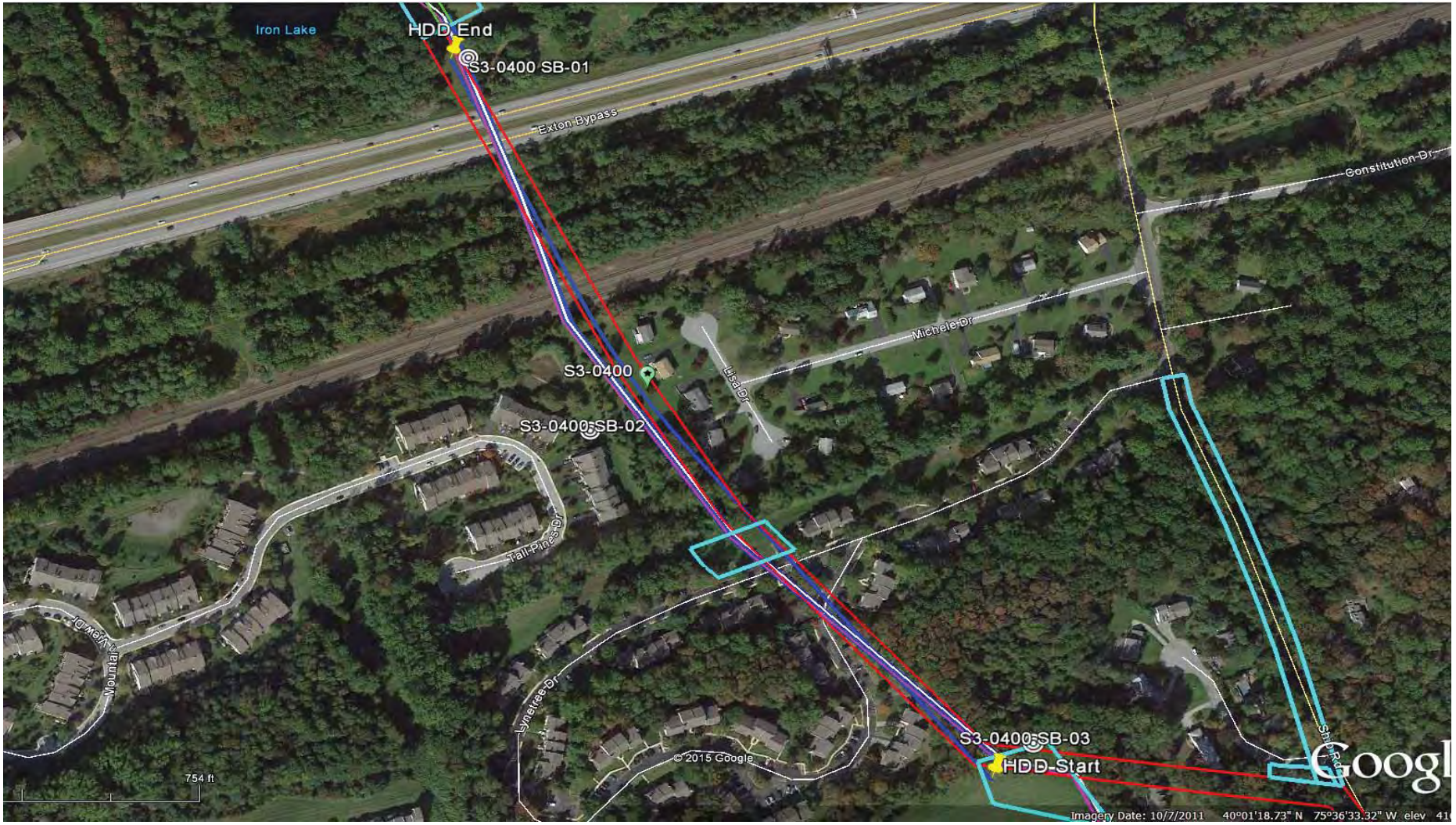
Geotechnical Boring Reports

Tetra Tech – June 2015

Terracon – September 2017

Interek/PSI – April 2019

GES / Parratt Wolff – April/May 2019



LEGEND:

◎ Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S3-0400
CHESTER COUNTY, WEST WHITELAND 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:	TRAINING FACILITY, 500 LINCOLN HWY, EXTON, PA		Page 1 of 1
HDD No.:	S3-0400	Dates(s) Drilled: 06-12-15	Inspector: J. COSTELLO
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller: GREG
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 27.0	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 1' 24.672" N	75° 36' 49.675" 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	0.5			TOPSOIL (6")					
			0.5	3.0		ML	DARK BROWN SILT WITH SOME FINE SAND,.					
1	3.0	5.0	3.0		20		DR, VARIEGATED DARK BROWN, REDDISH BROWN, GRAY SILT WITH	1	2	3	8	**5**
				6.5			SOME FINE SAND, TRACE FINE ROCK FRAGMENTS.					
2	8.0	10.0	6.5		15	SM	DR, REDDISH BROWN AND BROWN FINE TO MEDIUM SAND WITH SOME	5	5	7	10	**12**
				11.5			SILT, TRACE UNWEATHERED FINE ROCK FRAGMENTS.					
3	13.0	15.0	11.5		18	SM/ ML	DR, REDDISH BROWN AND BROWN FINE TO MEDIUM SAND AND	2	5	5	6	**10**
							SILT, TRACE FINE TO COARSE UNWEATHERED GRAVEL.					
4	18.0	20.0			21		DR, VARIEGATED GRAY, REDDISH BROWN, YELLOWISH BROWN	1	2	4	4	**6**
							F-SAND AND SILT, TRACE FINE UNWEATHERED GRAV. (USCS: SM/ML)					
5	23.0	25.0			20		DR, VARIEGATED GRAY, REDDISH BROWN, YELLOWISH BROWN	1	3	9	11	**12**
							F-SAND AND SILT, TRACE FINE UNWEATHERED GRAV. (USCS: SM/ML)					
6	28.0	30.0			22		DR, STRATIFIED LAYERS OF GRAY, RED, BRWN, AND YELLOW BRWN	4	22	22	28	**44**
							FINE TO MEDIUM SAND AND SILT, WITH A LITTLE UNWEATHERED					
				30.0			LIMESTONE GRAVEL.					
							WATER LEVEL THROUGH AUGERS AT 27'.					
							CAVED AT 29'.					

Notes/Comments:
Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

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

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

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406
Project Location:	TALL PINES DRIVE, WEST CHESTER, PA		Page 1 of 1
HDD No.:	S3-0400	Dates(s) Drilled: 06-16-15	Inspector: J. COSTELLO
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586	Driller: GREG
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 38.0	Total Depth (ft): 74.4
Boring Location Coordinates:		40° 1' 15.624" N	75° 36' 46.117" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.2			TOPSOIL (2")					
1	3.0	5.0	0.2		18		DR, WEATHERED TO A VARIEGATED BROWN, GRAY, ORANGE BRWN	4	6	4	8	**10**
							SILT WITH SOME FINE MICACEOUS SAND, LITTLE F-GRAVEL.					
2	8.0	10.0			22		DR, VARIEGATED LAYERS OF BROWN, GRAY, OR.BRWN SILT WITH	1	3	4	7	**7**
							SOME FINE SAND, TRACE FINE GRAVEL.					
3	13.0	15.0			24		DR SHIIST, VARIEGATED GRAY AND BROWN MICACEOUS SILT WITH	1	3	6	8	**9**
							SOME FINE SAND, TRACE FINE UNWEATHERED GRAVEL.					
4	18.0	20.0			22		DR SHIST, LIGHT GRAY SILT WITH A LITTLE FINE SAND.	1	6	7	9	**13**
5	23.0	25.0			22		DR SHIST, LIGHT GRAY SILT WITH A LITTLE FINE SAND.	1	3	6	12	**9**
6	28.0	30.0			23	ML	DR, VARIEGATED ORANGE AND YELLOW BROWN SILT WITH SOME	1	2	8	17	**10**
							FINE SAND (WEATHERED SCHIST). (USCS: ML).					
7	33.0	35.0			23		DR SCHIST, VARIEGATED ORANGE AND YELLOW BROWN SILT WITH	1	5	6	14	**11**
							SOME FINE SAND, TRACE UNWEATHERED FINE GRAVEL.					
8	38.0	40.0			24		DR SCHIST, VARIEGATED REDDISH BROWN AND GRAY SILT AND	1	6	7	14	**13**
							FINE SAND, TRACE UNWEATHERED FINE GRAVEL.					
9	43.0	45.0			13		DR SCHIST, VARIEGATED REDDISH BROWN AND GRAY SILT AND	2	6	17	19	**23**
							FINE SAND, TRACE UNWEATHERED FINE GRAVEL.					
10	48.0	50.0			16		DR SCHIST, VARIEGATED LIT GRAY TO OLIVE GRAY SILT WITH A	2	9	8	16	**17**
							LITTLE FINE SAND, MICACEOUS.					
11	53.0	55.0			12		DR SCHIST, VARIEGATED RED, YELLOW, GRAY, BRWN SILT WITH A	1	1	27	32	**28**
				57.0			LITTLE FINE SAND, MICACEOUS, TRACE F-GRAVEL (USCS: ML).					
12	58.0	59.3	57.0		18		DR SCHIST, VARIEGATED GRAY, RED, YELLOW BRWN SILT WITH A	11	37	50/4"		**>50**
							LITTLE FINE SAND, MICACEOUS.					
13	63.0	65.0			14		DR SCHIST, OLIVE GRAY MICACEOUS SILT WITH A LITTLE FINE	4	13	17	27	**30**
							SAND.					
14	68.0	70.0			18	ML	DR SCHIST, OLIVE GRAY MICACEOUS SILT WITH A LITTLE FINE	8	19	25	45	**44**
							SAND.					
15	73.0	74.4			15		DR SCHIST, OLIVE GRAY MICACEOUS SILT AND FINE SAND, WITH	10	31	50/5"		**>50**
				74.4			A LITTLE UNWEATHERED FINE GRAVEL.					

Notes/Comments:

Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

WET ON SPOON AT 38'.
CAVED AT 66'.

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:	BEHIND DURANT COURT, EXTON STATION COMMUNITY, PA		Page 1 of 1
HDD No.:	S3-0400	Dates(s) Drilled: 06-16-15	Inspector: E. WATT
Boring No.:	SB-03	Drilling Method: SPT - ASTM D1586	Driller: S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft): 30.0
Boring Location Coordinates:		40° 1' 8.538" N	75° 36' 34.227" W

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.3			TOPSOIL (4")					
1	3.0	5.0			16		DR SCHIST, VARIEGATED LIGHT GRAY, GRAY, AND BROWN FINE TO	3	5	12	12	**17**
						SM	MEDIUM SAND WITH A LITTLE SILT.					
2	8.0	10.0			18		DR SCHIST, VARIEGATED LIGHT GRAY, GRAY, AND BROWN FINE TO	6	8	10	11	**18**
				12.5			MEDIUM SAND WITH A LITTLE SILT, WITH A LITTLE F-C GRAVEL.					
3	13.0	13.8	12.5		10		DR SCHIST, VARIEGATED LIGHT GRAY AND LIGHT BROWN FINE TO	7	50/3"			**>50**
							MEDIUM SAND WITH A LITTLE SILT.					
4	18.0	18.4			5		DR SCHIST, VARIEGATED LIGHT GRAY AND LIGHT BROWN FINE TO	50/5"				**>50**
						SM	MEDIUM SAND WITH A LITTLE SILT.					
5	23.0	23.3			2		BROWN AND GRAY PARTIALLY WEATHERED SCHIST.	50/3"				**>50**
6	28.0	28.2		30.0	2		BROWN AND GRAY PARTIALLY WEATHERED SCHIST.	50/2"				**>50**
							AUGERED TO 30'.					
							AUGERS STARTED GRINDING AT 12.5'.					
							CAVED AND DRY AT 28'.					

Notes/Comments:
Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

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

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

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0400

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)
S3-0400	SB-01	1	3.0	5.0	22.0	69.7	-	-	-	-
		2	8.0	10.0	14.7	39.0	-	-	-	-
		3	13.0	15.0	19.1	46.8	-	-	-	-
		4	18.0	20.0	25.5	48.0	39	28	11	SM/ML
		6	28.0	30.0	14.5	47.8	-	-	-	-
	SB-02	2	8.0	10.0	20.4	68.6	-	-	-	-
		4	18.0	20.0	14.1	85.1	-	-	-	-
		6	28.0	30.0	16.4	75.0	28	23	5	ML
		8	38.0	40.0	16.5	63.0	-	-	-	-
		10	48.0	50.0	16.4	84.7	-	-	-	-
		11	53.0	55.0	19.7	80.5	32	25	7	ML
		13	63.0	65.0	19.4	82.0	-	-	-	-
	SB-03	1	1.0	3.0	5.0	16.9	-	-	-	-
		2	2.0	8.0	10.0	13.7	-	-	-	-
		3	3.0	13.0	13.8	18.3	-	-	-	-
		4	4.0	18.0	18.4	16.6	-	-	-	-
		6	6.0	28.0	28.2	18.7	-	-	-	-

Notes:

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

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0400

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
S3-0400		SB-01	Conestoga Formation - Light-gray, thin-bedded, impure, contorted limestone having shale partings; conglomeratic at base; in Chester Valley, includes micaceous limestone in upper part, phyllite in middle, and alternating dolomite and limestone in lower part.	Gently sloping to the North	Conestoga Formation(Ordovician and Cambrian)	Limestone; secondary: phyllite; other types: conglomerate, dolostone, shale	At least 300	Ranges from 5 to 43 ft bgs, Avg. 23 ft bgs (.5 mile radius)	Few sinkholes mapped in this area, mostly depressions (potential soft soils)
		SB-02	Octoraro Formation - Includes albite-chlorite schist, phyllite, some hornblende gneiss, and granitized members.	Gently to moderately sloping to the North	Octoraro Formation (Probably Lower Paleozoic)	Schist; secondary: phyllite; other types: gneiss, graitoid	Unknown		
		SB-03	Octoraro Formation - Includes albite-chlorite schist, phyllite, some hornblende gneiss, and granitized members.	Gently to moderately sloping to the NW	Octoraro Formation (Probably Lower Paleozoic)	Schist; secondary: phyllite; other types: gneiss, graitoid	Unknown		

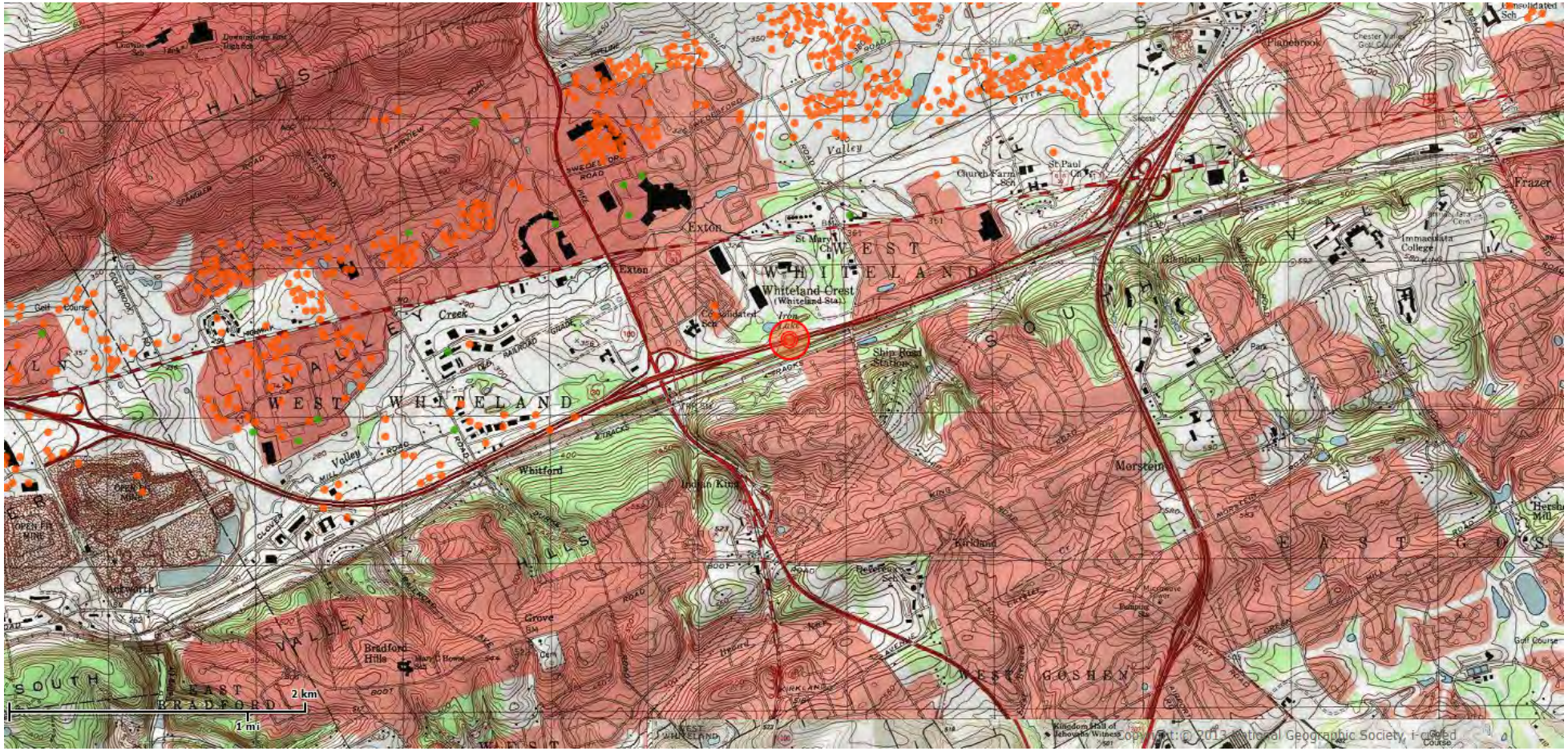
Note : Source of well log data - http://www.dcnr.state.pa.us/topogeo/groundwater/pagwis/records/index.htm. All other sources as referenced in comments section.

