HORIZONTAL DIRECTIONAL DRILL ANALYSIS
SCHOOL HOUSE ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E38-194
PA-LE-0005.0000-RD-16
(SPLP HDD No. S3-0091-16)

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This reanalysis of the horizontal directional drill (HDD) installation of a 16-inch diameter pipeline that traverses School House Road in South Londonderry Township, Lebanon County, Pennsylvania, is in accordance with the Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L for HDDs listed on Exhibit 3 of the Stipulated Order. This HDD is number 12 on the list of HDDs included on Exhibit 3 of the Order.

The installation of the 20-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. This first pipeline HDD had an inadvertent return (IR), and therefore, the installation of the second pipeline (16-inch diameter) requires reanalysis. The IR for the 20-inch pipeline was remediated and the HDD installation for the 20-inch diameter pipeline was completed.

The 16-inch pipeline HDD is referred to herein as HDD S3-0091-16.

PIPE INFORMATION

16-Inch: 0.438 wall thickness; X-70.

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

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 1,436 foot (ft)
- Entry/Exit angle: 10-12 degrees
- Maximum Depth of cover: 62 ft
- Pipe design radius: 1,600 ft

ROOT CAUSE ANALYSIS FOR THE 20-INCH PIPELINE INSTALLATION INADVERDENT RETURNS

The occurrence of the IR during the installation of the 20-inch diameter pipeline under the School House Road crossing resulted from the shallow depth of cover on the HDD exit radius while proceeding through weathered material in the upper 30 ft of the profile. This IR occurred approximately 50 ft in front of the target exit point, and is considered a “Punch Out” IR in the horizontal drilling industry.

GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (PABTGS, 2001), this HDD site lies within the Gettysburg-Newark Lowland Section of the Piedmont Physiographic Province of Pennsylvania, and is regionally underlain by mainly red shale, siltstone, and sandstone with some conglomerate and diabase. The geology underlying the16-inch HDD profile is mapped as the Triassic age Gettysburg (Trg) and Hammer Creek (Trh) Formations; a contact is mapped near the HDD entry. Intrusive diabase dikes have been mapped northwest and south of the HDD location. Generally, the Gettysburg Formation is soft reddish-brown shale and red-brown fine- to medium-grained sandstone. The Hammer Creek Formation near the HDD is described a red, brown, and less abundant light gray to gray very fine to coarse grained conglomerate, thin- to thick-bedded quartz-rich sandstone and thin to medium-bedded red shale and siltstone.

Karst geology is not present at this HDD location. SPLP possesses a complete geologic profile from the 20-inch pipeline HDD, and vertical geotechnical data. No additional information is required to reevaluate the installation of the 16-inch pipeline by HDD.

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

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

Groundwater in the vicinity of the School House Road HDD occurs and moves in interconnected, secondary openings such as bedding plans, fractures and joints in the sedimentary bedrock aquifer system. Groundwater within the Gettysburg and Hammer Creek Formations can occur under both unconfined (i.e., water table) and confined conditions. In general, groundwater occurs under unconfined conditions within the upper portion of the aquifer, and under confined or semiconfined conditions in the deeper portions of the aquifer.

Well records reviewed within a 0.5-mile radius of the School House Road HDD were obtained from the Pennsylvania Groundwater Information system (PaGWIS, February 7, 2019). A total of 12 well records were available. Based solely on this PaGWIS data, well depths varied from 100 to 450 ft below ground surface (bgs), and well yields varied from 10 to 80 gallons per minute (gpm).

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

INADVERTENT RETURN (IR) DISCUSSION

During the pilot phase drilling for the 20-inch pipe, an IR occurred 20 feet south of the limit of disturbance, when the drilling tool was approximately 50 ft before the exit point. The root cause of this IR is the weak weathered material overlying bedrock (bedrock/overburden interface) which as the pilot tool was drilling through and coming out of the bedrock, allowed for the movement of drilling fluids to the land surface. As stated previously, this is called a “Punch Out” IR in the drilling industry, and these type of events are difficult to prevent, especially when drilling out of the bedrock with shallow overburden between the bedrock and land surface.

“Punch In” and “Punch Out” IRs can be difficult to prevent when bedrock is shallow below the land surface, and the pilot hole mud motor has to continue cutting through rock to proceed into or out of bedrock to enter or exit the profile. The profile for the 16-inch pipeline has been redesigned so that it is deeper than previously permitted and the entry and exit angles increased to minimize drilling time while entering or exiting the profile.

ADJACENT FEATURES ANALYSIS

This HDD location is located 1.5 miles south of the Town of Campbelltown in Lebanon County, Pennsylvania. The installation of both the 16-inch and 20-inch pipeline in this location is within an existing SPLP easement along with two previously existing SPLP pipelines. The HDD alignment crosses under School House Road, Laurel Lane, and streams S-A49 and S-A51. This HDD location is set within a rural area and is surrounded by active agricultural lands with residential home sites adjacent or near to public roadways. This HDD avoids surficial impacts both streams, neither of which are designated as high quality or exceptional value, the stream floodways, public roadways, and a private residence that encroaches on and built over the SPLP easement.

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

As a result of these communications, six water supply wells were identified within the 450-foot buffer of the alignment. A map depicting the location of these water wells is provided within the Hydrogeology Report included as Attachment 1 of this reevaluation.

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

ALTERNATIVES ANALYSIS

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

Open-cut Analysis

Sunoco Pipeline, L.P. (SPLP) specifications require a minimum of 48-inches of cover over the installed pipelines. The Pennsylvania Department of Transportation (PennDOT) cover requirements under public roadways is 60-inches of cover. Due to the spacing of the two existing SPLP pipelines before and after the crossing of School House Road, which is where the easement also crosses stream A-51, there is no remaining space for an open cut or conventional bore pipeline installation. This roadway/stream junction crossing in conjunction with the presence of the stream channel immediately west of School House Road, and the encroaching residence and out building further to the west supports the use of HDD to avoid these features.

The use of HDD avoids direct surface impacts to all these features, including the HDDs avoid the two previously existing SPLP pipelines while undercrossing through this area.

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Use of Conventional Auger Bore

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

Based on experience gained during construction of the Mariner II Pipeline project, conventional auger bores should be limited to approximately 200 linear foot at a time, or less, varying by the underlying substrate. As stated above, a conventional bore of School House Road and stream A51 is blocked by the orientation of the existing SPLP pipelines. The crossing of Laurel Lane and the residential encroachment is feasible by a conventional auger bore; however, implementing this installation method to reduce the overall extent of the HDD then requires the setup of the HDD equipment immediately adjacent to the encroaching residence to complete the remainder of the area by HDD. This action would result in a shallower overall HDD profile which is more susceptible to an occurrence of an IR.

Re-Route Analysis

The pipeline route as currently permitted follows an existing SPLP easement. This alignment bypasses or avoids directly impacting School House Road, Laurel Lane, and streams S-A49and S-A51.