pennsylvania
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES

Visit us at http://www.dcnr.state.pa.us

Figure 1: Site Vicinity Map

Make online reservations at
www.visitPAparks.com
or call toll-free 888-PA-PARKS



Created using PA DCNR Map Viewer

Map created on Fri Apr 26 2019

FIGURE 2: BORING LOCATION PLAN

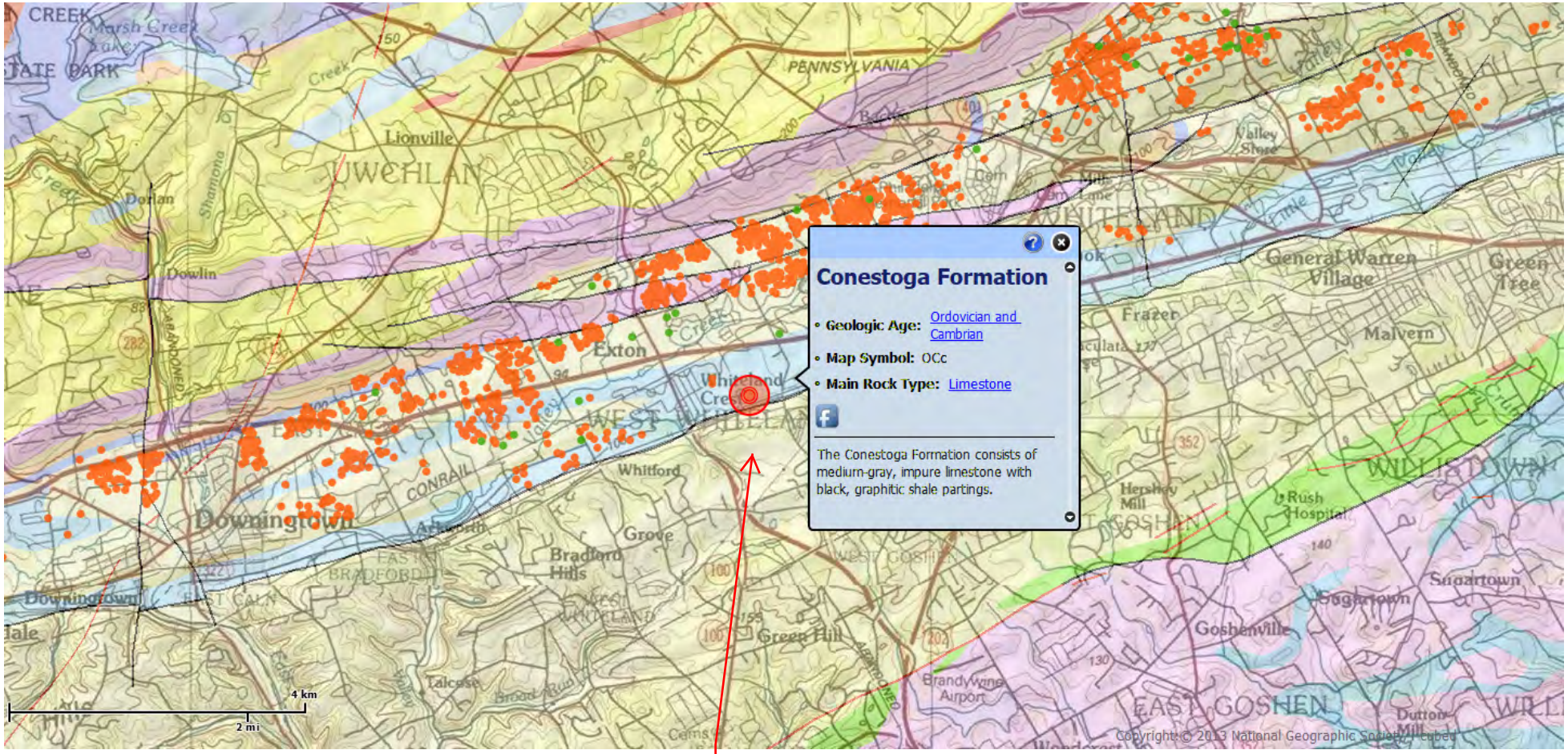
SITE NAME: S3-400 "US 30/Exton By-Pass"
Chesster Co., PA
PSI Project No.: 04911768

pennsylvania
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

Visit us at http://www.dcnr.state.pa.us

Figure 3: Site Geology Map

Make online reservations at
www.visitPAparks.com
or call toll-free 888-PA-PARKS



Octoraro Formation
Geologic Age: "Probably lower Paleozoic"
Main Rock Type: Albite-chlorite schist
The Octoraro Formation is a phyllite that contains some schist, hornblende gneiss, and granitized members.

Created using PA DCNR Map Viewer

Map created on Fri Apr 26 2019

FIGURE 4A: PA Geology Quad (Mavern)
S3-400 "US 30/Exton By-Pass"
Chesster Co., PA
PSI Project No.: 04911768

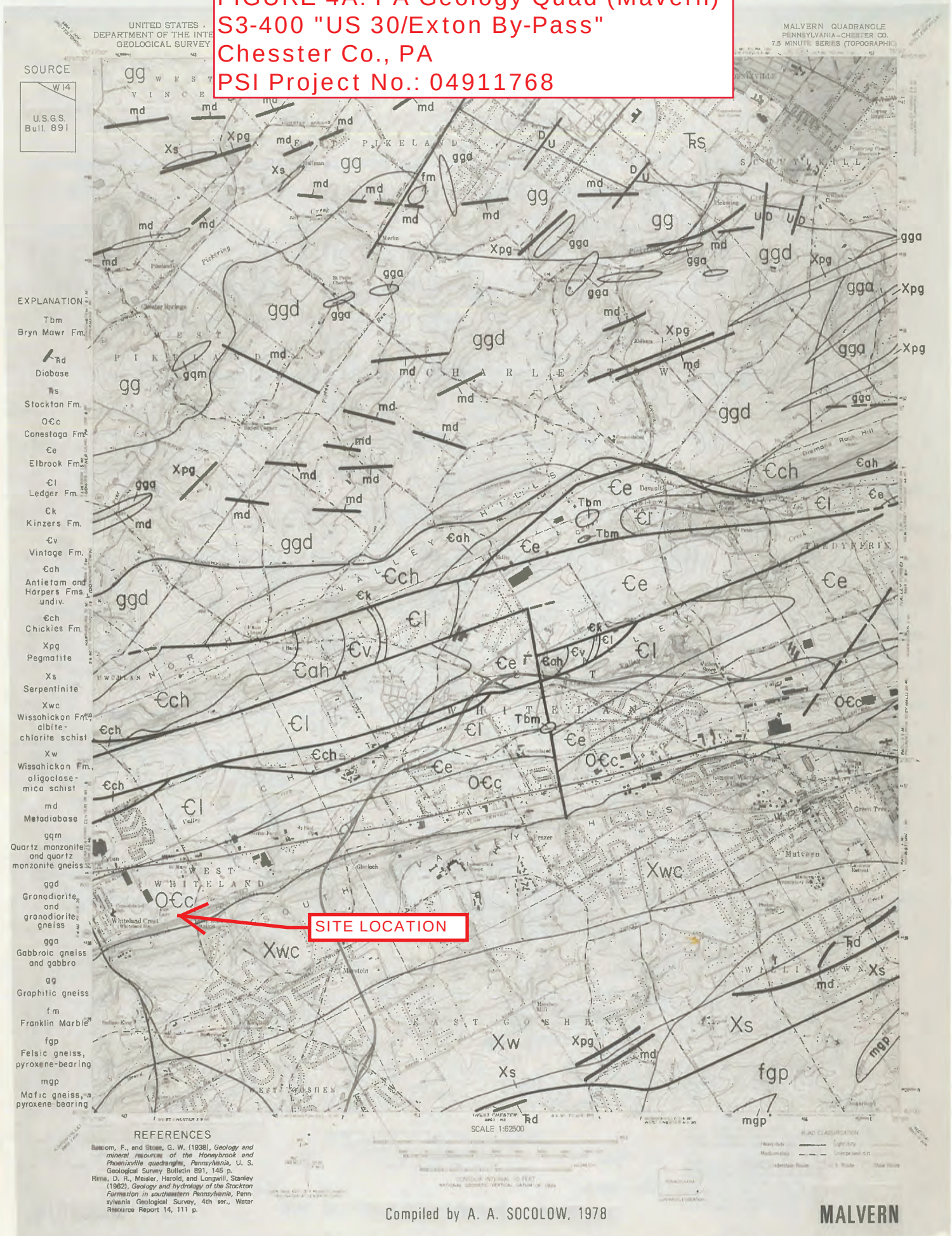


FIGURE 2: BORING LOCATION PLAN

SITE NAME: S3-400 "US 30/Exton By-Pass"
Chesster Co., PA
PSI Project No.: 04911768

BORING G400-A

DATE STARTED:	4/24/19	**DRILL COMPANY:**	Allied Well Drilling, Inc.
DATE COMPLETED:	4/25/19	**DRILLER:** R. Miller	**LOGGED BY:** F. Hoffman
COMPLETION DEPTH	60.0 ft	**DRILL RIG:**	Acker XLS Track Mounted
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	378.3 ft	**SAMPLING METHOD:**	2-in SS2-in Core
LATITUDE:	40.023141°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-75.613802°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	P. McMichael

REMARKS: Elevation, latitude and longitude provided by DPS.

Water

Pre-Core	Not Enc.
Upon Completion	7 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture ✕ / PL ◪ / LL ✚ (0, 25, 50) / STRENGTH, tsf Qu ▲ Qp ✳ (0, 2.0, 4.0)	Additional Remarks
	0					Vacuum- and hand-cleared to 5 feet.					
375	5			S-1	24	**RESIDUUM**-Medium Dense, Red-brown to dark gray-brown, Silty GRAVEL with Sand, moist	GM	10-10-8-6 N=18			
370	10			S-2	21	**RESIDUUM**-Medium Dense, Dark gray-brown, Silty SAND, trace Gravel, moist	SM	7-6-8-10 N=14			
365	15			S-3	18	**RESIDUUM**-Medium Dense, Red-brown to dark gray-brown, Silty Clayey SAND with Gravel, moist	SC-SM	8-7-8-10 N=15			
360	20			S-4	14	**Highly/Completely Weathered SCHIST Sampled As Soil**-Very Dense, Dark gray to dark gray-brown to dark red-brown, Silty SAND, trace Gravel, moist	SM	11-21-31-50/5" N=52		>>	
355	25			S-5	15			13-19-42-44 N=61		>>	

Continued Next Page

intertek psi
Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.:	04911768
PROJECT:	Energy Transfer HDD (DPS)
LOCATION:	Hwy 30 Bypass
	Chester Co., PA

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING G400-A

DATE STARTED:	4/24/19	**DRILL COMPANY:**	Allied Well Drilling, Inc.
DATE COMPLETED:	4/25/19	**DRILLER:** R. Miller	**LOGGED BY:** F. Hoffman
COMPLETION DEPTH	60.0 ft	**DRILL RIG:**	Acker XLS Track Mounted
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	378.3 ft	**SAMPLING METHOD:**	2-in SS2-in Core
LATITUDE:	40.023141°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-75.613802°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	P. McMichael

REMARKS: Elevation, latitude and longitude provided by DPS.

Water

Pre-Core	Not Enc.
Upon Completion	7 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture ✕ / PL ◪ / LL ✚ (0, 25, 50) / STRENGTH, tsf Qu ▲ / Qp ✳ (0, 2.0, 4.0)	Additional Remarks
	25					**Highly/Completely Weathered SCHIST Sampled As Soil**-Very Dense, Dark gray to dark gray-brown to dark red-brown, Silty SAND, trace Gravel, moist	SM				
350				S-6	14	With Gravel from 28 to 29.4 feet.		39-34-50/5"		>>◎	
				R-1	0	Initiated rock coring operations @ 29.5 feet.		RQD=0		>>◎	
	30					**NO SAMPLE RECOVERY**- Likely predominantly soil which washed away during rock coring activities		Rec=0%		>>◎	1 min.
										>>◎	2 min.
				R-2	0			RQD=0		>>◎	2 min.
345								Rec=0%		>>◎	
										>>◎	2 min.
										>>◎	1 min.
	35					**Highly Weathered to Completely Weathered Graphitic SCHIST**-Dark gray to dark gray-brown, very broken to broken, soft to moderately hard, with soil which washed away during rock coring activities				>>◎	1 min.
										>>◎	2 min.
				R-3	14			RQD=0		>>◎	1 min.
340								Rec=23%		>>◎	
										>>◎	2 min.
										>>◎	3 min.
	40									>>◎	2 min.
										>>◎	3 min.
										>>◎	3 min.
				R-4	15			RQD=0		>>◎	
335								Rec=24%		>>◎	1 min.
										>>◎	3 min.
	45					Core Run R-5: Gravel-sized Quartzite fragments also recovered.				>>◎	2 min.
										>>◎	2 min.
										>>◎	4 min.
				R-5	11			RQD=0		>>◎	
330								Rec=18%		>>◎	4 min.
										>>◎	2 min.
	50										

Continued Next Page

intertek psi
Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.: 04911768
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Hwy 30 Bypass
Chester Co., PA

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING G400-A

DATE STARTED:	4/24/19	**DRILL COMPANY:**	Allied Well Drilling, Inc.
DATE COMPLETED:	4/25/19	**DRILLER:** R. Miller	**LOGGED BY:** F. Hoffman
COMPLETION DEPTH	60.0 ft	**DRILL RIG:**	Acker XLS Track Mounted
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	378.3 ft	**SAMPLING METHOD:**	2-in SS2-in Core
LATITUDE:	40.023141°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-75.613802°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	P. McMichael

REMARKS: Elevation, latitude and longitude provided by DPS.

Water
- Pre-Core — Not Enc.
- Upon Completion — 7 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture × / PL ◪ / LL ✚ (0, 25, 50) / STRENGTH, tsf ▲ Qu ✳ Qp (0, 2.0, 4.0)	Additional Remarks
	50										
325				R-6	8	**Highly Weathered to Completely Weathered Graphitic SCHIST**-Dark gray to dark gray-brown, very broken to broken, soft to moderately hard, with soil which washed away during rock coring activities Core Run R-6: Gravel-sized Quartzite fragments also recovered.		RQD=0 Rec=13%		>>◎ 2 min. >>◎ 3 min. >>◎ 2 min. >>◎ >>◎ 3 min. >>◎ 3 min.	
	55					**Weathered to Completely Weathered Graphitic SCHIST**-Dark gray, very broken to slightly broken, moderately hard, diagonal to vertical fractures, with soil which washed away during rock coring activities				>>◎ 2 min.	
320				R-7	26	Core Run R-7: Gravel-sized Quartzite fragments also recovered.		RQD=0 Rec=43%		>>◎ 1 min. >>◎ 2 min. >>◎ >>◎ 3 min. >>◎ 3 min. >>◎ 2 min.	
	60					Test boring terminated @ 60 feet					

intertek psi

Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.: 04911768
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Hwy 30 Bypass
Chester Co., PA

The stratification lines represent approximate boundaries. The transition may be gradual.


0491768
Hwy 30 Bypass (PPP6)
4/24-4/25/19
G400A(29.5-60')
DPS 2019
Box 1
Run # | Depths | Length | Rec | RQD
1 | 29.5-30' | 0.5' | 0" | 0"
2 | 30-35' | 5.0' | 0" | 0"
3 | 35-40' | 5.0' | 14" | 0"
4 | 40-45' | 5.0' | 14.5" | 0"
5 | 45-50' | 5.0' | 10.5" | 0"
6 | 50-55' | 5.0' | 7.5" | 0"
7 | 55-60' | 5.0' | 25.5" | 0"
29.5'
30'
35'
46'
45'
50'
55'
60'
END

BORING G400-B

DATE STARTED:	4/19/19	**DRILL COMPANY:**	Allied Well Drilling, Inc.
DATE COMPLETED:	4/22/19	**DRILLER:**	R. Miller **LOGGED BY:** D. Kaufman/F. Hoffman
COMPLETION DEPTH	60.0 ft	**DRILL RIG:**	Acker XLS Track Mounted
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	379.4 ft	**SAMPLING METHOD:**	2-in SS2-in Core
LATITUDE:	40.022982°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-75.613706°	**EFFICIENCY**	N/A
STATION:	N/A **OFFSET:** N/A	**REVIEWED BY:**	P. McMichael

REMARKS: Elevation, latitude and longitude provided by DPS.

Water Pre-Core Not Enc.

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture / PL / LL (0, 25, 50) / STRENGTH, tsf Qu ▲ Qp ✳ (0, 2.0, 4.0)	Additional Remarks
	0					Hand-cleared to 2 feet where hand tool refusal was encountered.					
375	5			S-1	24	**RESIDUUM**-Dense, Red-brown to light gray-brown, Silty SAND with Gravel, moist	SM	18-20-23-16 N=43			
				S-2	24			20-16-18-18 N=34			
				S-3	24	**RESIDUUM**-Dense, Gray-brown, Silty GRAVEL with Sand, moist	GM	33-30-17-8 N=47			
370	10			S-4	24	**RESIDUUM**-Dense, Gray-brown, Silty SAND with Gravel, moist	SM	12-16-26-29 N=42			
365	15			S-5	16	**Highly/Completely Weathered SCHIST Sampled As Soil**-Very Dense, Light gray-brown to dark gray-brown, Silty SAND with Gravel, moist	SM	20-33-36-30 N=69		>>◎	
360	20			S-6	24			18-24-37-40 N=61		>>◎	
355	25			R-1	10	**Completely Weathered SCHIST**-Gray to brown, very broken to broken, soft to moderately soft, with soil which washed away during rock coring activities		RQD=0 Rec=17%		>>◎	

Continued Next Page

intertek psi
Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.: 04911768
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Hwy 30 Bypass
Chester Co., PA

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING G400-B

DATE STARTED:	4/19/19	**DRILL COMPANY:**	Allied Well Drilling, Inc.
DATE COMPLETED:	4/22/19	**DRILLER:**	R. Miller **LOGGED BY:** D. Kaufman/F. Hoffman
COMPLETION DEPTH	60.0 ft	**DRILL RIG:**	Acker XLS Track Mounted
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	379.4 ft	**SAMPLING METHOD:**	2-in SS2-in Core
LATITUDE:	40.022982°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-75.613706°	**EFFICIENCY**	N/A
STATION:	N/A **OFFSET:** N/A	**REVIEWED BY:**	P. McMichael

REMARKS: Elevation, latitude and longitude provided by DPS.