There are no existing utility corridors to the north or south that provide a practical alternative route. Any alternate route considered to the north or south would require the clearing of a new “greenfield” corridor through existing farmland, forested lands, potentially encounter stream crossings, and possibly encroach on additional private residences before it could rejoin the current route.

In summary, due to the 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 to acquire a new easement.

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

REVISED HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

After review of the original HDD designs, geotechnical data, field reports related to the IR event that occurred during installation of the 20” pipeline, SPLP HDD specialists have redesigned this HDD. A summary of the redesign factors is provided below. The original and redesigned HDD plan and profile drawings are provided in Attachment 2.

- Horizontal length: 1,569 ft
- Entry/Exit angle: 16 degrees
- Maximum Depth of cover: 81 ft
- Pipe design radius: 2,000 ft

CONCLUSION

As shown on Figure 2, the redesigned HDD extends the profile by 133 ft, increases the entry and exit angles, and adjusts the HDD profile deeper to minimize the risk of drilling fluid loss and IRs.

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The redesign of the HDD will not prevent all IRs. IR's are common on entry and exit of the drilling tool and other measures are required to minimize IR potential. In particular, upon the start of this HDD, SPLP will employ the following HDD best management practices:

- SPLP will mandate annular pressure monitoring during the drilling of the pilot hole, which assists in immediate identification of pressure changes indicative of loss of return flows or over pressurization of the annulus, to help manage development pressures that can induce an IR;

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

- SPLP will mandate short-tripping of the reaming tools to ensure an open annulus is maintained to manage the potential inducement of IRs;

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

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

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FEASIBILITY DETERMINATION

Based on the information reviewed by the Geotechncial Evaluation Leader, Professional Geologists, Professional Engineers, and HDD specialists, the HDD Reevaluation Team's opinion is that the proposed HDD design and implementation of the management measures contained within this re-revaluation report will minimize the risk of IRs and impacts to public and private water supplies during the construction phases of the HDD.

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

2-20-2019
Date

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

Pertaining to the practice of geology

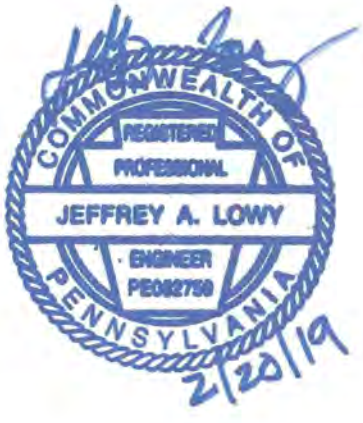
2-20-2019
Date

Douglas J. Hess, P.G.
License No. PG-000186-G
Skelly and Loy, Inc.
Director of Groundwater
and Site Characterization
Geo-Environmental Services

Pertaining to the pipeline stress and HDD geometry

2/20/19
Date

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



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ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

RETTEW

We answer to you.

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Engineers
Environmental Consultants
Surveyors
Landscape Architects
Safety Consultants

February 15, 2019

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

RE: Sunoco Pipeline, LP Pipeline Project - Mariner East II
School House Road HDD (S3-0091), PA-LE-0005.0000-RD-16
Hydrogeological Re-Evaluation Report for 16-Inch Pipeline
South Londonderry Township, Lebanon County, Pennsylvania
RETTEW Project No. 096302011

EXECUTIVE SUMMARY

1. During drilling of HDD S3-0091 for installation of the 20-inch diameter pipeline, an inadvertent return (IR) of drilling fluids occurred during the pilot phase. Due to the occurrence of this IR during HDD operations for the 20-inch pipeline, this hydrogeologic report was prepared to address the potential for IRs during the proposed 16-inch HDD operations.
2. The School House Road HDD (the site) is underlain by sedimentary rocks of the Triassic age Gettysburg (Trg) and Hammer Creek (Trh) Formations. The Gettysburg Formation consists of shale, sandstone and conglomerate, all of which can be interbedded to some extent. The Hammer Creek Formation consists of conglomerate, coarse sandstone and minor amounts of shale.
3. Water-bearing zones generally occur in secondary openings along bedding planes, joints, and fractures. The openings are best developed near the surface which allows water to move more freely near the ground surface than within deeper zones due to the compression of the overlying materials.
4. Water-bearing zones in the Gettysburg Formation are most frequent within 280 feet of the surface and most frequent within 197 feet of the surface in the Hammer Creek Formation.
5. To date, HDD operations have been completed at the S3-0091 location for the 20-inch pipeline. The 20-inch product pipe pull was completed on September 14, 2017. The HDD profile for the proposed 16-inch drill has been redesigned to increase its depth beneath the as-built 20-inch pipe, referenced streams, roads, and buried utilities.
6. Based on the hydro-structural characteristics of the underlying geology, the occurrence of an inadvertent return (IR) near the exit of the pilot hole for the School House Road HDD, and profile of the permitted 16-inch HDD within shallow unconsolidated soil materials and generally shallow bedrock, the proposed 16-inch HDD is similarly susceptible to an IR of drilling fluids during HDD operations. A redesigned 16-inch HDD profile and proactive HDD best management practices (BMPs) during drilling operations will be used to reduce the risk of an IR.

1.0 INTRODUCTION

The purpose of this report is to describe the geologic and hydrogeologic setting of the School House Road S3-0091 HDD location on the Sunoco Pipeline, L.P. (SPLP) Pennsylvania Pipeline Project - Mariner East II (PPP-ME2) Project. The School House Road HDD (the site) is located in South Londonderry Township, Lebanon County, Pennsylvania as shown on **Figure 1**. The HDD will be drilled under Laurel Lane, existing buried Sunoco pipelines, buried utilities, two small streams (S-A50 and S-A51) and School House Road. This re-evaluation report is part of the response to the Corrected Stipulated Order dated August 10, 2017, related to the inadvertent return (IR) of drilling fluids that occurred on July 8, 2017, during HDD operations for the 20-inch HDD pipeline, which was completed on September 14, 2017.