Water Pre-Core Not Enc.

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0, 25, 50) STRENGTH, tsf ▲ Qu ✳ Qp (0, 2.0, 4.0)	Additional Remarks
	25					**Completely Weathered SCHIST**-Gray to brown, very broken to broken, soft to moderately soft, with soil which washed away during rock coring activities					
				R-2	4			RQD=0 Rec=7%		>>◎	
350	30					**Highly Weathered to Completely Weathered SCHIST**-Dark gray to gray-brown, very broken to slightly broken, soft to moderately hard, with soil which washed away during rock coring activities					
				R-3	35			RQD=0 Rec=58%		>>◎	
345	35										
				R-4	21			RQD=7 Rec=35%		>>◎	
340	40					**Weathered to Completely Weathered SCHIST**-Gray-brown to dark gray-brown, very broken to massive, moderately soft to moderately hard, horizontal to vertcial fractures, with soil which washed away during rock coring activities					
				R-5	39			RQD=23 Rec=65%		>>◎	
335	45										
				R-6	43			RQD=0 Rec=72%		>>◎	
330	50										

Continued Next Page

intertek psi
Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.: 04911768
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Hwy 30 Bypass
Chester Co., PA

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING G400-B

DATE STARTED:	4/19/19	**DRILL COMPANY:**	Allied Well Drilling, Inc.
DATE COMPLETED:	4/22/19	**DRILLER:** R. Miller	**LOGGED BY:** D. Kaufman/F. Hoffman
COMPLETION DEPTH	60.0 ft	**DRILL RIG:**	Acker XLS Track Mounted
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	379.4 ft	**SAMPLING METHOD:**	2-in SS2-in Core
LATITUDE:	40.022982°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-75.613706°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	P. McMichael

REMARKS: Elevation, latitude and longitude provided by DPS.

Water: Pre-Core — Not Enc.

BORING LOCATION: See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / STRENGTH, tsf	Additional Remarks
	50					**Highly Weathered to Completely Weathered SCHIST**-Gray to dark gray-brown, very broken to slightly broken, moderately soft, diagonal to vertical fractures, with soil which washed away during rock coring activities					
				R-7	29			RQD=0 Rec=48%		>>◎	
325	55					**Weathered to Completely Weathered SCHIST**-Light gray to gray-brown, very broken to massive, moderately soft to moderately hard, horizontal to vertical fractures, with soil which washed away during rock coring activities					
				R-8	32			RQD=38 Rec=53%		>>◎	
320	60					Test boring terminated @ 60 feet					

Moisture: × Moisture; ◪ PL; ✚ LL; 0 — 25 — 50

STRENGTH, tsf: ▲ Qu; ✳ Qp; 0 — 2.0 — 4.0

intertek psi

Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.: 04911768
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Hwy 30 Bypass
Chester Co., PA

The stratification lines represent approximate boundaries. The transition may be gradual.

PSI 04911768
U.S. 30 Bypass. Chester Co
4-19-19
S3-400 (2.0-
DPS2019

Box 1

Run	Depth	Length	Rec	RQD
1	21.0 - 25.0	48"	10"	0"
2	25.0 - 30.0	60"	4"	0"
3	30.0 - 35.0	60"	35"	0
4	35.0 - 40.0	60"	21"	4"
5	40.0 - 45.0	60"	39"	14"
6	45.0 - 50.0	60"	43"	0


PSI 0491768
U.S 30 bi Pass Chester Co.
4-22-19
SS 400
DPS 2017
Bor2
Run | Depth | Length | Rec | RQD
7 | 50.0-55.0 | 60" | 29" | 0
8 | 55.0-60.0 | 60" | 32" | 22.5"
50'
55'
60'

BORING G400-C

DATE STARTED:	4/17/19	**DRILL COMPANY:**	Allied Well Drilling, Inc.
DATE COMPLETED:	4/18/19	**DRILLER:** R. Miller	**LOGGED BY:** F. Hoffman
COMPLETION DEPTH	60.0 ft	**DRILL RIG:**	Acker XLS Track Mounted
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	376.6 ft	**SAMPLING METHOD:**	2-in SS2-in Core
LATITUDE:	40.022823°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-75.613622°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	P. McMichael

REMARKS: Elevation, latitude and longitude provided by DPS.

Water

Pre-Core	Not Enc.
Upon Completion	5.5 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture ✕ / PL ◪ / LL ✚ (0, 25, 50) / STRENGTH, tsf Qu ▲ / Qp ✳ (0, 2.0, 4.0)	Additional Remarks
	0					Hand-cleared to 1.5 feet where hand tool refusal was encountered.					
375				S-1	22	**RESIDUUM**-Medium Dense to Dense, Dark gray to dark gray-brown to red-brown, Silty GRAVEL with Sand, moist	GM	14-13-13-10 N=26			
	5			S-2	24			8-9-22-19 N=31			
370				S-3	16	**Highly/Completely Weathered SCHIST Sampled As**-Very Dense, Light red-brown to dark gray-brown, Silty GRAVEL with Sand, moist	GM	19-30-45-50/3" N=75		>>◎	
				S-4	17	**Highly/Completely Weathered SCHIST Sampled As Soil**-Very Dense, Gray-brown, Silty SAND with Gravel, moist	SM	36-35-50/5"		>>◎	
	10			S-5	12	**Highly/Completely Weathered SCHIST Sampled As**-Very Dense, Brown to dark gray-brown, Silty GRAVEL with Sand, moist	GM	26-36-50/5"		>>◎	
365				S-6	13	**Highly/Completely Weathered SCHIST Sampled As**-Very Dense, Dark gray-brown, Silty SAND with Gravel, moist	SM	25-35-49-50/5" N=84		>>◎	
	15					Rollerbit refusal @ 16 feet.					
360				R-1	28	**Weathered to Completely Weathered SCHIST**-Brown to dark gray, very broken to massive, soft to moderately soft, horizontal to vertical fractures, with soil which washed away during rock coring activities		RQD=0 Rec=76%		>>◎ 1 min. >>◎ >>◎ 1 min. >>◎ 1 min.	
	20									>>◎ 2 min.	
355				R-2	46			RQD=9 Rec=77%		>>◎ 1 min. >>◎ >>◎ 1 min. >>◎ 1 min. >>◎ 1 min.	
	25					*Continued Next Page*					

Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.:	04911768
PROJECT:	Energy Transfer HDD (DPS)
LOCATION:	Hwy 30 Bypass
	Chester Co., PA

The stratification lines represent approximate boundaries. The transition may be gradual.

DATE STARTED:	4/17/19	**DRILL COMPANY:**	Allied Well Drilling, Inc.
DATE COMPLETED:	4/18/19	**DRILLER:** R. Miller	**LOGGED BY:** F. Hoffman
COMPLETION DEPTH	60.0 ft	**DRILL RIG:**	Acker XLS Track Mounted
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	376.6 ft	**SAMPLING METHOD:**	2-in SS2-in Core
LATITUDE:	40.022823°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-75.613622°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	P. McMichael

REMARKS: Elevation, latitude and longitude provided by DPS.

BORING G400-C

Water

Pre-Core	Not Enc.
Upon Completion	5.5 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ Moisture × PL ◪ LL ✚ (0, 25, 50) STRENGTH, tsf Qu ▲ Qp ✳ (0, 2.0, 4.0)	Additional Remarks
	25					**Highly Weathered to Completely Weathered SCHIST Sampled As**-Brown to dark gray, with soil which washed away during rock coring activities				>>◎3 min.	
350				R-3	11			RQD=0 Rec=18%		>>◎2 min.	
										>>◎	
										>>◎2 min.	
										>>◎3 min.	
										>>◎1 min.	
	30					**Highly Weathered to Completely Weathered SCHIST**-Gray-brown, very broken to slightly broken, vertical fractures, with soil which washed away during rock coring activities				>>◎2 min.	
										>>◎2 min.	
345				R-4	25			RQD=0 Rec=42%		>>◎	
										>>◎2 min.	
										>>◎2 min.	
										>>◎2 min.	
	35					**Weathered to Completely Weathered SCHIST**-Dark gray to gray-brown to red-brown, very broken to massive, moderately soft to moderately hard, nearly horizontal to vertical fractures, with soil which washed away during rock coring activities				>>◎2 min.	
										>>◎2 min.	
340				R-5	31			RQD=0 Rec=52%		>>◎	
										>>◎4 min.	
										>>◎2 min.	
										>>◎2 min.	
	40									>>◎1 min.	
										>>◎2 min.	
335				R-6	30			RQD=8 Rec=50%		>>◎	
										>>◎3 min.	
										>>◎2 min.	
										>>◎3 min.	
	45									>>◎2 min.	
										>>◎2 min.	
330				R-7	34			RQD=0 Rec=57%		>>◎	
										>>◎1 min.	
										>>◎2 min.	
										>>◎2 min.	
	50										

Continued Next Page

intertek psi
Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.:	04911768
PROJECT:	Energy Transfer HDD (DPS)
LOCATION:	Hwy 30 Bypass
	Chester Co., PA

The stratification lines represent approximate boundaries. The transition may be gradual.

BORING G400-C

DATE STARTED:	4/17/19	**DRILL COMPANY:**	Allied Well Drilling, Inc.
DATE COMPLETED:	4/18/19	**DRILLER:** R. Miller	**LOGGED BY:** F. Hoffman
COMPLETION DEPTH	60.0 ft	**DRILL RIG:**	Acker XLS Track Mounted
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	376.6 ft	**SAMPLING METHOD:**	2-in SS2-in Core
LATITUDE:	40.022823°	**HAMMER TYPE:**	Automatic
LONGITUDE:	-75.613622°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	P. McMichael

REMARKS: Elevation, latitude and longitude provided by DPS.

Water
- Pre-Core — Not Enc.
- Upon Completion — 5.5 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ / Moisture × / PL ◪ / LL ✚ (0, 25, 50) / STRENGTH, tsf ▲ Qu ✳ Qp (0, 2.0, 4.0)	Additional Remarks
	50					**Weathered to Completely Weathered SCHIST**-Dark gray to gray-brown to red-brown, very broken to massive, moderately soft to moderately hard, nearly horizontal to vertical fractures, with soil which washed away during rock coring activities				>>◎	2 min.
325				R-8	42			RQD=20 Rec=70%		>>◎	3 min.
										>>◎	
										>>◎	2 min.
										>>◎	2 min.
	55					**Highly Weathered to Completely Weathered SCHIST**-Dark gray to red-brown, very broken to slightly broken, moderately soft to moderately hard, nearly horizontal to nearly vertical fractures, with soil which washed away during rock coring activities				>>◎	2 min.
320				R-9	34			RQD=0 Rec=57%		>>◎	4 min.
										>>◎	
										>>◎	2 min.
										>>◎	3 min.
										>>◎	3 min.
				R-10	7			RQD=0 Rec=58%		>>◎	
	60					Test boring terminated @ 60 feet				>>◎	3 min.

intertek psi

Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.:	04911768
PROJECT:	Energy Transfer HDD (DPS)
LOCATION:	Hwy 30 Bypass
	Chester Co., PA

The stratification lines represent approximate boundaries. The transition may be gradual.


0491768
Hwy 30 Bypass (PPP4)
4/17-4/18/19
6400 C (16-44')
DPS 2019
Box 1
Run # | Depths | Length | Rec | RQD
1 | 16-19' | 3.0' | 27.5" | 0"
2 | 19-24' | 5.0' | 46" | 5.5"
3 | 24-29' | 5.0' | 11" | 0"
4 | 29-34' | 5.0' | 25" | 0"
5 | 34-39' | 5.0' | 31" | 0"
6 | 39-44' | 5.0' | 30" | 5"
16'
19'
24'
29'
34'
39'
44'


0491168
Hwy 30 Bypass (PPP6)
4/18/19
G400 ∠(44-60°)
DPS 2019
Box 2
Run # | Depths | Length | Rec | RQD
7 | 44-49' | 5.0' | 34" | 0"
8 | 49-54' | 5.0' | 42" | 12"
9 | 54-59' | 5.0' | 34" | 0"
10 | 59-60' | 1.0' | 7" | 0"
44'
49'
54'
59'
60'
END

MONITORING WELL LOG — MW-1D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	175'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	5/2 - 3/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	Geoprobe GVS Sonic	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Recovery	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
0			10'	ML: (0-10) Red-gray gravelly silt	ML	Dry	Flush-mounted well vault, locking cap
5							Concrete (0 - 1')
10				ML: (10-15) Brown gravelly silt, stiff			Bentonite Pellets (160' - 163')
15			5'	SAPROLITE: (15-20) Tannish brown saprolite, stiff	SAPROLITE		Grout (1' - 160')
20				SAPROLITE: (20-30) Tan-gray-brown saprolite, mottled, soft		Moist	No. 2 Sand (163' - 175')
25			5'				3-inch diameter PVC riser (0 - 165')
30				SAPROLITE: (30-40) Tan-gray-brown saprolite, graphitic, soft		Moist	3-inch diameter PVC screen (165' - 175')
35			5'				
40				SAPROLITE: (40-50) Tan-gray saprolite, foliated, stiff		Moist	
45			10'				
50							

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567332.871

257542.959

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG — MW-1D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	175'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	5/2 - 3/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	Geoprobe GVS Sonic	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
55			2'	SAPROLITE: (50-60) Gray-orangish brown saprolite, foliated, stiff	SAPROLITE	Moist	
60				SAPROLITE: (60-75) Gray-orangish brown saprolite, foliated, stiff		Moist	
65			4'				
70						Moist	
75			5'	SAPROLITE: (75-80) Gray-light gray-brown saprolite, foliated, very stiff		Dry	
80				SAPROLITE: (80-90) Gray-brown-orangish brown saprolite with gravel, mottled, soft		Moist	
85			10'				
90				SAPROLITE: (90-100) Tan-orangish brown saprolite, mottled, very soft			
95			8'			Moist	
100							

General Comments:
bgs - below ground surface
NA - not applicable
NM - not measured; Wh - Weight of hammer

Coordinates
2567332.871
257542.959

Symbol Key:
Apparent Water Level
Soil Sample Location

MONITORING WELL LOG MW-1D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	175'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	5/2 - 3/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	Geoprobe GVS Sonic	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
105			5'	SAPROLITE: (100-110) Tan saprolite, friable	SAPROLITE	Dry	
110			5'	SAPROLITE: (110-120) Grayish-tan saprolite, graphitic		Moist	
115							
120			5'	SAPROLITE: (120-139) Tan-gray saprolite, friable		Dry	
125							
130			5'			Dry	
135							
140			10'	SAPROLITE: (139-140) Brown-reddish brown saprolite, graphitic SAPROLITE: (140-148) Brown-reddish brown saprolite, graphitic, increasing stiffness with depth to 148'		Dry	
145							
150				SAPROLITE: (148-150) Yellowish-tan saprolite, very stiff		Dry	

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567332.871

257542.959

Symbol Key:

Apparent Water Level

Soil Sample Location

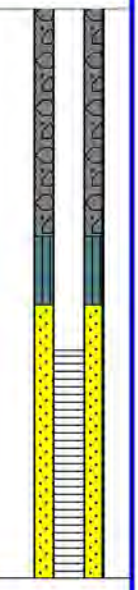
MONITORING WELL LOG MW-1D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	175'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	5/2 - 3/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	Geoprobe GVS Sonic	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
155			5'	SAPROLITE: (150-160) Light brown saprolite, graphitic, soft	SAPROLITE	Moist	
160				SAPROLITE: (160-170) Light brown saprolite, graphitic, soft, increasing stiffness to 170'		Moist	
165			5'				
170				SAPROLITE: (170-173) Yellowish brown saprolite, graphitic, very stiff		Dry	
175			5'	SAPROLITE: (173-175) Light brown saprolite, graphitic, medium stiff		Moist	



General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567332.871

257542.959

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG MW-2D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	180'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	4/17 - 29/2019	Sampling Method:	
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	BL Sonic Rig LS250	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
0				ML: (0-5) Brown clayey silt, some gravel	ML	Dry	
5			7'	ML: (5-9.5) Red brown clayey silt with gravel		Dry	
10				SAPROLITE: (9.5-15) Gray-tan saprolite, foliated, stiff	SAPROLITE	Dry	
15			6'	SAPROLITE: (15-20) Gray-tan saprolite, friable		Dry	
20				SAPROLITE: (20-25) Orangish-tan saprolite, mottled, stiff		Moist	
25			9'	SAPROLITE: (25-29) Gray-tan saprolite, mottled, stiff to friable at 28'			
				SAPROLITE: (29-30) Orangish-brown saprolite, stiff			
30				SAPROLITE: (30-35) Brown saprolite, foliated, soft		Moist to Wet	
35			10'	SAPROLITE: (35-39) Brown-gray saprolite, foliated, medium stiff			
				SAPROLITE: (39-40) Tan-gray saprolite, stiff			
40				SAPROLITE: (40-45) Gray-brown saprolite, foliated		Wet	
45			10'	SAPROLITE: (45-49) Tan-brown saprolite with gravel		Moist to Dry	
50				SAPROLITE: (49-50) Gray saprolite, very stiff			

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567228.284

257673.984

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG — MW-2D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	180'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	4/17 - 29/2019	Sampling Method:	
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	BL Sonic Rig LS250	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
55			10'	SAPROLITE: (50-52) Orangish brown-gray saprolite, mottled, stiff	SAPROLITE	Moist	
				SAPROLITE: (52-53) Orangish brown-gray saprolite, mottled, some gravel, stiff			
				SAPROLITE: (53-57) Orangish brown-gray saprolite, mottled, stiff		Dry	
60				SAPROLITE: (57-60) Orangish brown-gray saprolite, mottled, very stiff		Dry	
				SAPROLITE: (60-63) Brownish-tan saprolite, stiff			
65			10'	SAPROLITE: (63-70) Brownish-tan saprolite, friable			
70				SAPROLITE: (70-80) Tan-light gray-brown saprolite, mottled, stiff to very stiff		Dry	
75			10'				
80				SAPROLITE: (80-90) Gray-brown-dark brown saprolite, foliated, medium stiff to stiff		Moist	
85			10'				
90				SAPROLITE: (90-92) Brown saprolite, friable		Dry	
				(92-95) Void	VOID		
95			10'	SAPROLITE: (95-97) Gray-tan saprolite, foliated, stiff	SAPROLITE	Dry	
				SAPROLITE: (97-100) Brown-tan saprolite with gravel, foliated			
100							

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567228.284

257673.984

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG — MW-2D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	180'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	4/17 - 29/2019	Sampling Method:	
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	BL Sonic Rig LS250	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
105			10'	SAPROLITE: (100-109) Dark gray saprolite, foliated, medium stiff	SAPROLITE	Moist	
110				SAPROLITE: (109-110) Brown saprolite with gravel, friable		Moist to Wet	
				SAPROLITE: (110-117) Brown saprolite, soft to medium stiff		Moist	
115			10'				
120				SAPROLITE: (117-120) Gray-brown saprolite, mottled, stiff			
				SAPROLITE: (120-127) Brown saprolite, some gravel, soft		Moist	
125			7'				
130				SAPROLITE: (127-130) Gray-brown saprolite, foliated		Moist	
				SAPROLITE: (130-136) Grayish brown saprolite, soft		Wet	
135			10'				
140				SAPROLITE: (136-140) Grayish brown saprolite, mottled, stiff		Moist	
				SAPROLITE: (140-150) Dark gray-brown saprolite, foliated, stiff to very stiff		Dry	
145			10'				
150							

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567228.284

257673.984

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG MW-2D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	180'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	4/17 - 29/2019	Sampling Method:	
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	BL Sonic Rig LS250	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
155			8'	SAPROLITE: (150-160) Tan-orangish brown-gray saprolite, foliated, soft	SAPROLITE	Moist	
160				SAPROLITE: (160-166) Grayish tan saprolite, soft		Moist	
165			2'	SAPROLITE: (166-175) Tan to gray saprolite, very stiff		Dry	
170							
175				SAPROLITE: (175-180) Tannish gray saprolite, friable			
180							

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567228.284

257673.984

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG — MW-3D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	150'
	City, State	BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	5/8 - 9/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	Geoprobe GVS Sonic	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
0				ML: (0-1) Brown clayey silt with gravel, trace organics	ML	Moist	Flush-mounted well vault, locking cap
				SAPROLITE: (1-10) Orangish brown saprolite, firm	SAPROLITE	Dry	
5			6'				Concrete (0 - 1')
10				SAPROLITE: (10-12) Orangish brown-gray mottled saprolite			Grout (1' - 135')
				SAPROLITE: (12-15) Gray friable saprolite with gravel, soft		Moist	
15			6'	SAPROLITE: (15-30) Tan foliated saprolite, stiff, increasing stiffness to 30' bgs		Dry	Bentonite Pellets (135' - 138')
20						Slightly moist	
25			9'				3-inch diameter PVC riser (0 - 140')
30				SAPROLITE: (30-39) Brownish gray-orangish brown foliated saprolite, stiff to very stiff		Dry	No. 2 Sand (138' - 150')
35			8'				3-inch diameter PVC screen (140' - 150')
				SAPROLITE: (39-40) Orange-dark gray foliated saprolite, very stiff			
40				SAPROLITE: (40-50) Orangish brown-gray foliated saprolite, stiff to very stiff		Dry	
45			10'				

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567068.104

257870.348

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG — MW-3D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	150'
	City, State	BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	5/8 - 9/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	Geoprobe GVS Sonic	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
50				SAPROLITE: (50-55) Gray-tan-orangish brown foliated saprolite, stiff	SAPROLITE		
55			6'	SAPROLITE: (55-60) Gray-brown foliated saprolite, very stiff		Dry	
60				SAPROLITE: (60-80) Orangish brown-gray graphitic foliated saprolite, very stiff		Dry	
65			6'				
70						Dry	
75			10'				
80				SAPROLITE: (80-90) Dark gray saprolite transitioning to orangish-brown saprolite, foliated stiff to very stiff		Dry	
85			10'				
90				SP: (90-92) Gray coarse sand	SP	Moist	
				SAPROLITE: (92-100) Orangish brown-gray foliated saprolite	SAPROLITE	Dry	
95			10'				

General Comments:
bgs - below ground surface
NA - not applicable
NM - not measured; Wh - Weight of hammer

Coordinates
2567068.104
257870.348

Symbol Key:
Apparent Water Level
Soil Sample Location

MONITORING WELL LOG — MW-3D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	150'
	City, State	BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	5/8 - 9/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	Geoprobe GVS Sonic	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
100				SP: (100-104) Gray coarse sand	SP	Moist to wet	
105			10'	SAPROLITE: (104-109) Orangish brown-gray foliated saprolite	SAPROLITE	Dry	
				SAPROLITE: (109-110) Orangish brown foliated saprolite			
110				SAPROLITE: (110-114) Brown saprolite, very soft, wet		Wet	
115			8'	SAPROLITE: (114-117) Orangish brown-gray foliated saprolite, stiff, dry		Dry	
				SAPROLITE: (117-120) Gray-dark gray foliated saprolite, very stiff		Dry	
120				SAPROLITE: (120-130) Gray-brown-orangish brown foliated saprolite, soft		Moist	
125			10'				
130				SAPROLITE: (130-135) Brown-gray foliated saprolite		Slightly moist	
135				LIMESTONE: (135-150) Gray Limestone, some weathering at 150' bgs	LIMESTONE		
140							
145							

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567068.104

257870.348

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG MW-3D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	NM	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	NM	TOTAL DEPTH:	150'
	City, State	BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	5/8 - 9/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	Geoprobe GVS Sonic	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
150							

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567068.104

257870.348

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG — MW-4D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	415.482'	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	415.249'	TOTAL DEPTH:	136'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM'

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	4/4 - 4/17/2019	Sampling Method:	
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	BL Sonic Rig LS250	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
0			4'	ML: (0-10) Brown clayey silt, some gravel	ML	Moist	Flush-mounted well vault, locking cap
5			4'				Grout (0' - 121')
10			4'	SAPROLITE: (10-20) Tan-gray saprolite, friable	SAPROLITE	Dry	Bentonite Pellets (121' - 124')
15			4'				No. 2 Sand (124' - 136')
20			1'	SAPROLITE: (20-26) Grayish brown saprolite, soft		Wet	3-inch diameter PVC riser (0 - 126')
25			4'	SAPROLITE: (26-30) Gray-tan saprolite, foliated, stiff		Dry	3-inch diameter PVC screen (126' - 136")
30			4'	SAPROLITE: (30-40) Gray saprolite, foliated, medium stiffness		Moist	
35			4'				
40			5'	SAPROLITE: (40-45) Orangish brown-gray-dark gray saprolite, mottled, soft		Wet	
45			5'	SAPROLITE: (45-50) Brown-gray saprolite, foliated, medium stiffness		Dry	
50							

General Comments:
bgs - below ground surface
NA - not applicable
NM - not measured; Wh - Weight of hammer

Coordinates
2567112.190
257890.216

Symbol Key:
Apparent Water Level
Soil Sample Location

MONITORING WELL LOG MW-4D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	415.482'	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	415.249'	TOTAL DEPTH:	136'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM'

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	4/4 - 4/17/2019	Sampling Method:	
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	BL Sonic Rig LS250	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
55				SAPROLITE: (50-60) Brown-gray saprolite, mottled, medium stiffness	SAPROLITE	Wet	
60				SAPROLITE: (60-64) Brown-gray-dark gray saprolite, foliated, medium stiffness		Wet	
65				SAPROLITE: (64-70) Gray saprolite, stiff		Dry	
70				SAPROLITE: (70-80) Dark gray saprolite, vertical foliations, medium stiffness		Moist	
75							
80				SAPROLITE: (80-85) Dark gray saprolite, foliated, soft		Wet	
85				SAPROLITE: (85-90) Dark gray saprolite, medium stiffness		Moist	
90				SAPROLITE: (90-95) Gray-tan saprolite, foliated, increasing stiffness to stiff at 95'		Moist to Dry	
95				SAPROLITE: (95-100) Gray-tan saprolite, foliated, stiff			
100							

General Comments:
bgs - below ground surface
NA - not applicable
NM - not measured; Wh - Weight of hammer

Coordinates
2567112.190
257890.216

Symbol Key:
Apparent Water Level
Soil Sample Location

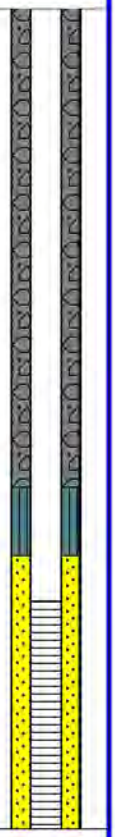
MONITORING WELL LOG — MW-4D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	415.482'	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	415.249'	TOTAL DEPTH:	136'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	NM'

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	4/4 - 4/17/2019	Sampling Method:	
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	BL Sonic Rig LS250	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
105			5'	SAPROLITE: (100-110) Brown-gray saprolite, foliated, medium stiffness	SAPROLITE	Moist	
110				SAPROLITE: (110-121) Brown-gray saprolite, stiff		Moist	
115							
120				LIMESTONE: (121-130) Gray limestone with calcite veins	LIMESTONE		
125							
130				LIMESTONE: (130-136) Gray limestone			
135							



General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567112.190

257890.216

Symbol Key:

Apparent Water Level

Soil Sample Location

MONITORING WELL LOG MW-5D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	409.426'	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	409.081'	TOTAL DEPTH:	85'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	19.75'

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	4/2-3/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	BL Sonic Rig LS250	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
0			1'	ML: (0-10) Brown gravelly silt	ML		Flush-mounted well vault, locking cap
5			1'				Grout (0' - 70.2')
10				ML: (10-12) Brown gravelly silt with clay		Wet	Bentonite Pellets (70.2' - 73')
				GM: (12-15) Light brown silty gravel	GM	Dry	
15			5'	SAPROLITE: (15-20) Orangish brown saprolite, foliated	SAPROLITE		No. 2 Sand (73' - 85.4')
20				(20-30) No Recovery			3-inch diameter PVC riser (0 - 75.25')
25							3-inch diameter PVC screen (75.25' - 85.25")
30				SAPROLITE: (30-32) Orangish brown saprolite with gravel	SAPROLITE	Wet	
			5'	SAPROLITE: (32-36) Orangish brown saprolite with gravel and quartz fragments		Dry	
35				SAPROLITE: (36-40) Gray saprolite, soft		Moist	
			5'	WEATHERED LIMESTONE: (40-41) Gray weathered limestone	WEATHERED LIMESTONE		
40						Wet	
				LIMESTONE: (41-50) Gray limestone bedrock	LIMESTONE		
45			1'				
50			1'				

General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567010.040

258000.704

Symbol Key:

Apparent Water Level

Soil Sample Location

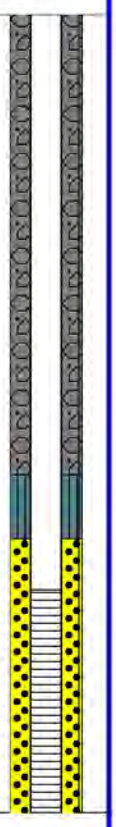
MONITORING WELL LOG MW-5D

Groundwater and Environmental Services, Inc.

PROJECT:	Lisa Drive Subsidence (8" pipeline)	SURFACE ELEVATION	409.426'	WELL DIAMETER:	3"
ADDRESS:	491 Lisa Drive, West Chester, PA	CASING ELEVATION:	409.081'	TOTAL DEPTH:	85'
		BOREHOLE DIAMETER:	6"	WATER DEPTH:	19.75'

Logged By:	Will Avery/Bryan Emilius	Drilling Method:	Sonic
Dates Drilled:	4/2-3/2019	Sampling Method:	NA
Drilling Company:	Parratt Wolff	Soil Class. System:	USCS
Drill Rig Type:	BL Sonic Rig LS250	Field Screening:	NA

Depth (feet)	Sample Number	N-Value	Rec-overy	SAMPLE LITHOLOGY (USCS)	Stratigraphy	Comments	COMPLETION DETAILS
55			4'	LIMESTONE: (50-60) Gray limestone bedrock	LIMESTONE		
60			2'	WEATHERED LIMESTONE: (60-65) Weathered limestone	WEATHERED LIMESTONE		
65			4'	LIMESTONE: (65-80) Gray limestone, foliated 45°	LIMESTONE		
70			4'				
75			2'				
80			4'	FRACTURED LIMESTONE: (80-81) Fractured limestone	FRACTURED LIMESTONE		
85				LIMESTONE: (81-85) Competent limestone	LIMESTONE		



General Comments:

bgs - below ground surface

NA - not applicable

NM - not measured; Wh - Weight of hammer

Coordinates

2567010.040

258000.704

Symbol Key:

Apparent Water Level

Soil Sample Location

Attachment C

Geophysical Survey Report

Quantum Geophysics – October 13, 2017

QUANTUMGEOPHYSICS

October 13, 2017

David Demko and Martin Helmke
GES
440 Creamery Way, Suite 500
Exton, Pennsylvania 19341

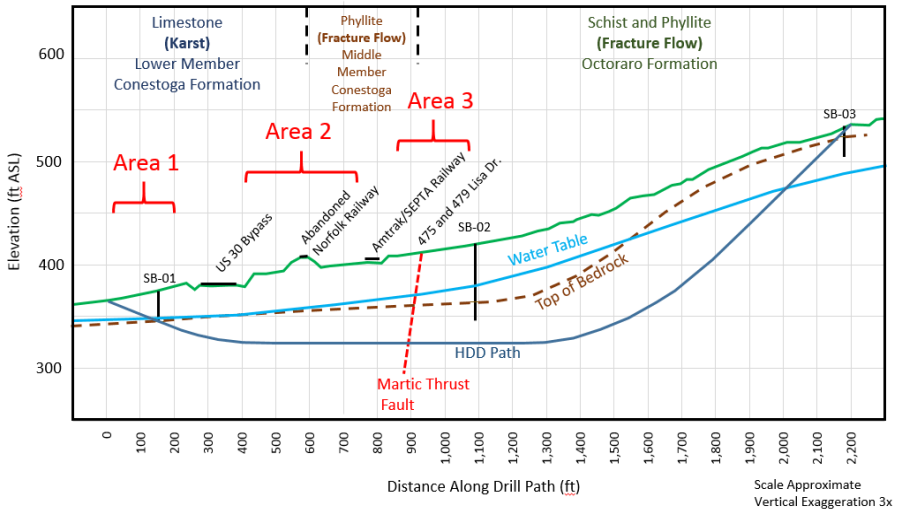
Re: Report
Geophysical Investigation
Sunoco Mariner Pipeline HDD 400
Exton, PA

Dear Messrs. Demko and Helmke:

This report presents the findings of Quantum Geophysics' geophysical investigation to identify subsurface conditions along a section of the Sunoco Mariner Pipeline known as HDD 400 in Exton, PA. The areas of investigation included:

- Area 1 - the pipeline right-of-way (ROW) from the HDD rig to the fence line 220 ft south,
- Area 2 - the pipeline ROW between the 30 By-Pass and the AMTRAK/SEPTA rail lines,
- Area 3 - the pipeline ROW from the southern edge of the AMTRAK/SEPTA rail lines 200 ft south into the residential neighborhood, and
- the abandoned Norfolk rail line (250 ft on either side of the pipeline ROW).

The areas of investigation are indicated below in a cross-section of the HDD alignment.



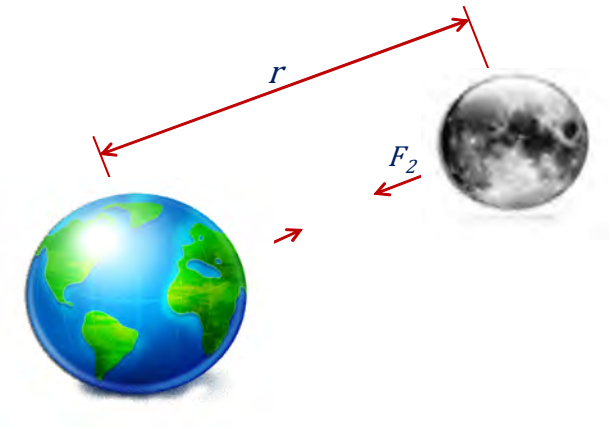
Provided by GES. "North" is down-station (towards left of profile).

The geophysical investigation included a microgravity survey and a multi-channel analysis of surface waves (MASW) survey. The surveys were carried-out September 25-28, 2017 by Quantum's staff geophysicists Matt Serzega and Chris Mayer. Provisions were made by GES and Sunoco to cut-down brush, and a basemap (PA-CH-02249.0000-RR.dwg) was provided for plotting the geophysical data and findings.

TECHNICAL APPROACH

Microgravity Survey

The microgravity method is based upon Newton's Law of Gravity which relates the mutual attractive force between 2 masses and the distance between the center of the 2 masses.
The relationship is graphically shown below:



$F_1 = F_2 = F$

$F = G(m1m2)/r^2$

where: F = gravitational force (Newtons)

m1 =1st mass (kilograms)
m2 = 2nd mass (kilograms)
r = distance between the 2 masses (meters)
G = Gravitational Constant (6.674×10^{-11} Newtons-m^2/kg^{-2})

The expression is a ratio whereby force is proportional to the masses and inversely proportional to distance. As the distance between the masses increases, the gravitational force decreases. This is what is observed when depth to top of rock increases with respect to the gravity meter. A decrease in gravitational force can also be caused by a decrease in mass in either object. This is the response associated with voids and cavities because these features represent an absence of mass. How do we tell whether decreases in gravity are due to changes in depth to rock or by voids/cavities? Decreases in gravity caused by increasing depth to rock are generally observed over a broad area because depth to rock generally occurs over a broad area. Decreases in gravity caused by voids are localized (spatially small) because they typically have small footprints. Fractures are expressed as linear low gravity anomalies. Pinnacles (shallow rock) cause localized high gravity anomalies.