The original 16-inch HDD profile was redesigned on November 16, 2018 to increase the depth of the HDD bore path crossing beneath the sensitive receptors described above. Additionally, the inclination of the entry and exit angles has been increased to install the 16-inch pipe through the protective soils, residual soils and bedrock in closer proximity to the entry and exit points than the original, shorter and shallower profile. The redesigned western HDD entry point is at an elevation of approximately 556 feet above mean sea level (AMSL). The redesigned eastern HDD exit point is at an elevation of approximately 577 feet AMSL. The HDD was extended approximately 133 feet to the east and west resulting in a new vertical length of 1,569 feet and a new boring/pipe length of 1,592 feet. The inclination angles for the eastern and western entry/exit points been increased to 16^{o}. By extending the HDD and increasing the entry/exit angles, the depth of the proposed 16-inch HDD boring has been increased to 65 and 61 feet under Streams A-A49 and S-A51, respectively (this is approximately 15 and 10 feet deeper than the 20-inch pipe). The as-built 20-inch and proposed 16-inch, S3-0091 HDD locations are shown on **Figure 1**, and the redesigned 16-inch profile is included as **Attachment 1.**

2.0 GEOLOGY AND SOILS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (PABTGS, 2001), the site lies within the Gettysburg-Newark Lowland Section of the Piedmont Physiographic Province of Pennsylvania, and is regionally underlain by mainly red shale, siltstone, and sandstone with some conglomerate and diabase. Local topography is characterized by rolling lowlands, shallow valleys and isolated hills (Sevon, 2000). The altitude ranges from 40 to 1,355 feet AMSL, with many of the higher ridges being underlain by more resistant bedrock, such as diabase dikes (Low et al., 2002). The general regional structure of the Newark Group consists of a north-northwestward dipping homocline, modified by local folds plunging northward and reversed dips adjacent to the north border of the basin, and cut by a few faults at large angles to the general strike. The overall dip direction is northwestward or northward ranging from 15 to 30 degrees and sometimes exceeding 40 degrees (MacLachlan et al., 1975). Outcrop patterns are broadly parallel to the Appalachian fold belt. These rocks generally have good surface drainage (Wood, 1980). Based on the United States Geologic Survey (USGS) 7.5-Minute Palmyra, PA Topographic Quadrangle Map shown on **Figure 1**, the site is situated at an approximate elevation range of 580 to 560 feet AMSL. Surface topography at the site slopes to the west along the HDD towards an unnamed tributary of Spring Creek. Spring Creek flows primarily in a northwesterly direction before discharging into Swatara Creek, and ultimately the Susquehanna River.

The geology underlying the redesigned 16-inch HDD profile is mapped as the Triassic age Gettysburg (Trg) and Hammer Creek (Trh) Formations; a contact is mapped near the HDD entry as shown on **Figure 2**. Intrusive diabase dikes have been mapped northwest and south of the HDD location.

Generally, the Gettysburg Formation is soft reddish-brown shale and red-brown fine- to medium-grained sandstone. The Gettysburg Formation is moderately well bedded with thin to flaggy beds. Joints possess a blocky pattern, are moderately developed and abundant but have an uneven regularity. The joints are described as closely spaced, steeply dipping, open and filled with quartz and calcite. The formation typically is moderately resistant to weathering forming undulating hills of low relief to small hills and ridges that are higher than the surrounding countryside. The formation tends to be moderately weathered to a moderate depth with weathered fragments ranging in size from elongated and pencil-like to medium sized irregularly shaped blocks. Smaller weathered fragments typically result from rapid hydration of minerals in exposed outcrops. The mantle is moderately thick. From an engineering standpoint, weathered zones are moderately easy to excavate, while unweathered rock is difficult to excavate. Drilling rates are expected to be moderate to fast except in areas adjacent to diabase intrusions were the rock is harder making the drilling rate slower. Foundation stability is good when material is excavated to sound rock. Slope stability tends to be fair to poor with landslides occurring where the cut slopes are steep and rocks dip towards the cut. Surface drainage for this formation is good. Joint and bedding plane openings provide moderate secondary porosity. Permeability is described as moderate (Geyer and Wilshusen, 1982).

The Hammer Creek Formation near the HDD is described a red, brown, and less abundant light gray to gray very fine to coarse grained conglomerate, thin- to thick-bedded quartz-rich sandstone and thin to medium-bedded red shale and siltstone. The sandstones exhibit some crossbedding, lensing, channeling, and ripple marks, while the siltstone and shale exhibit ripple marks and mud cracks (Low et al., 2002). The Hammer Creek Formation is well bedded with thick to massive beds. Joints are regularly occurring, open and steeply dipping, moderately developed and moderately abundant with a blocky pattern. Overall, the formation is moderately resistant to weathering, generally forming a rough terrain of high relief. The shale is highly weathered to a moderate depth, while the sandstone and conglomerate display less weathering. The weathered product ranges in size from large blocks to sand grains. The overlying mantle tends to be thick. From an engineering stand point, the formation is difficult to excavate with slow drilling rates because of quartz-pebble conglomerate and in areas adjacent to diabase intrusions were the rock is harder. Foundation stability is good when material is excavated to sound rock. Slope stability tends to be good to fair with landslides occurring where the cut slopes are steep and rocks dip towards the cut. Surface drainage for this formation is good. The formation has low primary porosity, but the joints and bedding openings provide moderate secondary porosity and low to moderate permeability. (Geyer and Wilshusen, 1982).

According to the United States Department of Agriculture (USDA) Soil Surveys for Dauphin County and Lebanon County Pennsylvania, soils in the vicinity of the School House Road HDD consist of four separate soil units. A USDA soils map that depicts the mapped area, along with the soil profile descriptions, is included in **Attachment 2**.

3.0 HYDROGEOLOGY

Groundwater in the vicinity of the School House Road HDD occurs and moves in interconnected, secondary openings such as bedding plans, fractures and joints in the sedimentary bedrock aquifer system. Typically, these openings are best developed and found more frequently near the surface. At depth, these openings occur less frequently and tend to be smaller because compressional loading can close the openings (Wood, 1980).

Bedrock geology ultimately influences the storage, transmission, and use of groundwater. Geologic factors such as rock type, intergranular porosity, rock strata inclination, faults, joints, bedding planes, and solution channels affect groundwater movement and availability. Groundwater within the Gettysburg and Hammer Creek Formations can occur under both unconfined (i.e., water table) and confined conditions. In general, groundwater occurs under unconfined conditions within the upper portion of the aquifer, and under confined or semiconfined conditions in the deeper portions of the aquifer. The groundwater flow system is described as a series of sedimentary beds with relatively high transmissivity separated by beds exhibiting lower transmissivities. This sequence of beds exhibits different hydraulic properties that collectively act as a series of alternating aquifers and confining or semi-confining units forming a leaky (i.e., hydraulically interconnected) multi-aquifer system (LMAS). Groundwater flow direction within the Gettysburg and Hammer Creek Formations is controlled by hydraulic gradients and variability of hydraulic conductivity. The predominant flow direction is parallel to bedding (Wood, 1980).

Of 332 wells reported in the Gettysburg Formation, water-bearing zones range from 5 to 900 feet below ground surface (bgs). Fifty percent of the 669 water-bearing zones were penetrated at depth of 115 or less with 90% of the water-bearing zones by a depth of 288 feet bgs or less. The greatest of density of water-bearing zones is from 51 to 100 feet bgs. The density of water-bearing zones encountered at depths greater than 401 feet are based on five or fewer zones per 50-foot interval. The overall density of water-bearing zones in the Gettysburg Formation is 0.41 per 50-feet of well depth (Low, et al., 2002).