The Scintrex CG-5 is a high-precision gravimeter (0.001 mGals) based on a fused quartz elastic system. The gravitational force on the proof mass is balanced by a spring and a small electrostatic restoring force. The position of the mass is altered by a change in gravity. An

automatic feedback circuit applies DC voltage to bring the mass back to a null position. The feedback voltage is a measure of the relative value of gravity at the reading site. It is converted into a digital signal for processing, display, and storage. The CG-5 automatically corrects observed readings for tidal effects once the latitude, longitude, and GMT for the site are entered into the instrument.

The CG-5 incorporates electronic tilt sensors that automatically correct for tilt in real-time.
The CG-5 measures the earth's gravitational force at a reading station by cycling through a series of 1-second samples, applying a running mean of the samples until a desired standard deviation is obtained. During the "reading period", a statistical rejection criterion is used to discard noise spikes, and corrections for tilt and long-term drift are made every 5 seconds. Tide and temperature correction are applied at the end of the reading, and then the reading is stored in solid-state memory.

Making a gravity measurement with the CG-5 on the HDD 400 alignment.

Data Acquisition and Processing

Gravity data were acquired on a 10 ft x 10 ft grid (every 10 ft). As standard operating procedure, a base station was established and occupied at the beginning, end, and every 2 hours during the field day to monitor diurnal drift. The relative elevation of each measurement station was measured using a horizontal laser and a stadia rod, and entered into a fieldbook for later use in correcting observed readings for changes in elevation. The data were downloaded onto a PC for storage at the end of each day.

Before gravity measurements can be evaluated with respect to subsurface conditions, corrections have to be made to the observed readings. These corrections may include:

- Tidal
- Diurnal Drift
- Elevation
- Latitude
- Terrain (valleys and mountains)
- Eotvos (moving vehicle)
- Isostatic (crustal thickness)

Prior to data acquisition, the latitude and longitude for the site, and the local GMT were entered into the CG-5 and instrument's software automatically corrected observed readings for tidal effects.

Observed readings were corrected for diurnal drift by applying a linear progression to the base station readings, as follows:

$$C_D = [(R_o-R_1)-(R_2-R_1)][(T_3-T_1)/(T_2-T_1)]$$

where:

R_o = base station gravity value at beginning of survey
R_1 = observed value at the start of the day, at time T_1 at the base station
R_2 = observed value at the end of the day (or base station re-occupation), at time T_2 at the base station
R_2 = observed value at a new station, at the T_3 (between T_1 and T_2).

The drift corrected reading for R_3 is R_3(initial) + CD.

The elevation correction is a combination of the “free-air effect” which accounts for changes in elevation (gravitational attraction decreases as the inverse square of the distance to the center of the earth, per Newton’s Law of Gravity) and the Bouguer effect which accounts for the additional mass (an assumed slab of infinite horizontal extent) between the gravity meter and the datum (typically mean sea level). The additional mass exerts a positive gravitational attraction which acts to reduce the free-air effect. The elevation correction is expressed as:

$$\Delta g_E = -(0.3086-0.0419d) \text{ mGal/meter}$$

where:

d = mean density of the slab in grams/cm^3

The elevation correction was applied using a density of 2.55 grams/cm^3 (average density for limestone).

The earth is not a perfect sphere - it is squashed at the poles (North & South) and bulges at the equator, though in the slightest sense. Therefore, there is a general increase in gravity with latitude (θ), expressed as:

$$\Delta g_L = 0.813 \sin 2\theta - 1.78\text{x}10^{-3} \sin 4\theta \text{ mGals/km}$$

The data were corrected for changes in latitude. When applied to observed readings, Δg_L is known as the latitude correction (negative with increasing latitude).

Nearby mountains exert an upward pull on the gravity meter which slightly offsets the downward pull by the earth beneath the meter. Nearby valleys also cause a reduction in gravity because the deficit of mass would be included in the Bouguer assumption of an infinite slab. Observed readings are corrected for this reduction in gravity by applying a “terrain correction”. A terrain correction was not applied to the data because the site is not located near mountains or valleys.

Eotvos was not applied to the data because the data were collected in “stationary mode”, not in a moving vehicle or aircraft.

The isostatic correction does not apply to the site - the isostatic correction accounts for the gravitational effect of low-density mountain roots below areas of high topography.

Once the appropriate corrections have been applied, the result is known as the Bouguer Gravity. Changes in the Bouguer Gravity are attributed to changes in the subsurface. The Bouguer Gravity can include small, subtle responses (Bouguer Gravity anomalies) superimposed on a much broader response (regional gradient), as shown below:

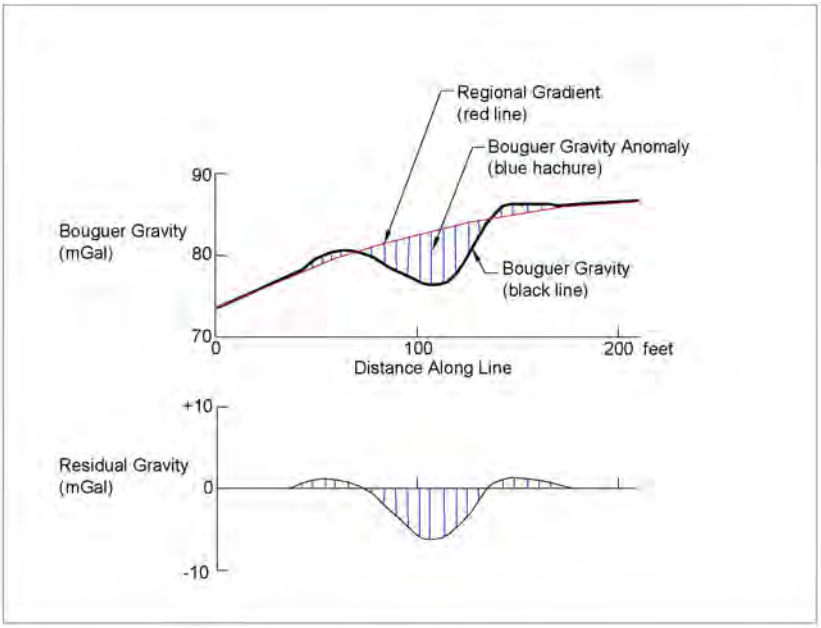


Diagram illustrating how Bouguer Gravity anomalies can be better observed by removing the regional gradient.

Bouguer Gravity anomalies are the targets of interest but they can be masked and difficult to observe in the presence of a strong regional gradient. As illustrated above, the Bouguer Gravity anomalies can be easier to observe by removing (or minimizing the effects of) the regional gradient. The Geosoft software program Oasis Montaj was used to remove the regional gradient from the Bouguer Gravity data, resulting in a Residual Gravity contour map.

Color contour maps of the Bouguer Gravity and Residual Gravity were constructed using the surface applications software program Surfer.

Multi-Channel Analysis of Surface Waves (MASW) Survey

The multi-channel analysis of surface waves method is a surface wave method that identifies subsurface conditions based upon differences in shear wave velocity (V_s). V_s is a direct measure of material stiffness much like N-values from standard penetration test (SPT) borings. Higher V_s indicate stiffer materials (e.g., rock). This makes MASW a good method for profiling top of rock (TOR). MASW can also identify relatively small features with a contrast in material stiffness such as voids, cavities, and fractures (fractured rock is less stiff than the bounding non-fractured rock).

MASW is based upon the dispersion of surface waves (Rayleigh Waves). Surface waves propagate along the free-air boundary. Their penetration depths are wavelength dependent. With seismic velocities increasing with depth, longer wavelengths (lower frequencies) penetrate deeper and travel faster than shorter wavelengths (higher frequencies) - they travel at the velocity of the subsurface materials. This is the essence of dispersion. The dispersive property of surface waves is determined by several elastic properties that include density, and the depth-variation of S- and P-wave velocities (V_s and V_p). These material properties, in turn, can be derived through dispersion curve analysis and inversion (fitting a model to the data).

MASW survey on the HDD 400 alignment.

Data Acquisition and Processing

The MASW survey was carried-out using a Geometrics Stratavisor seismograph, Pro-Seismic spread cables, and 4.5 Hz vertical geophones. Data (shot records) were acquired every 10 ft of traverse with geophones spaced 5 ft apart. Where conditions permitted (e.g., Norfolk rail line), a landstreamer (kevlar strip with geophones mounted on adjustable metal plates) was used to collect the data. Where conditions were not conducive to the use of a landstreamer, the MASW data were collected using spiked geophones.

The MASW survey included a total of four (4) lines, designated A-A' (Area 1), B-B' (Area 2), C-C'(Area 2), and D-D (Area 3)'.

Each record comprised 3 strikes with the hammer & plate (known as "shots") to increase the signal-to-noise ratio. The data were processed using the Kansas Geological Survey (KGS) software program Surfseis. Surfseis converts the shot records into KGS format, performs dispersion curve analysis, and inverts the data into a layered model. The surface applications software program Surfer was used to grid the layered model data and construct color contoured

V_s profiles at a scale of 1" = 40 ft. The profiles were constructed with a color scheme whereby cooler colors indicate lower V_s (less stiff materials) and warmer colors indicate higher V_s (stiffer materials).

Note that each shot record is inverted into a 1D V_s profile. A 2D V_s is produce by interpolating amongst the 1D V_s profiles. Each 1D V_s profile is plotted in the middle of the active receiver array. This is the reason why a MASW line and the resulting 2D V_s profile may start a half a receiver array length "in" from one end of a survey area and end roughly a half a receiver array length from the other end of the survey area.

Voids are typically observed as localized low V_s anomalies, especially air-filled voids since air has no resistance to shear forces. Fractures are generally expressed as linear low V_s anomalies because fractured rock tend to be less stiff than the bounding non-fractured rock.

FINDINGS

There is little difference between the Bouguer Gravity and the Residual Gravity with respect to subsurface features. Therefore, we elected to use the Bouguer Gravity to report the findings (Residual Gravity contour maps are provided in Appendix A). Both Bouguer and Residual Gravity contour maps are constructed with a color scheme whereby cooler colors indicate lower gravity and warmer colors indicate higher gravity.

For each area, the Bouguer Gravity contour map was superimposed onto the basemap using grid points that LW Survey located in the field with respect to the local state plane system (NAD83, Pennsylvania State Plane South Zone). The location of the MASW lines were plotted on the Bouguer Gravity contour maps.

Area 1 (Figures 1 and 2)

The Area 1 Bouguer Gravity Contour Map is shown in Figure 1. The V_s profile for A-A' is shown in Figure 2.

There is a potential void located at Line 30 station 60 (equivalent to N258676 E2566641).[1] It is observed in the Bouguer Gravity data and it is designated #1. It is unclear how big it might be since there is no closure on the anomaly. There is a potential fracture observed on V_s profile A-A'. It is designated PF#1. The potential fracture is relatively large, possibly upwards of 10 +/- ft wide, and voids may be present (given the size of the feature). It is observed at a nominal depth of 47 +/- ft bgs. It trends upwards (towards the surface) at the beginning of the line which is approximately 20 +/- ft from potential void #1.

[1] *State plane coordinates obtained by placing CADD cursor on a feature.*

Depth to top of rock (TOR) along V_s profile A-A' is nominally 22 +/- ft bgs. The gravity data suggest that TOR is relatively deeper at the north end of Area 1, and relatively shallower at the south end near the 30 By-Pass.

Area 2 (Figures 3, 4, and 5)

The Bouguer Gravity Contour Map for Area 2 is shown in Figure 3. V_s profiles for B-B' and C-C' are shown in Figures 4 and 5, respectively. B-B' is located within the pipeline ROW; C-C' is located in the Norfolk rail line easement.

Five potential voids, designated #2 through #6, were identified in the Bouguer Gravity data. Potential voids #5 and #6 are very prominent in terms of spatial extent and response (0.250-0.300 mGal). They are located on the southern embankment of the Norfolk Rail line. A large response generally indicates a relatively large target.

Two potential fractures were identified in the Bouguer Gravity data in Area 2. They are designated PF#2 and PF#3. They trend approximately $N22^0E$.They cross MASW line B-B' but are not observed in the MASW data because TOR is close to the bottom of the V_s profile and we do not see deep enough into the rock in order to corroborate the Bouguer Gravity finding.

Two potential fractures were identified on MASW line C-C' (Figure 5). They are designated PF#4 and PF#5. Both daylight TOR where C-C' crosses the pipeline ROW. PF#5 daylights TOR where potential void #4 is observed in the Bouguer Gravity contour map (Figure 3).

A potential void, designated #7, is observed on C-C'. It is about 20-30 ft wide, and is centered at approximately station 130 at a depth of 50 +/- ft bgs. It is located approximately 100 ft east of the pipeline ROW. It is associated with a vertical conduit that extends upwards and daylights TOR. It is suggestive of a "throat" in carbonate rocks prone to sinkhole activity.

It should be noted that MASW does not account for changes in elevation - data are plotted with respect to a flat surface. This explains why TOR is "depressed" where B-B' crosses the Norfolk Rail line embankment.

Area 3 (Figures 6 and 7)

There was one potential fracture identified in Area 3. It was observed on MASW line D-D' and is designated PF#6. We plotted its' location on the Bouguer Gravity contour map in Figure 6 where it is shown to be located approximately 65 ft south of the reported Martic Thrust Fault. There is no linear low gravity anomaly suggestive of a fault at the reported location of the Martic Thrust Fault. This suggests that the Martic Thrust Fault is "too thin" to be observed in the gravity data or is not located at its' reported location.

Rock identified in the V_s profiles (A-A' through D-D') may be partly decomposed (with high blow counts) based upon nearby geotechnical borings SB-01 and SB-02. The borings are located outside of the pipeline ROW as shown in Figures 1, 3 and 6. The boring logs are included in Appendix B.

Figure 8 shows the Bouguer Gravity contour maps for all three areas and the location of all MASW lines at a scale of 1 inch = 100 ft. There are no indications of potential voids south of potential voids #5 and #6.

We appreciate this opportunity to be of service. Please call if you have any questions or if we can be of further assistance.

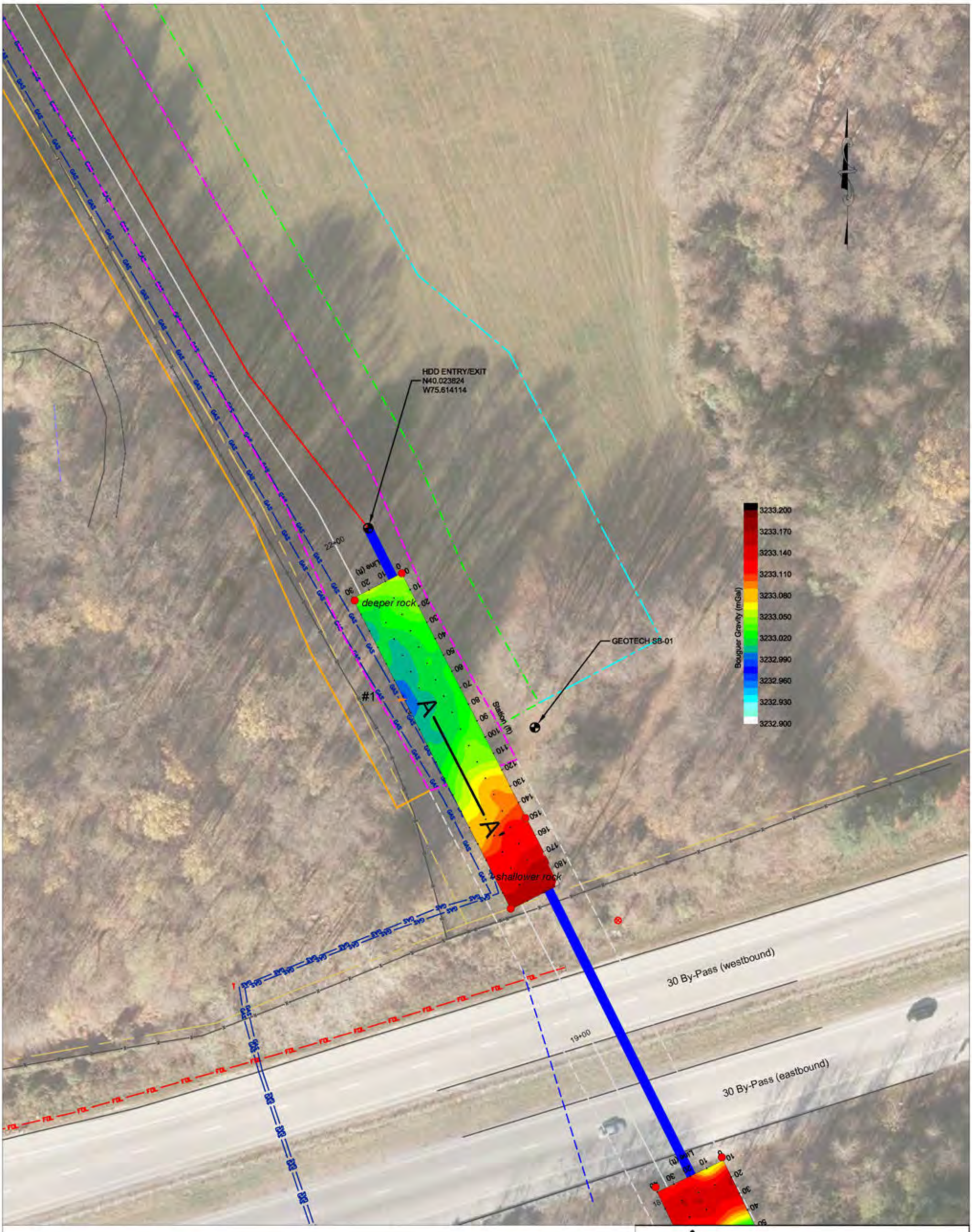
Sincerely,

Quantum Geophysics
A Division of Gannett Fleming, Inc.

Richard K. Lee

Richard K. Lee, P.G., R.GP.
President and Principal Geophysicist

RKL/jas



0 50 100

Scale (ft)

LEGEND

A——A' MASW Line.

Control Points Surveyed-in by LW Survey Company.

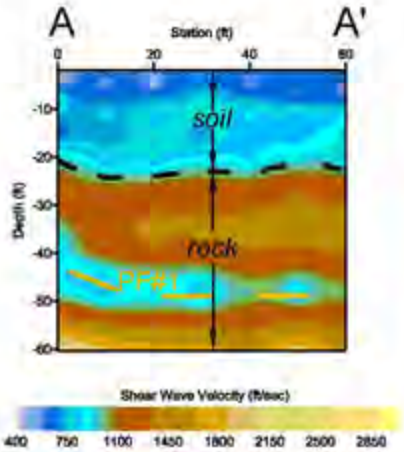
#1 Potential Void.

QUANTUMGEOPHYSICS

Engineering, Groundwater, and Environmental Geophysics
29 Richard Lee Lane, Phoenixville, PA 19460

Area 1
Bouguer Gravity Contour Map
MASW Line A-A'
Sunoco Mariner Pipeline - Drill 400
Exton, Pennsylvania

For:	GES		Figure
Date: 10-11-17	Job No.: 063252.001	By: RKL	1



LEGEND

Interpreted Top of Rock (TOR).

PF#1 Potential Fracture, Voids May Be Present.

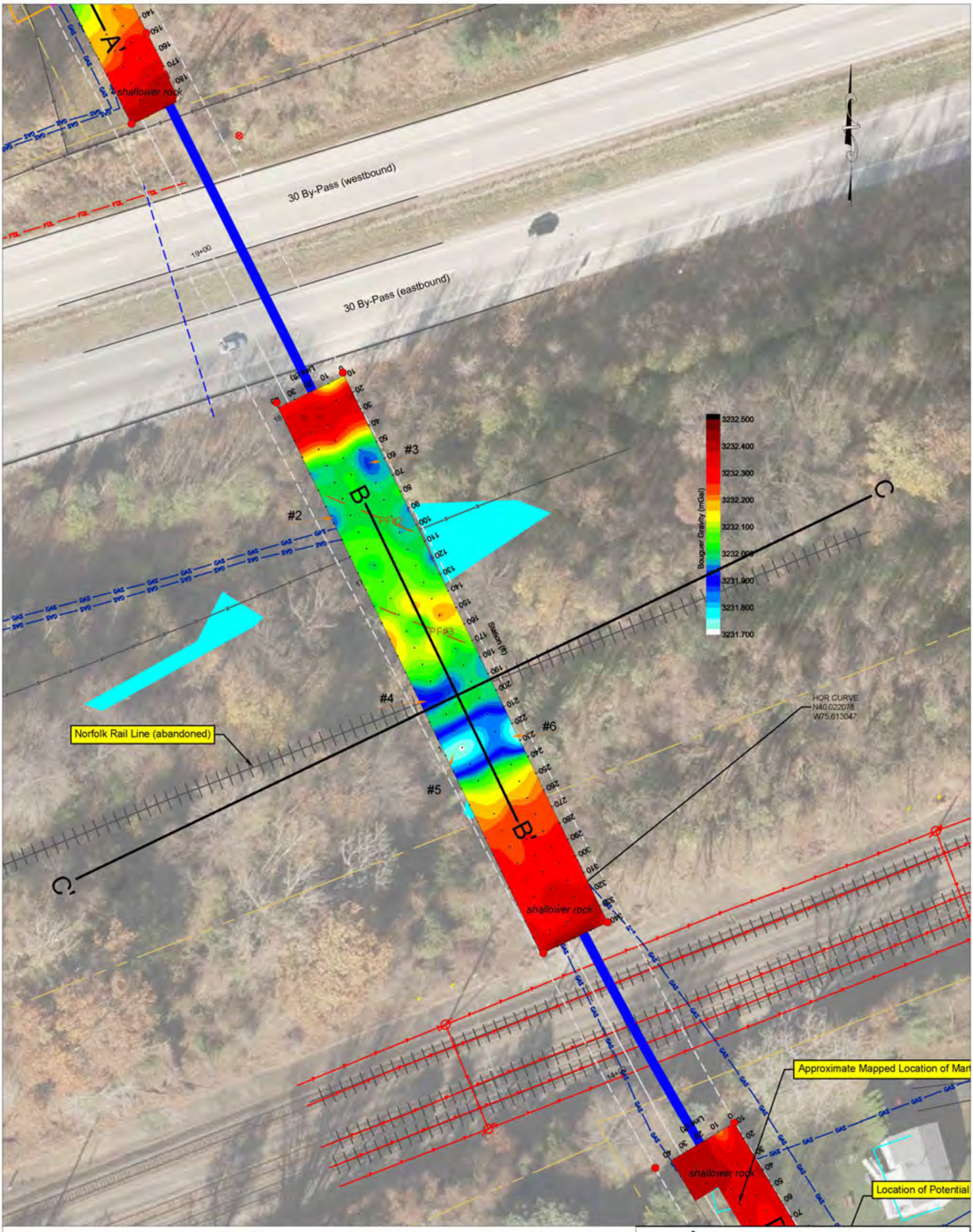
Note: Rock may be partly decomposed with high blow counts as reported in nearby geotechnical borings.

QUANTUMGEOPHYSICS

Engineering, Groundwater, and Environmental Geophysics
29 Richard Lee Lane, Phoenixville, PA 19460

V_S Profile A-A'
Sunoco Mariner Pipeline - Drill 400
Exton, Pennsylvania

For:	GES		Figure
Date: 10-11-17	Job No.: 063252.001	By: RKL	2



LEGEND

B —— B' MASW Line.

Control Points Surveyed-in by LW Survey Company.

#2 Potential Void.

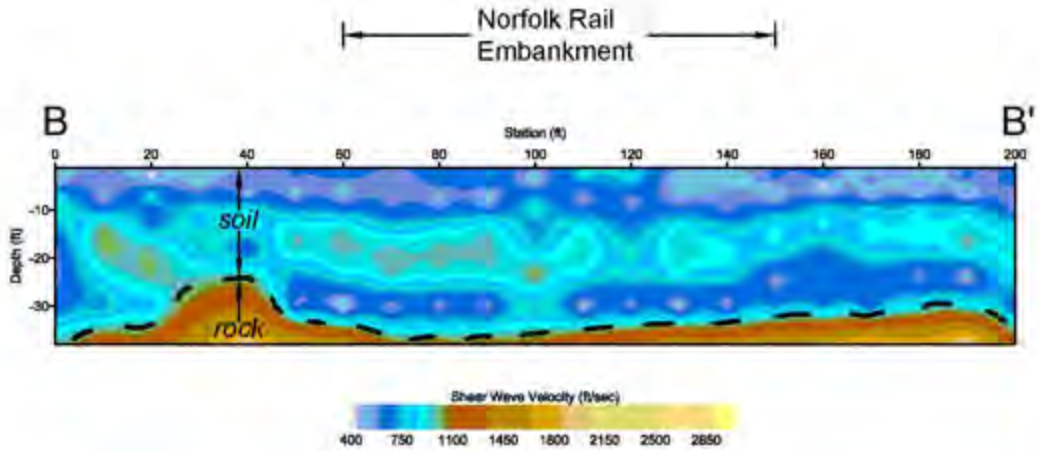
PF#1 Potential Fracture.

QUANTUMGEOPHYSICS

Engineering, Groundwater, and Environmental Geophysics
29 Richard Lee Lane, Phoenixville, PA 19460

Area 2
Bouguer Gravity Contour Map
MASW Lines B-B' and C-C'
Sunoco Mariner Pipeline - Drill 400
Exton, Pennsylvania

For:	GES		Figure
Date:	Job No.:	By:	3
10-11-17	063252.001	RKL	



LEGEND

Interpreted Top of Rock (TOR).

Potential Fracture, Voids May Be Present.

Note: Top of rock (TOR) is depressed beneath Norfolk Rail Embankment because MASW does not adjusted by changes in elevation.

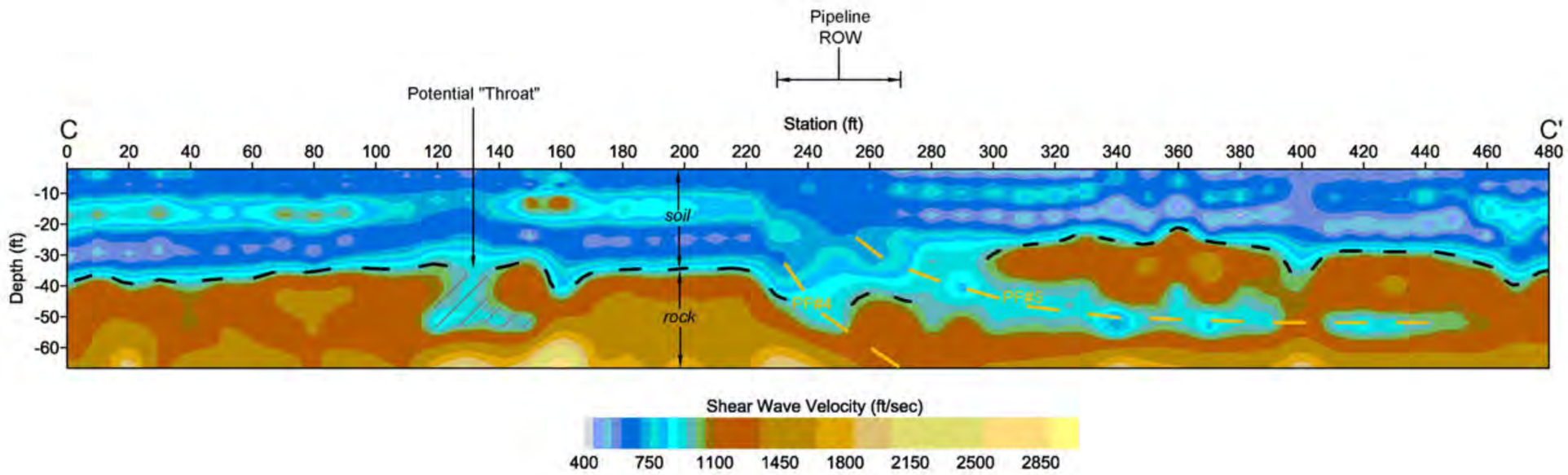
Note: Rock may be partly decomposed with high blow counts as reported in nearby geotechnical borings.

QUANTUMGEOPHYSICS

Engineering, Groundwater, and Environmental Geophysics
29 Richard Lee Lane, Phoenixville, PA 19460

V_S Profile B-B'
Sunoco Mariner Pipeline - Drill 400
Exton, Pennsylvania

For:	GES		Figure
Date: 10-11-17	Job No.: 063252.001	By: RKL	4



LEGEND

Interpreted Top of Rock (TOR).

PF#4 Potential Fracture, Voids May Be Present.

#7 Potential Void.

Note: line cut short 20 ft because of yellow jacket nest.

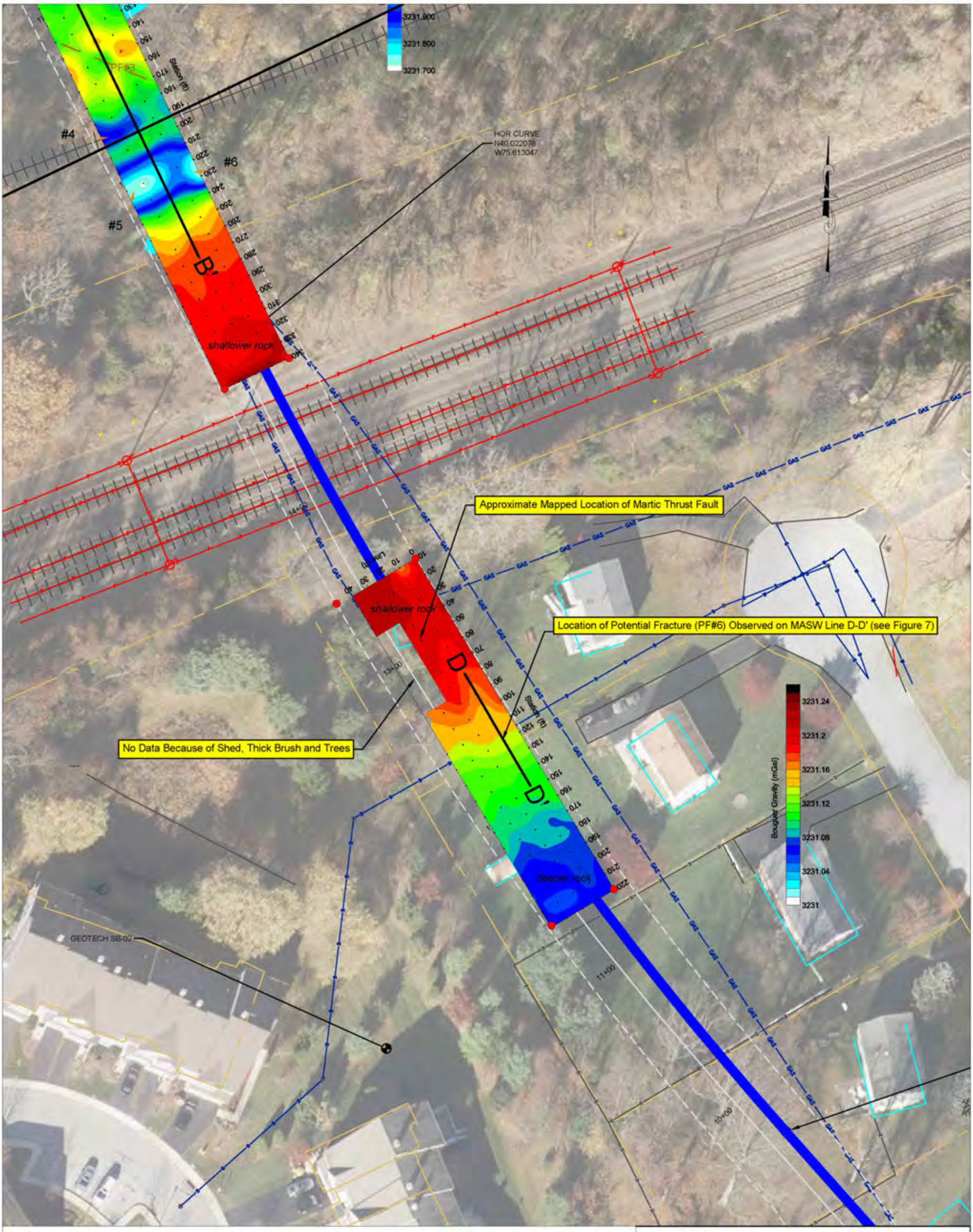
Note: Rock may be partly decomposed with high blow counts as reported in nearby geotechnical borings.

QUANTUMGEOPHYSICS

Engineering, Groundwater, and Environmental Geophysics
29 Richard Lee Lane, Phoenixville, PA 19460

V_s Profile C-C'
Sunoco Mariner Pipeline - Drill 400
Exton, Pennsylvania

For:	GES		Figure
Date: 10-11-17	Job No.: 063252.001	By: RKL	5



0 50 100

Scale (ft)

LEGEND

D——D' MASW Line.

Control Points Surveyed-in by LW Survey Company.

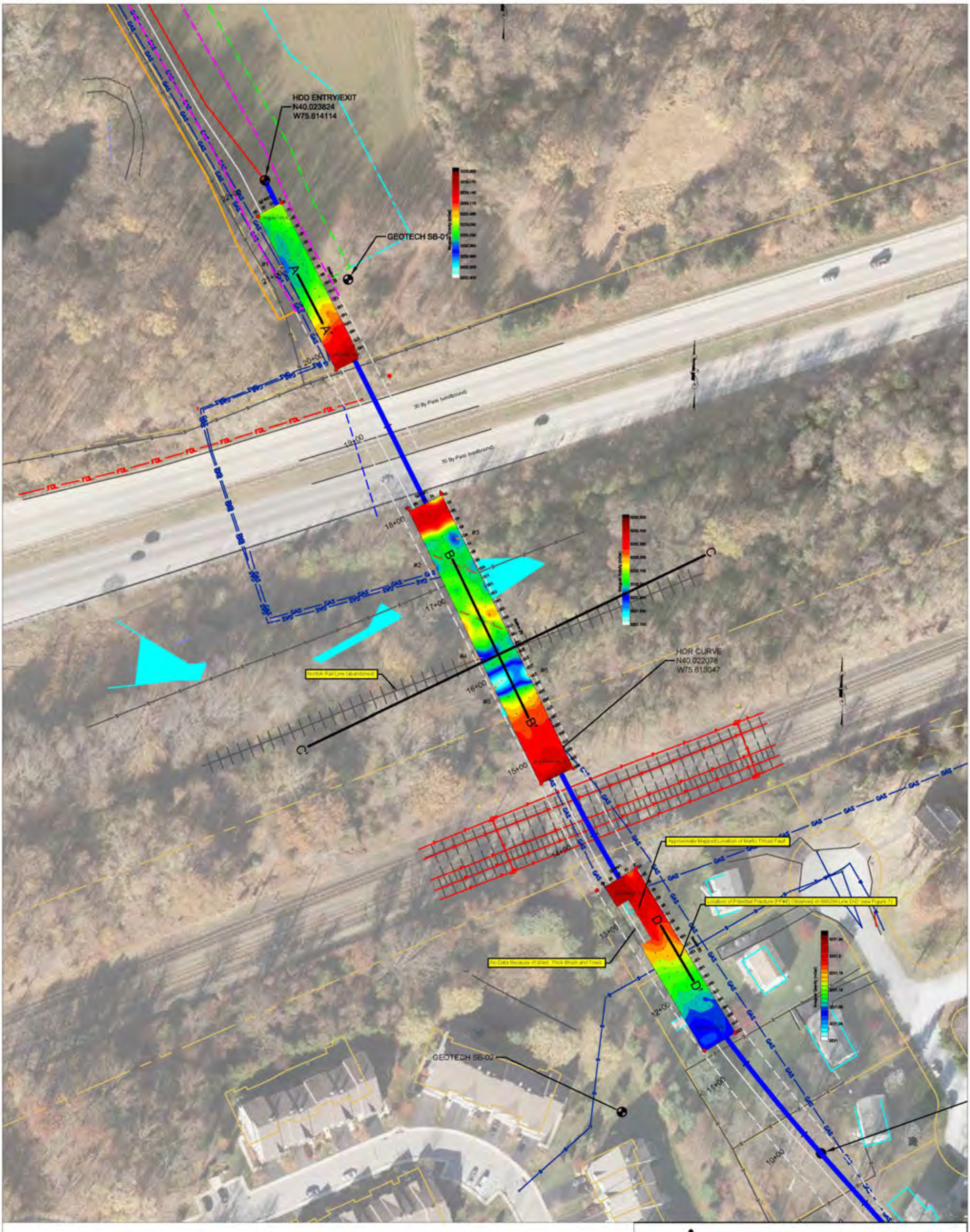
#2 Potential Void.