In the Hammer Creek Formation, depths of water-bearing zones range from 5 to 445 feet bgs in 207 wells that were evaluated. Fifty percent of the 544 water-bearing zones were penetrated at a depth of less than 90 feet with 90% of the water-bearing zones occurring at a depth of less than 197 feet. The greatest density of water-bearing zones is from 51 to 100 feet bgs. The density of water-bearing zones encountered at depths greater than 301 feet are based on the presence of six or fewer water-bearing zones per 50-foot interval. The overall density of water-bearing zones in the Hammer Creek Formation is 0.67 per 50-feet of well depth (Low, et al., 2002).

Well records reviewed within a 0.5-mile radius of the School House Road HDD were obtained from the Pennsylvania Groundwater Information system (PaGWIS, February 7, 2019). A total of 12 well records were available and are summarized in the table below. These well locations are shown on **Figures 2** and **3.**

Well No.	Well Use	Casing Depth (feet)	Total Depth (feet)	Water Level (feet)	Yield (gpm)
669744	DOMESTIC	102	275	UNKNOWN	80
667669	DOMESTIC	99	450	UNKNOWN	15
625206	DOMESTIC	84	140	38	50
508778	DOMESTIC	105	250	UNKNOWN	25
486325	DOMESTIC	105	200	UNKNOWN	30
481148	DOMESTIC	105	175	UNKNOWN	40

Well No.	Well Use	Casing Depth (feet)	Total Depth (feet)	Water Level (feet)	Yield (gpm)
415899	DOMESTIC	95	150	UNKNOWN	20
22818	DOMESTIC	63	120	35	10
127396	DOMESTIC	90	150	UNKNOWN	12
127370	DOMESTIC	64	100	UNKNOWN	25
127350	DOMESTIC	66	120	40	30
127349	DOMESTIC	63	120	35	10

As a condition of the corrected Stipulated Order, other Sunoco subcontractors researched private water supplies located within a 450-foot radius of the School House Road HDD. Six water supply wells were identified within the 450-foot radius of the HDD alignment. Information regarding well depth, depth to water, or pump setting was not provided. A map of these locations is included as **Attachment 3.**

4.0 FRACTURE TRACE ANALYSIS

Fracture traces underlying, or in close proximity to, the School House Lane HDD were evaluated using historical aerial photographs from the years 1992 through 2016 (Google Earth, 2017), the Elizabethtown and Palmyra USGS 7.5-minute Topographic Quadrangle Maps, the Elizabethtown Quadrangle Geologic Map (Berg and Dodge, 1981), Plate 1-Part 2 Geologic Map of the Gettysburg and Hammer Creek Formations in Southcentral Pennsylvania (Wood, 1980), and the United States Geological Survey (USGS) 7.5-minute Topographic Quadrangle Maps. The photographs and maps were reviewed to approximate locations of natural linear features or lineaments expressed on the ground surface. The linear features may be the surficial representation of deeper fractures, joints, faults or bedding planes within the subsurface which can transmit groundwater in the fractured bedrock aquifer underlying the proposed HDD bore path.

Figures 2 and **3** show the results of the fracture trace analysis which were added to the geologic map and an aerial base map, respectively. Five fracture traces were identified within close proximity to the School House Road HDD that are likely related to the primary geologic structure. Two of the fracture traces trend approximately northwest-southeast (NW-SE), while one trends roughly north-south (N-S), similar to the general regional structure. These fracture traces run roughly perpendicular to the orientation of the HDD alignment. The two remaining fracture traces are trending approximately northeast-southwest (NE-SW).

5.0 GEOTECHNICAL EVALUATION

Two geotechnical drilling investigations were performed at the site. The initial investigation was performed in October 2016 during the preliminary investigation of the School House Road HDD and prior to initiating the 20-inch HDD operations. A second phase of geotechnical drilling was performed in December of 2017. The 2016 test borings were advanced by hollow-stem auger drilling methods to a maximum depth of 28.7 feet bgs or until auger refusal. NQ-sized wireline rock coring methods were utilized in borings that were continued past auger refusal. Soil, residual soil and weathered bedrock were sampled using split-spoon sampling methods. These borings are designated as SB-01, SB-02 and SB-03. The second phase test boring completed in 2017 was advanced using hollow-stem auger drilling

and NQ-sized wireline rock coring methods. The 2017 boring is designated as B-2. Soil, residual soil and weathered bedrock collected during both investigations were sampled using split-spoon sampling methods. Geotechnical boring logs are included in **Attachment 1**.

Borings SB-01 and SB-02 were located approximately 150 and 700 feet northeast of the HDD western entry/exit point. Boring SB-03 was located approximately 30 feet south of the HDD eastern entry/exit point. Boring B-2 was located approximately 950 feet to the east-northeast of the HDD eastern entry/exit point. The locations of these borings are depicted on **Figures 2** and **3.**

The generalized subsurface profile at the site, as observed in the borings, is described as follows:

- Variable and residual soil depths are variable in the borings; 28.7 feet at SB-01, 19 feet at SB-02, 19 feet at SB-03, and 25 feet at B-2. The residual soils are described as follows:
  - **Boring SB-01**: Topsoil, silty fine SAND (SM), fine to coarse SAND (SM) with some silt, partially weathered SHALE. The boring was completed to a total depth of 28.7 feet bgs. Groundwater was not encountered in this boring.
  - **Boring SB-02**: Topsoil, fine SAND (SM) with some fine to coarse gravel with some silt, fine SAND and SILT (SM/ML) with a little fine gravel. Auger refusal occurred at 19.0 feet bgs. Groundwater was encountered at 19 feet bgs after rock coring was initiated. Perched groundwater may have been encountered at 19 feet bgs at soil/bedrock interface.
  - **Boring SB-03**: Topsoil, fine SAND (SM) with some silt and some fine to coarse gravel, partially weathered SILTSTONE or SHALE. Auger refusal occurred at 19.0 feet bgs and groundwater was not encountered.
  - **Boring B-2**: stiff to very stiff sandy SILT (ML), moist, medium to very dense silty SAND (SM), moist, highly weathered SANDSTONE sampled as dense silty SAND (SM), moist, highly weathered SANDSTONE sampled as hard sandy SILT (ML), moist, highly weathered SANDSTONE sampled as dense silty SAND (SM), moist. Auger refusal occurred at 25 feet bgs and groundwater was not encountered.
- From the initiation of coring operations to the total depth of the NQ cores, weathered bedrock and bedrock were encountered and are described as follows:
  - **Boring SB-01**: Rock coring was not completed at this location.
  - **Boring SB-02**: was completed to a total depth of 29 feet bgs. From 19 to 20 feet bgs reddish brown, highly fractured SHALE was encountered. Rock recovery was 92% and rock quality designation (RQD) was poor (36). From 20 to 22.5 feet bgs reddish gray slightly fractured LIMESTONE was observed. Rock recovery was 100% and the RQD was good (86). From 22.5 to 29 feet bgs reddish brown SANDSTONE with conglomerate lenses was encountered. Rock recoveries ranged from 92% to 100% and RQDs were fair (58) to good (79).
  - **Boring SB-03**: Rock coring was not completed at this location.
  - **Boring B-2**: B-2 was completed to a total depth of 200 feet bgs.
    - From 25 to 65 feet bgs red-brown to dark gray-brown, slightly weathered, very broken to massive, hard to very hard, flat medium to thick bedded, random SANDSTONE with moderately to widely spaced fractures with tight joints was encountered. Broken layers were observed at 28.6, 49.5 and 63.9 feet bgs, while weathered/broken layers were present at 30, 30.9 to 32.3, and 63.4 feet bgs. A weathered layer was observed at 45.3 feet bgs. Siltstone and conglomeritic sandstone interbeds of varying thicknesses

were observed between 50 and 65 feet bgs. Rock recoveries ranged from 90 to 100% and RQD values ranged from very poor to excellent (10 to 100).

- From 65 to 78.5 feet bgs red-brown to red-gray-brown, slightly weathered, very broken to massive, moderately hard to hard, laminated flat to shallow bedding, closely to moderately spaced, shallow to moderately angled fractured SILTSTONE with interbedded sandstone was encountered. Weathered layers were observed at 67.1 and 69.8 feet bgs and a highly weathered layer was observed at 70.7 feet bgs. Rock recovers were 100% and RQDs ranged from poor (37) to good (80).
- From 78.5 to 112.75 feet bgs red-brown to light gray, slightly weathered, very broken to massive, moderately hard to very hard, flat medium to thick bedded, SANDSTONE with random moderately to widely spaced fractures and tight joints was encountered. Broken layers were observed at 78.6 and 82.5 feet bgs, while weathered/broken layers were present at 81.3, 85, 95, and 98.9 feet bgs. A weathered/highly weathered layer was observed at 110 feet bgs. Rock recoveries ranged from 98 to 100% and RQD values ranged from fair to excellent (58 to 100).
- From 112.75 to 128.75 feet bgs red-brown, slightly weathered, very broken to massive, moderately hard, laminated, flat to shallow bedding, closely to moderately spaced, shallow to moderate dip fractures SILTSTONE with interbedded sandstone was encountered. Rock recoveries ranged from 97 to 100% and RQD values were excellent (90 to 100).
- From 128.75 to 148.5 dark red-brown to gray-brown, slightly weathered, broken to massive, hard, flat medium to thick bedded, SANDSTONE with random moderately to widely spaced fractures with tight joints was encountered. A weathered/highly weathered layer was observed at 133.4 feet bgs and a soil layer was encountered at 148 feet bgs. Rock recoveries ranged from 97 to 100% and RQD values ranged from fair to excellent (72 to 100).
- From 148.5 to 154.5 feet bgs tan to light gray to dark brown, weathered to slightly weathered, broken to slightly broken, hard to very hard, cross bedded, crypto crystalline CONGLOMERATE with flat to moderate, indistinct, tight bedded joints was encountered. Rock recovery was 100% and the RQD value was fair (57).
- From 154.5 to 168.5 feet bgs red-gray-brown to dark brown, slightly weathered, very broken to massive, moderately hard to hard, laminated, flat to shallow bedding, very closely to moderate spaced, shallow to moderate tight fractures, tight bedding joints, calcareous, conglomerate interbedded with SILTSTONE and interbedded sandstone was encountered. Rock recoveries ranged from 72 to 100% and RQD values were fair to excellent (72 to 92).
- From 168.5 to 180 feet bgs dark red-brown to gray-brown, slightly weathered, broken to massive, moderately hard, medium bedding, flat to moderate, moderate to wide fractures, tightly jointed SANDSTONE interbedded with siltstone was encountered. A weathered and broken SANDSTONE layer was encountered at 177.4 feet bgs, and a broken SANDSTONE layer was encountered at 178.2 feet bgs. Rock recovery was 100% and the RQD was excellent (95).
- From 180 to 185 feet bgs dark red-brown to light gray-brown, weathered to slightly weathered, very broken to massive, moderately hard to very hard, flat to medium bedding, moderately to highly weathered, medium hard, steep to moderate dip, closed,

spaced fractures, tight to open jointed SANDSTONE was encountered. A broken layer was observed at 180.7 feet bgs, a soil layer was encountered at 180.3 feet bgs, and a highly weathered/very broken layer was present at 183.6 feet bgs. Rock recovery was 100% and RQD was poor (30).

- From 185 to 200 feet bgs light red-brown to dark gray-brown, slightly weathered, broken to massive, moderately hard to very hard, shallow bedding, moderate to thick, moderately to widely spaced, shallow to steep random fractures with tightly jointed SANDSTONE with interbedded conglomeratic SANDSTONE was encountered. A weathered/highly weathered layer with soil was observed between 191.9 and 194 feet bgs. Rock recovery was 100% and RQD values ranged from very poor (10) to excellent (100). Groundwater was observed at 36.7 feet bgs at the completion of coring operations.

Unconfined compressive strength testing was performed on core samples collected from Borings SB-02 and B-2, and these testing results are summarized in the table below.

Boring	Sample Depth (feet bgs)	Compressive Strength (pounds per square inch)
SB-02	20-21	8,120
SB-02	23-23.5	2,940
B-2	27.5	202.96
B-2	33.9	439.73
B-2	42.2	770.78
B-2	53.3	404.99
B-2	58.9	410.23
B-2	68.4	531.33
B-2	77.3	619.62
B-2	86.9	559.91
B-2	94.1	470.82
B-2	105.2	454.91
B-2	113.3	427.24
B-2	123.4	530.95
B-2	129	642.81
B-2	137.7	249.01
B-2	144	474.84
B-2	148.8	88.82

Boring	Sample Depth (feet bgs)	Compressive Strength (pounds per square inch)
B-2	154	179.65
B-2	163.4	330.67
B-2	170.8	698.58
B-2	181.1	459.74
B-2	187.3	416.55
B-2	198.1	158.69

Please note that RETTEW or Skelly and Loy did not oversee or direct the geotechnical drilling program associated with HDD S3-0091 including, but not limited to, the selection of boring locations and target depths, observations of rock cores during drilling operations, or preparation of boring logs. The geotechnical reports, boring logs, and core photographs that resulted from these programs were generated by other Sunoco Pipeline, L.P. contractors. RETTEW and Skelly and Loy relied on these reports and incorporated the data into the general geologic and hydrogeologic framework of the analysis of the proposed 16-inch S3-0091 HDD for this report.