QUANTUMGEOPHYSICS

Engineering, Groundwater, and Environmental Geophysics
29 Richard Lee Lane, Phoenixville, PA 19460

Area 3
Bouguer Gravity Contour Map and MASW Line D-D'
Sunoco Mariner Pipeline - Drill 400
Exton, Pennsylvania

For:	GES		Figure
Date: 10-11-17	Job No.: 063252.001	By: RKL	6



0 100 200

Scale (ft)

LEGEND

D——D' MASW Line.

Control Points Surveyed-in by LW Survey Company.

#2 Potential Void.

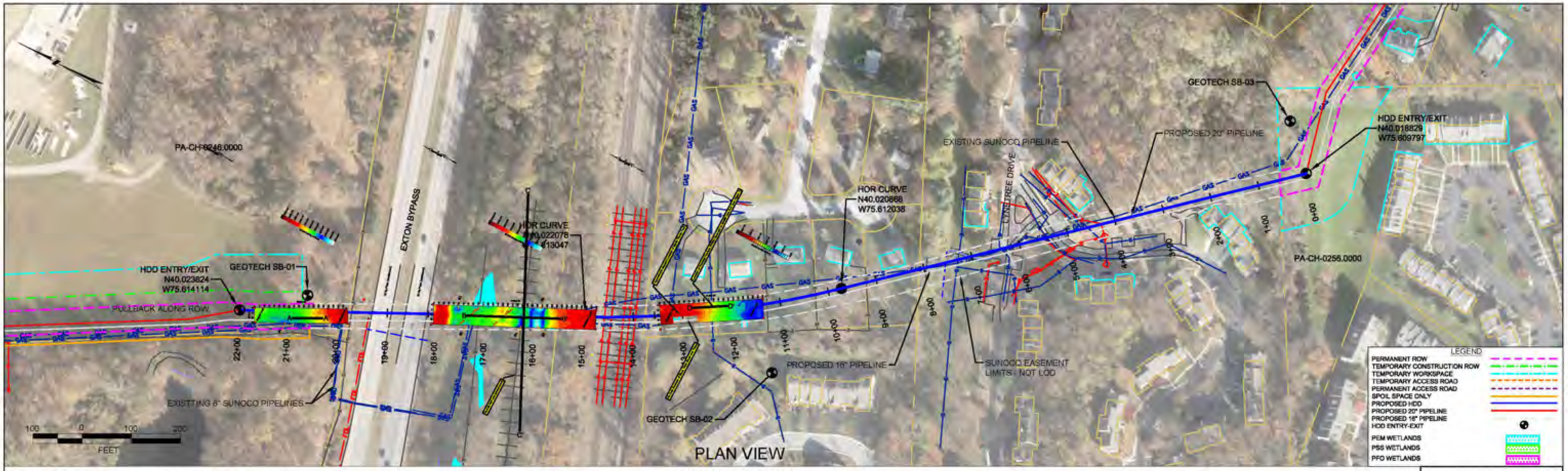
PF#1 Potential Fracture.

QUANTUMGEOPHYSICS

Engineering, Groundwater, and Environmental Geophysics
29 Richard Lee Lane, Phoenixville, PA 19460

Areas 1, 2 and 3
Bouguer Gravity Contour Maps and MASW Lines
Sunoco Mariner Pipeline - Drill 400
Exton, Pennsylvania

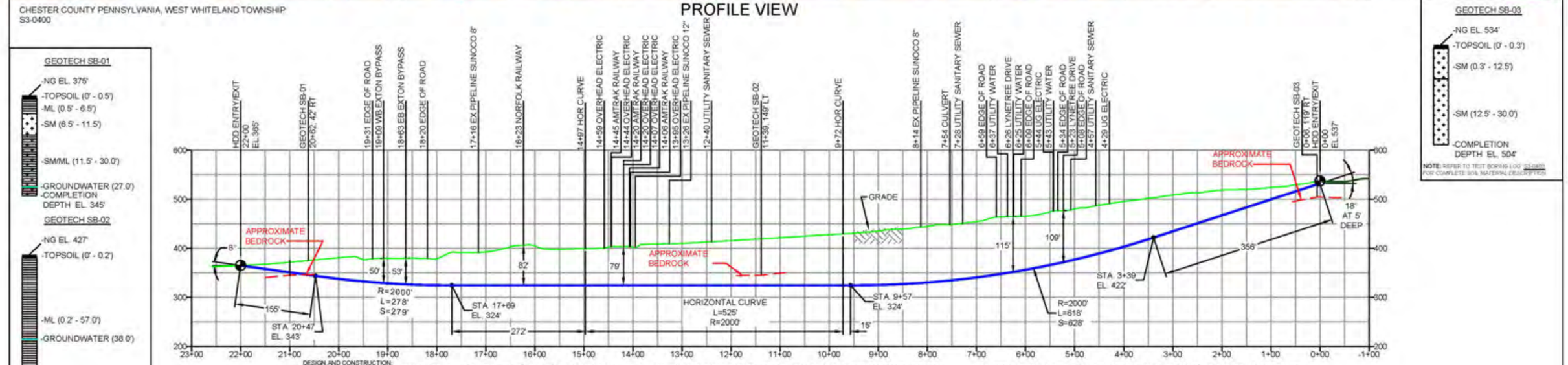
For:	GES		Figure
Date: 10-11-17	Job No.: 063252.001	By: RKL	8



PLAN VIEW

PROFILE VIEW

CHESTER COUNTY PENNSYLVANIA, WEST WHITELAND TOWNSHIP
S3-0400



GEOTECH SB-01
-NG EL. 375'
-TOPSOIL (0' - 0.5')
-ML (0.5' - 6.5')
-SM (6.5' - 11.5')
-SM/ML (11.5' - 30.0')
-GROUNDWATER (27.0')
-COMPLETION DEPTH EL. 345'

GEOTECH SB-02
-NG EL. 427'
-TOPSOIL (0' - 0.2')
-ML (0.2' - 57.0')
-GROUNDWATER (38.0')
-ML (57.0' - 74.4')
-COMPLETION DEPTH EL. 353'

NOTE: REFER TO TEST BORING LOG S3-0400 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH SB-03
-NG EL. 534'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 12.5')
-SM (12.5' - 30.0')
-COMPLETION DEPTH EL. 504'

NOTE: REFER TO TEST BORING LOG S3-0400 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=): 2200'
   HDD PIPE LENGTH (S=): 2230'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS))
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. PIPELINE AND CROSSING TO BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH LAST APPROVED AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION SPECIFICATIONS FOR PIPELINES CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES.
12. BLASTING NOT PERMITTED.
13. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

Figure 8

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	DESIGN CHANGE - ADJUSTED DRILL CENTERLINE ALIGNMENT - RFI 0140	MRS	04/06/17	RMB	04/06/17	AMC	04/06/17
4	DRILL ENTRY / EXIT LAT LONG UPDATE	MRS	03/31/17	RMB	03/31/17	AMC	03/31/17
3	REVISED PROFILE WITH 2017 LIDAR	MRS	02/15/17	RMB	02/15/17	AMC	02/15/17
2	REVISED PER ENGINEERING COMMENTS	MRS	08/12/16	RMB	08/12/16	AAW	08/12/16
1	REVISED PER COMMENTS FROM REI REVIEW	MRS	03/03/16	RMB	03/03/16	AAW	03/03/16
0	ISSUED FOR CONSTRUCTION	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

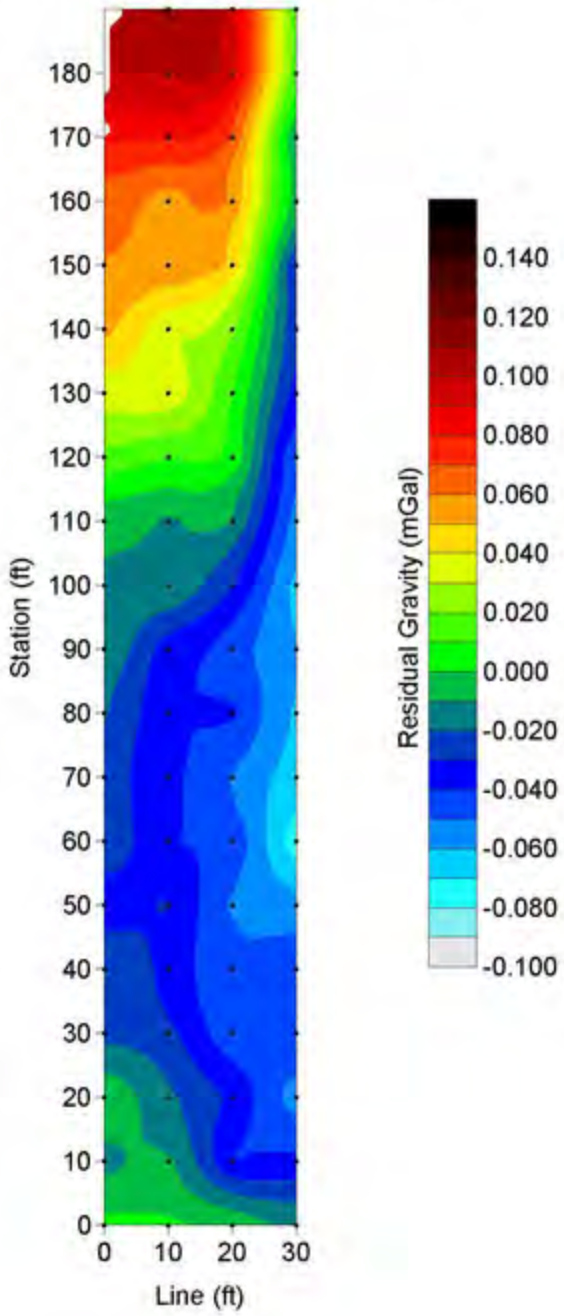
SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
EXTON BYPASS
PENNSYLVANIA PIPELINE PROJECT

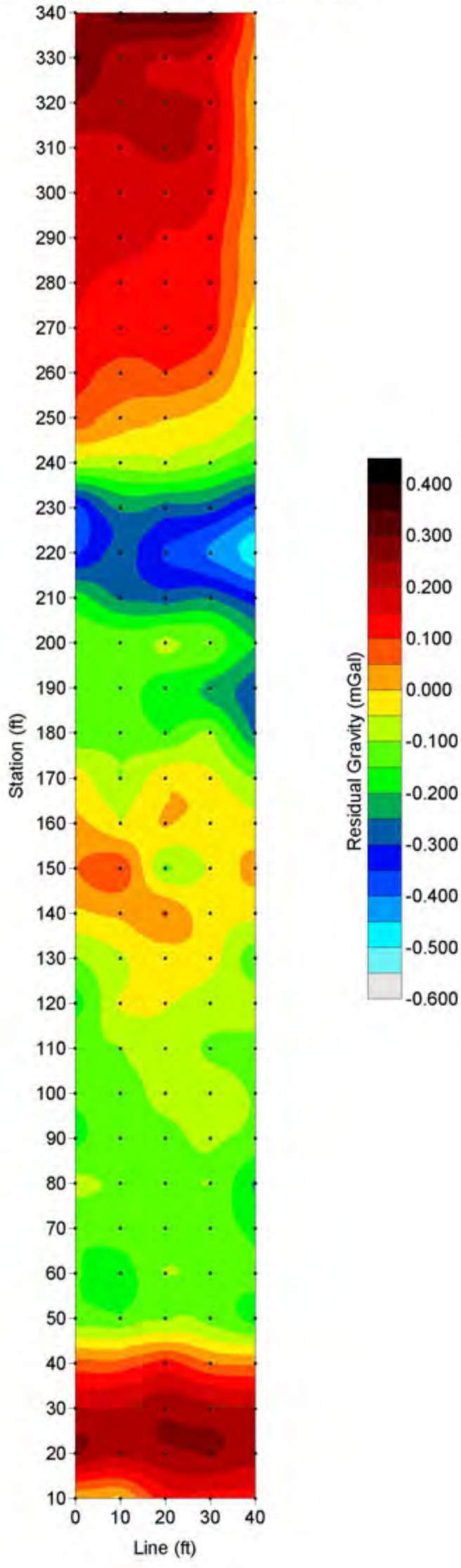
SCALE: 1"=200' | DWG. NUMBER: PA-CH-0249.0000-RR

Appendix A - Residual Gravity Contour Maps

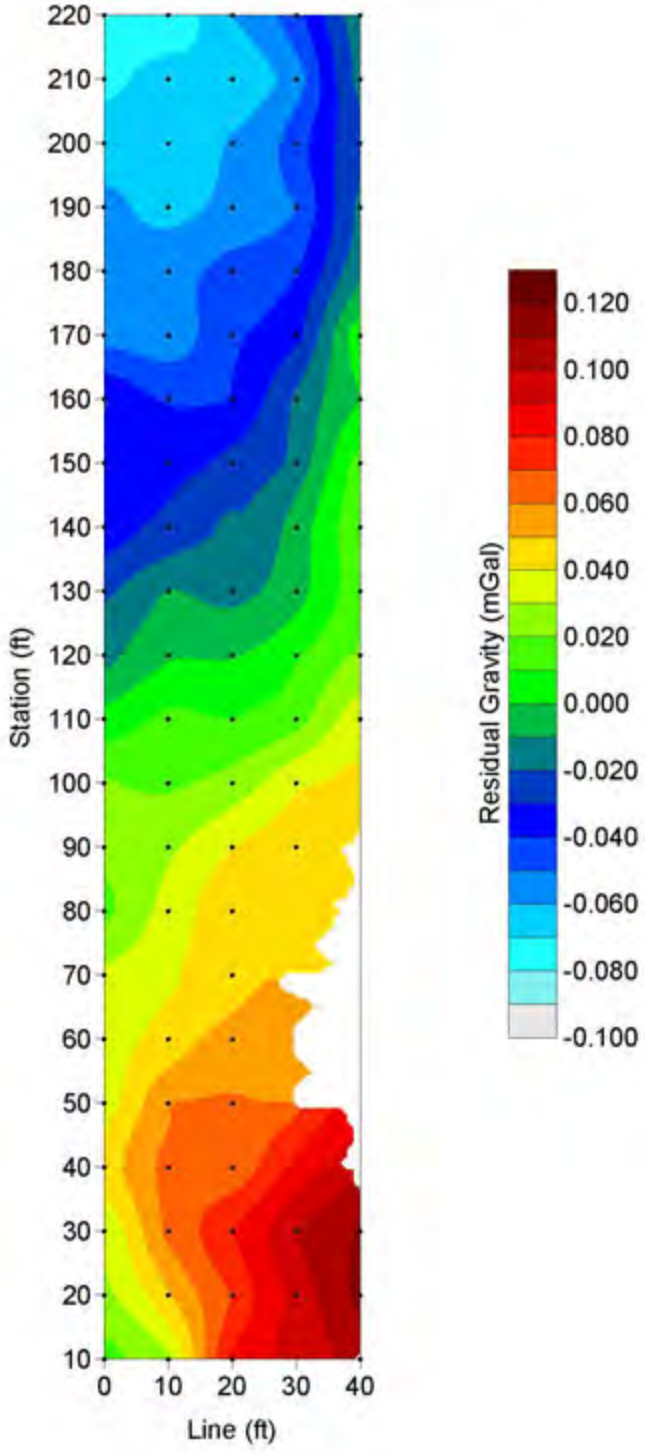
Area 1 - Residual Gravity Contour Map



Area 2 - Residual Gravity Contour Map



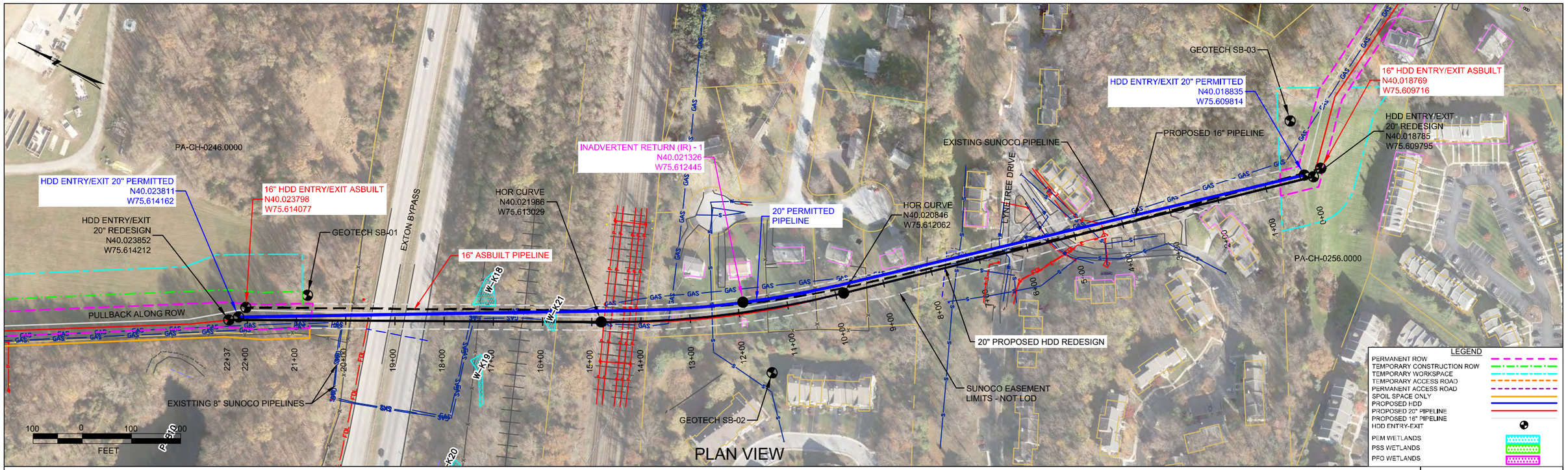
Area 3 - Residual Gravity Contour Map



EXTON BYPASS CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0256-0000-RR
(SPLP HDD No. S3-0400)