6.0 GEOPHYSICAL SURVEY

No karst geology was observed during the field reconnaissance or is mapped as being present at this HDD location. Secondly, SPLP possesses a complete geologic record of the proposed 16-inch bore path based on the drilling results of the adjacent 20-inch bore path. Although the PA DEP has requested that geophysical surveys be considered in karst areas, based on the lack of carbonate bedrock, karst geologic features, and extensively fractured bedrock observed during the 20-inch HDD, the use of geophysical surveys during the site hydrogeologic re-evaluation of HDD S3-0091 was considered but was ultimately not implemented. The results of geophysical surveys would not provide additional information that would reduce the risk of an IR. Based on our experience working in karst geology, the lack of mapped karst geology along the HDD trace and the lack of continuous thick-bedded limestone units, the Gettysburg and Hammer Creek formations are not deemed susceptible to the solution activity present in other more thickly bedded carbonate geologic formations in Pennsylvania. The data generated from these surveys will not reduce the risk of the type of shallow IR that occurred during the 20-inch HDD operations during HDD operations near the entry or exit points of the proposed 16-inch HDD.

7.0 FIELD OBSERVATIONS DURING 20-INCH HDD ACTIVITIES

RETTEW staff were on-site during pilot-hole drilling for the 20-inch pipe, which began on June 30, 2017. On July 8, 2017, an IR occurred within 50 feet of the eastern HDD exit, as shown on **Figures 2 and 3**, as the pilot hole was being completed**.** Drilling operations were suspended while containment and control measures were implemented. The occurrence of IRs in the vicinity of an HDD entry or exit is not uncommon. Following containment of the IR, the pilot hole was completed. The 24-inch ream pass was started on July 10, 2017 and continued until July 21, 2017 when all drilling activities on the PPP-ME2 Project were suspended by the Pennsylvania Department of Environmental Protection (PA DEP). Following PA DEP's restart approval, drilling operations resumed on August 29, 2017. The IR at the

July 8th location did not re-occur and no additional IRs were reported during reaming operations. The 20-inch pipe was successfully pulled through on September 14, 2017.

A field investigation was performed by RETTEW staff on September 18, 2017 to identify rock outcrops for fracture trace analysis, evaluation and ground-truthing of fracture traces identified during the desktop exercise, and to identify potential sensitive receptors to IRs. Readily accessible bedrock outcrops were not observed. No additional sensitive receptors to IRs were identified during the site reconnaissance.

8.0 CONCEPTUAL HYDROGEOLOGIC MODEL AND CONCLUSION

Based on published geologic and hydrogeologic information results of the geotechnical investigations and field observations during the completion of the 20-inch HDD, the School House Road HDD is underlain by clastic sedimentary rocks of the Gettysburg Formation and the Hammer Creek Formation. The geologic formations underlying the proposed 16-inch HDD site are highly anisotropic, with the predominant groundwater flow direction parallel to bedrock strike. The hydrogeologic setting is dominated by groundwater flow occurring in secondary openings formed along geologic features that include bedrock bedding planes, joints, and fractures. In these formations, secondary openings are more common near the surface. Well records indicate 90% of the water-bearing zones in the Gettysburg Formation are within 280 feet of the surface. In the Hammer Creek Formation, 90% of the water-bearing zones are within 197 feet of the surface.

The originally designed 16-inch HDD profile was relatively shallow at the eastern and western entry/exit points in comparison to the land surface, Laurel Lane, existing buried Sunoco pipelines, buried utilities, two small surface streambeds (S-A49 and S-A51) and School House Road. The original profile also passed through soil overburden and fractured bedrock. Based on the hydro-structural characteristics of the underlying geology described in this report and geologic information obtained and utilized during installation of the 20-inch HDD, the School House Road HDD is susceptible to an IR of drilling fluids during HDD operations. As a result, the 16-inch HDD profile was redesigned to a depth greater than the as-built 20-inch HDD boring to allow for a deeper crossing beneath the streams, roads, and buried utilities. The revised profile is approximately 65 and 61 feet below streams S-A49 and S-A51, respectively (this is approximately 15 and 10 feet deeper than the 20-inch pipe). The inclination of the entry and exit angles has been increased to allow the pipe to be installed through protective residual soils and bedrock, and in closer proximity to the entry and exit points than the original, shorter and shallower profile. From a geologic perspective, the longer and deeper profile, in conjunction with the proposed proactive engineering controls and/or drilling BMPs, will be used to reduce the risk of an IR and/or a loss of drilling fluid. Drilling BMPs are described in the Horizontal Directional Drill Analysis component of the overall re-evaluation package.

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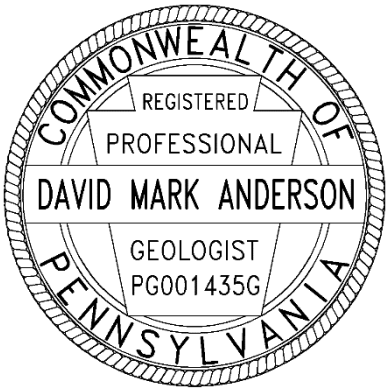
10.0 CERTIFICATION

The studies and evaluations presented in this report (other than Section 5.0) were completed under the direction of a licensed professional geologist (PG) and are covered under the PG seals that follow.

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

Douglas J. Hess, PG
License No. PG000186G

David M. Anderson, PG
License No. PG001435G



Enclosures

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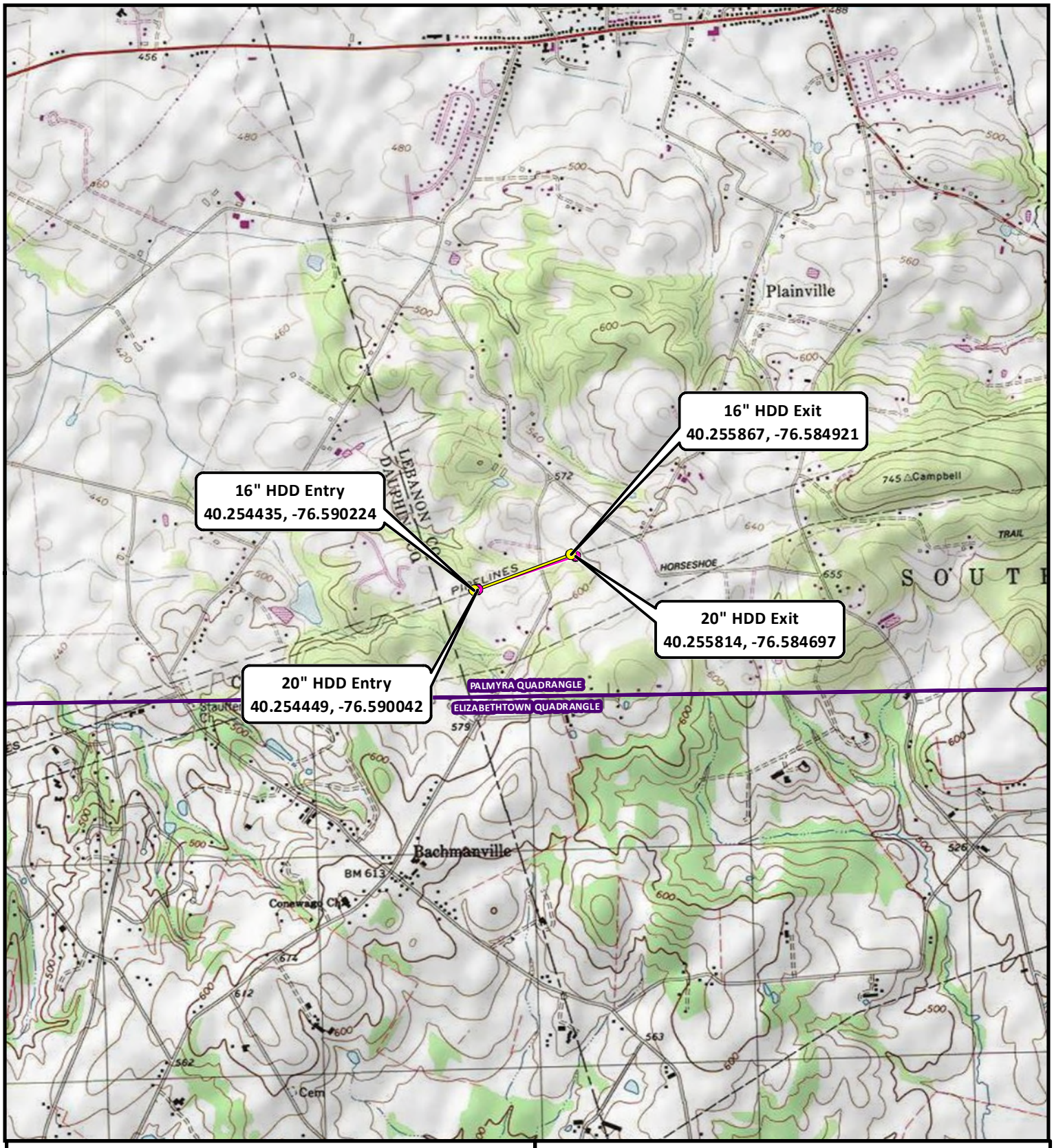
RETTEW

FIGURES



16" HDD Entry/Exit

20" HDD Entry/Exit

16" HDD Profile

20" HDD Profile

Palmyra, PA USGS 7.5' Topographic Quadrangle

2/11/2019

Sunoco Pipeline, L.P.

Schoolhouse Road HDD Location

Figure 1 - Topographic Basemap

South Londonderry Township, Lebanon County, PA

Project No. 096302011

N

W E

S

0 2,000 Feet

1 inch = 2,000 feet

Sunoco Logistics Partners L.P.

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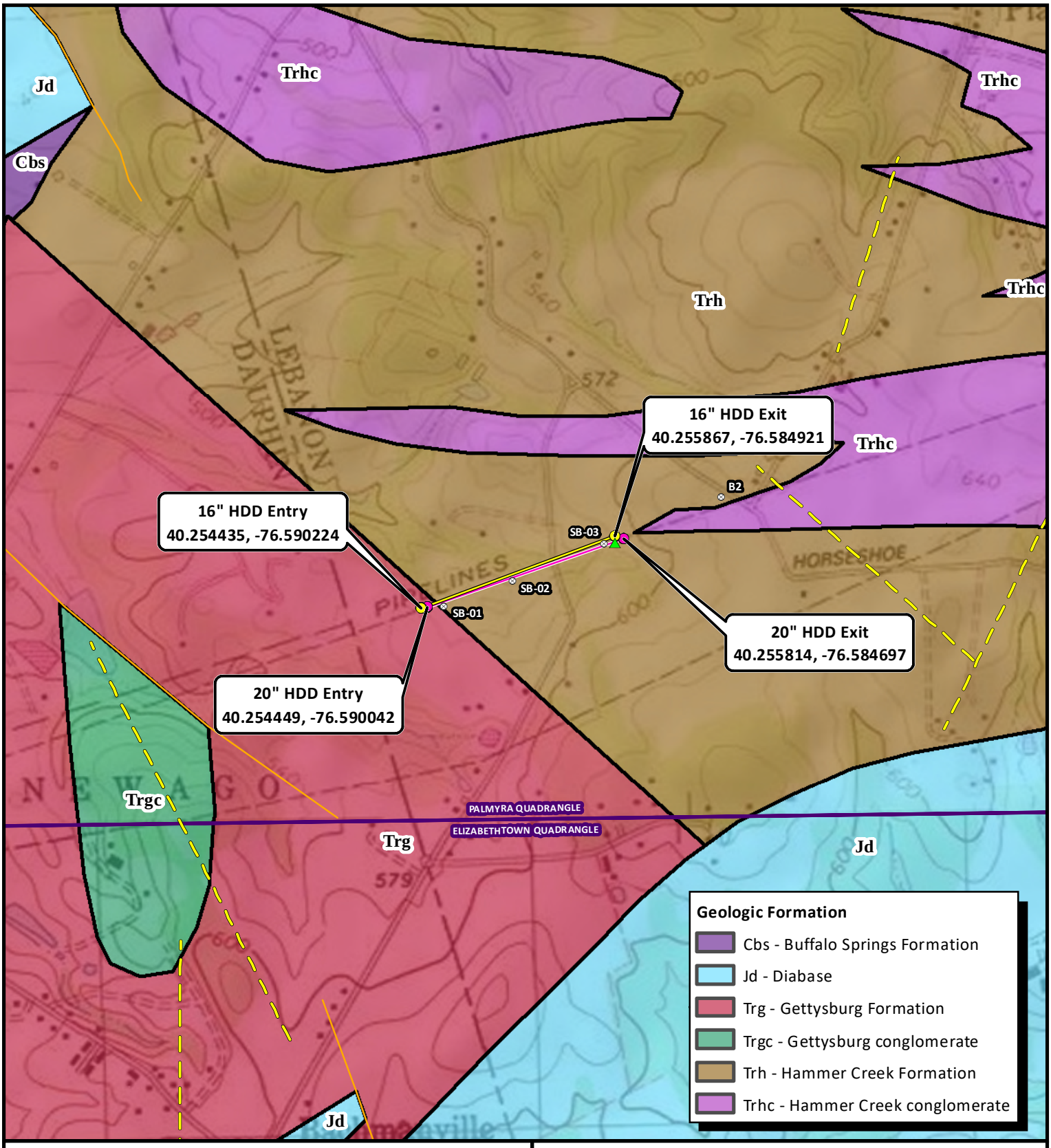

Inadvertent Return
Soil Boring
16" HDD Entry/Exit;
20" HDD Entry/Exit
16" HDD Profile
20" HDD Profile
Inferred Fracture Trace
Geologic Fault

Palmyra, PA USGS 7.5' Topographic Quadrangle
2/11/2019

Sunoco Pipeline, L.P.

Schoolhouse Road HDD Location

Figure 2 - Geologic Map

South Londonderry Township, Lebanon County, PA
Project No. 096302011

N
W E
S

0 1,000 Feet
1 inch = 1,000 feet

Sunoco Logistics Partners L.P.