ATTACHMENT 2

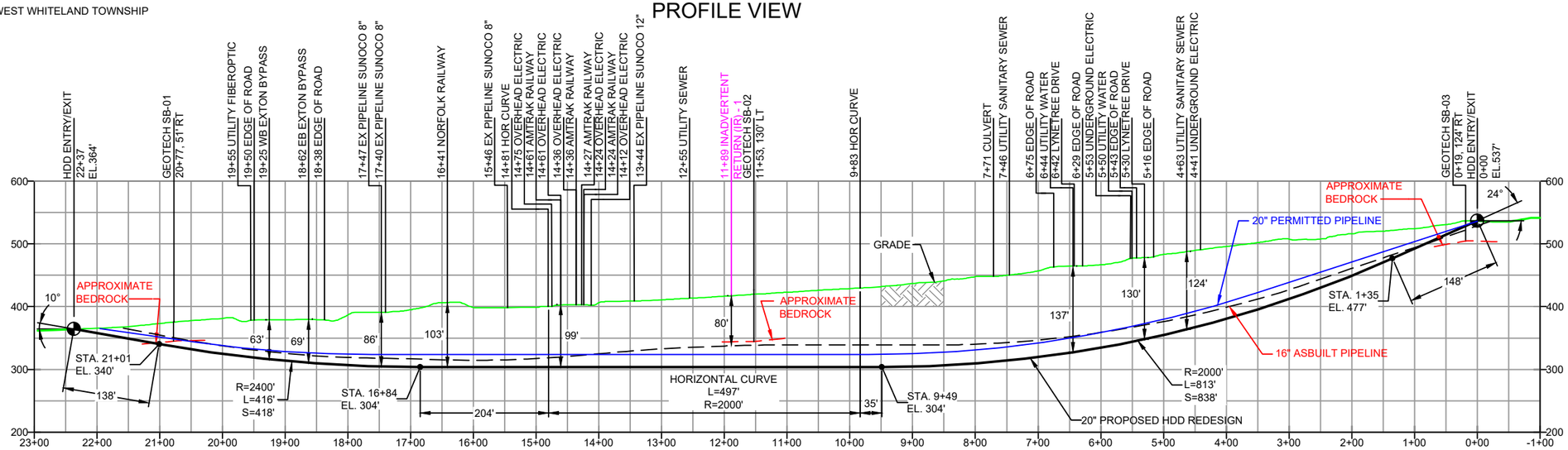
HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



PLAN VIEW

PROFILE VIEW

CHESTER COUNTY PENNSYLVANIA, WEST WHITELAND TOWNSHIP
S3-0400

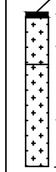


GEOTECH SB-01

GEOTECH SB-02

NOTE: REFER TO TEST BORING LOG S3-0400 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH SB-03



NOTE: REFER TO TEST BORING LOG S3-0400 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=): 2237'
   HDD PIPE LENGTH (S=): 2278'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. PIPELINE AND CROSSING TO BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH LAST APPROVED AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION SPECIFICATIONS FOR PIPELINES CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES.
12. BLASTING NOT PERMITTED.
13. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

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

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
5	DESIGN CHANGE - ADJUSTED DRILL CENTERLINE ALIGNMENT - RFI 0140	MRS	04/06/17	RMB	04/06/17	AMC	04/06/17
4	DRILL ENTRY / EXIT LAT LONG UPDATE	MRS	03/31/17	RMB	03/31/17	AMC	03/31/17
3	REVISED PROFILE WITH 2017 LIDAR	MRS	02/15/17	RMB	02/15/17	AMC	02/15/17
2	REVISED PER ENGINEERING COMMENTS	MRS	08/12/16	RMB	08/12/16	AAW	08/12/16
1	REVISED PER COMMENTS FROM REI REVIEW	MRS	03/03/16	RMB	03/03/16	AAW	03/03/16
0	ISSUED FOR CONSTRUCTION	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16

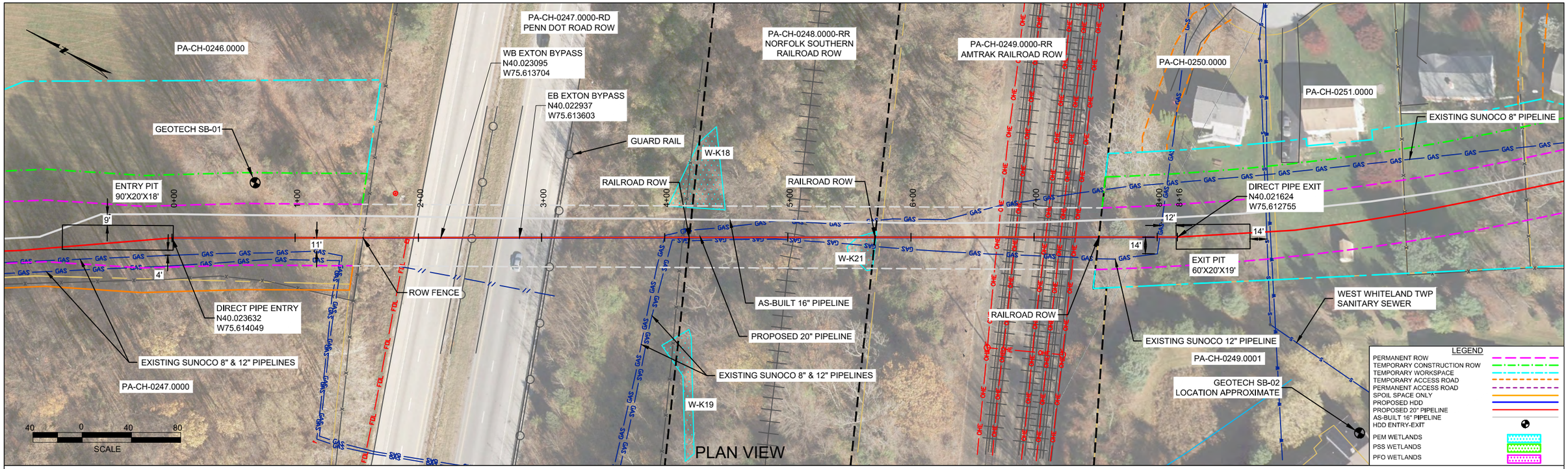
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

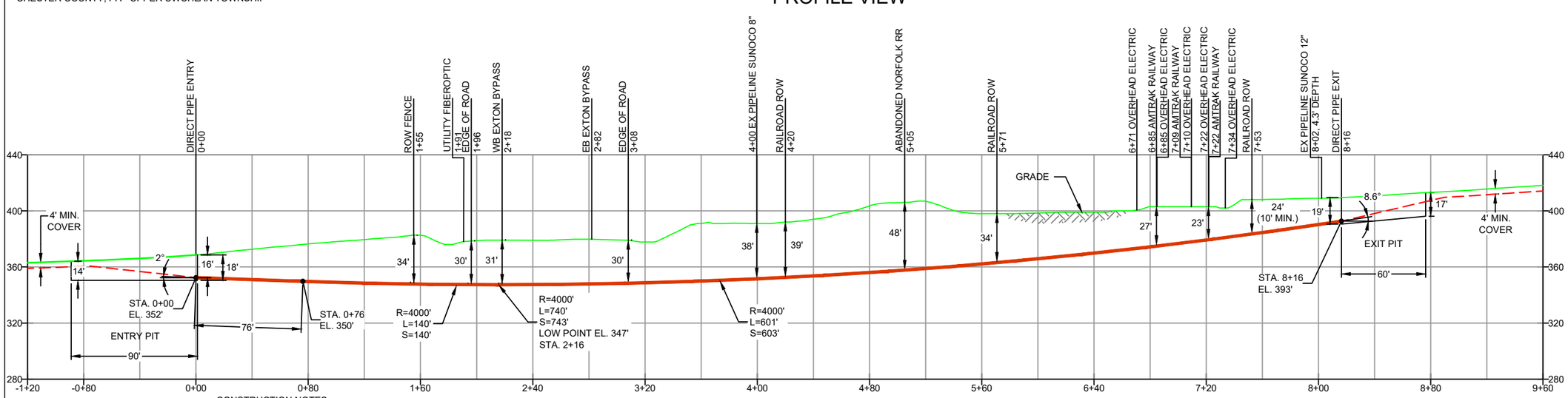
HORIZONTAL DIRECTIONAL DRILL
EXTON BYPASS
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' | DWG. NO: PA-CH-0256.0000-RR



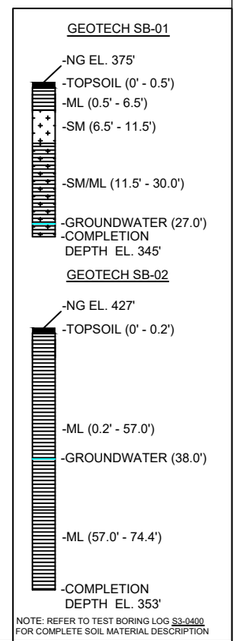
CHESTER COUNTY, PA - UPPER UWCHLAN TOWNSHIP

PROFILE VIEW



CONSTRUCTION NOTES

1. 20" PIPE WILL BE INSTALLED INTO A SINGLE WELDED STEEL CASING (48" OD, 0.750" WT, X-52) USING DIRECT PIPE METHOD.
2. 20" WELDED STEEL PIPE: 20" OD x 0.456" WT, X-65, API-5L, PSL2, ERW, BFW, DRL
   HORIZONTAL PIPE LENGTH (L) = 816'
   PIPE LENGTH (S) = 819'
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
3. 20" DESIGN PRESSURE: 1480 PSIG
   CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF PIPE STRING TO MINIMUM 1850 PSIG.
4. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
5. THE COATING ON THE CARRIER PIPE SHALL BE INSPECTED IMMEDIATELY PRIOR TO ITS INSTALLATION AND ALL DAMAGED COATING SHALL BE REPAIRED IN ACCORDANCE WITH SUNOCO'S PIPELINE COATING SPECIFICATIONS.
6. INSTALL CATHODIC PROTECTION TEST LEADS AS SPECIFIED ON THE ALIGNMENT SHEETS OR SUNOCO CORROSION TECHNICIAN.
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. WELDED JOINTS INSIDE R.O.W. SHALL BE 100% X-RAYED.
9. CONTRACTOR WILL MAINTAIN A MINIMUM 4' OF COVER TO THE TOP OF PIPE USING FIELD BENDS.
10. CONTRACTOR WILL MAINTAIN A MINIMUM 24" OF COVER FROM ALL EXISTING UTILITIES.
11. CONTRACTOR WILL MAINTAIN A MINIMUM 5' OF COVER FROM BOTTOM OF STREAMS.
12. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
13. IN ADDITION TO THE SITE-SPECIFIC INFORMATION PROVIDED IN THIS DRAWING, GENERAL REQUIREMENTS INCLUDED IN ALIGNMENT SHEETS, PERMITS AND APPROVAL FROM FEDERAL, STATE AND LOCAL AGENCIES ALSO APPLY.
14. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
15. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.



NOTE: REFER TO TEST BORING LOG S3-0400 FOR COMPLETE SOIL MATERIAL DESCRIPTION

Figure 3. 42-Inch Direct Pipe Bore Plan and Profile

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-6.49	TO	ES-6.50	EROSION & SEDIMENT PLAN
SHEET 33	TO	SHEET 34	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
0	ISSUED FOR CONSTRUCTION	MRS	05/03/19	RMB	05/03/19	AMC	05/03/19

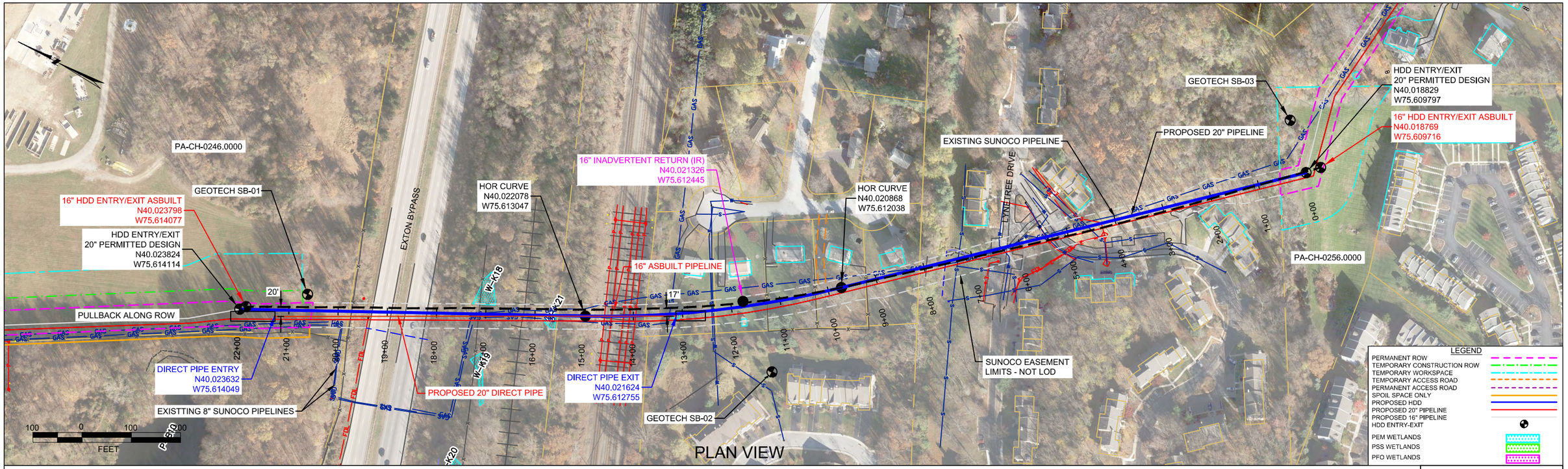
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

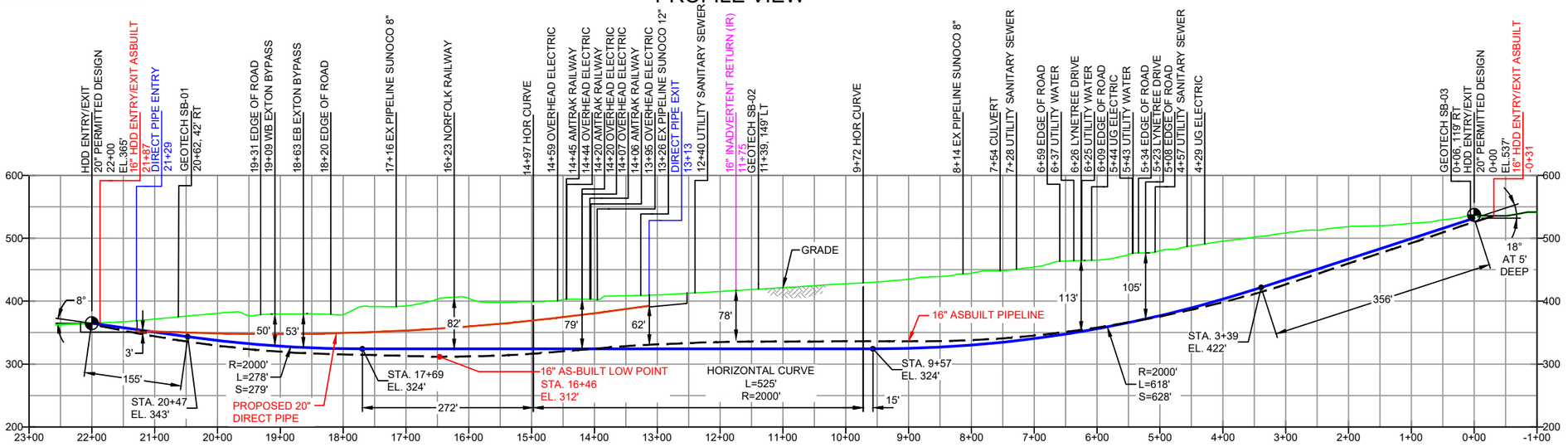
DIRECT PIPE
EXTON BYPASS / AMTRAK RAILWAY
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=80' | DWG. NO.: PA-CH-0249.0000-RR

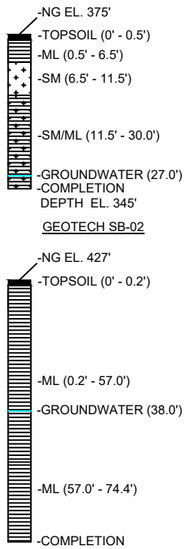


CHESTER COUNTY PENNSYLVANIA, WEST WHITELAND TOWNSHIP
S3-0400

PROFILE VIEW



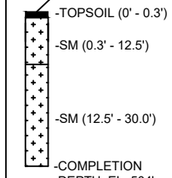
GEOTECH SB-01



GEOTECH SB-02

NOTE: REFER TO TEST BORING LOG S3-0400 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH SB-03



NOTE: REFER TO TEST BORING LOG S3-0400 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=): 2200'
   HDD PIPE LENGTH (S=): 2230'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. PIPELINE AND CROSSING TO BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH LAST APPROVED AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION SPECIFICATIONS FOR PIPELINES CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES.
12. BLASTING NOT PERMITTED.
13. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

Figure 2. Revised 20-Inch HDD Plan and Profile Evaluated with IR Data and Revised Direct Bore Plan

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	DESIGN CHANGE - ADJUSTED DRILL CENTERLINE ALIGNMENT - RFI 0140	MRS	04/06/17	RMB	04/06/17	AMC	04/06/17
4	DRILL ENTRY / EXIT LAT LONG UPDATE	MRS	03/31/17	RMB	03/31/17	AMC	03/31/17
3	REVISED PROFILE WITH 2017 LIDAR	MRS	02/15/17	RMB	02/15/17	AMC	02/15/17
2	REVISED PER ENGINEERING COMMENTS	MRS	08/12/16	RMB	08/12/16	AAW	08/12/16
1	REVISED PER COMMENTS FROM REI REVIEW	MRS	03/03/16	RMB	03/03/16	AAW	03/03/16
0	ISSUED FOR CONSTRUCTION	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
EXTON BYPASS
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200'

DWG. NUMBER: PA-CH-0249.0000-RR