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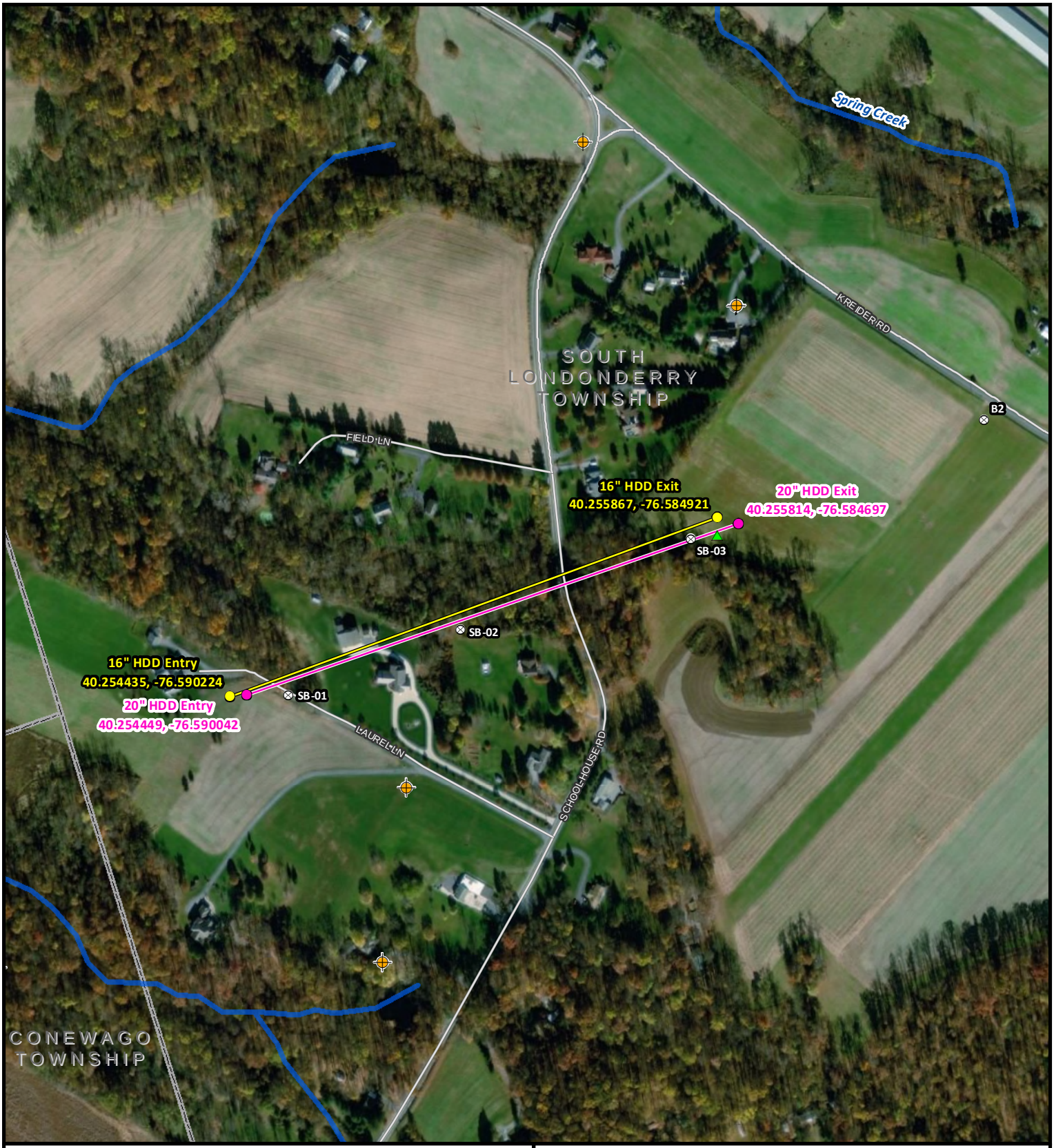

- Inadvertent Return
- Boring Location
- 20" HDD Entry/Exit
- 16" HDD Entry/Exit
- Residential Well
- 16" HDD Profile
- 20" HDD Profile
- NHD Stream
- Road
- Municipal Boundary

2/11/2019

Sunoco Pipeline, L.P.

Schoolhouse Road HDD Location

Figure 3 - Aerial Basemap

South Londonderry Township, Lebanon County, PA

Project No. 096302011

N W E S

0 400 Feet

1 inch = 400 feet

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

Sunoco Logistics Partners L.P.

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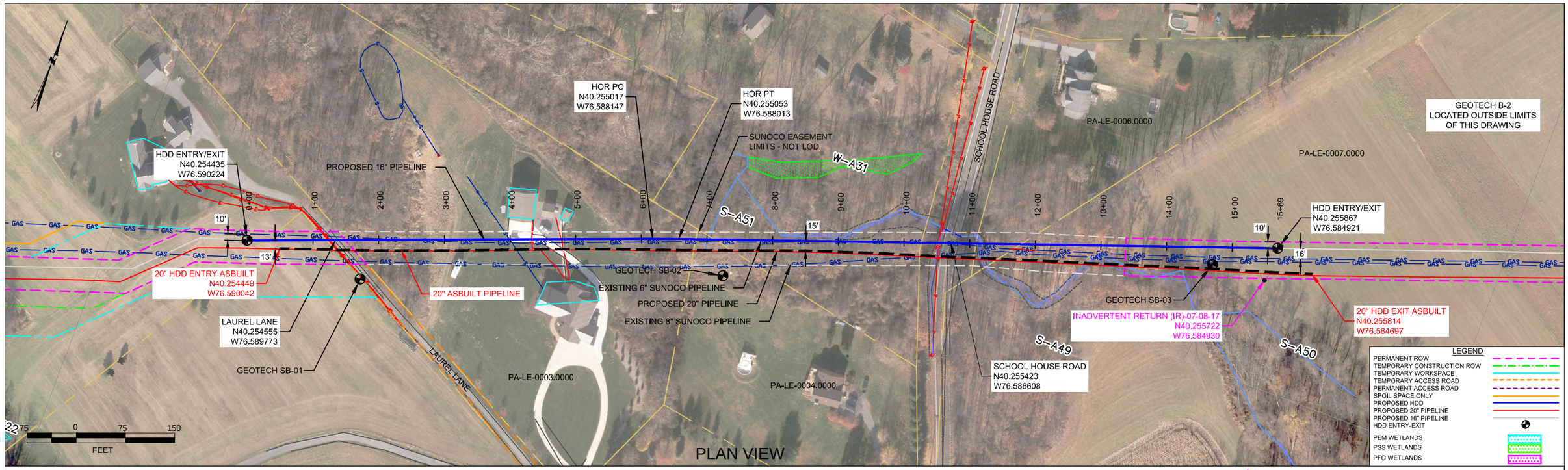
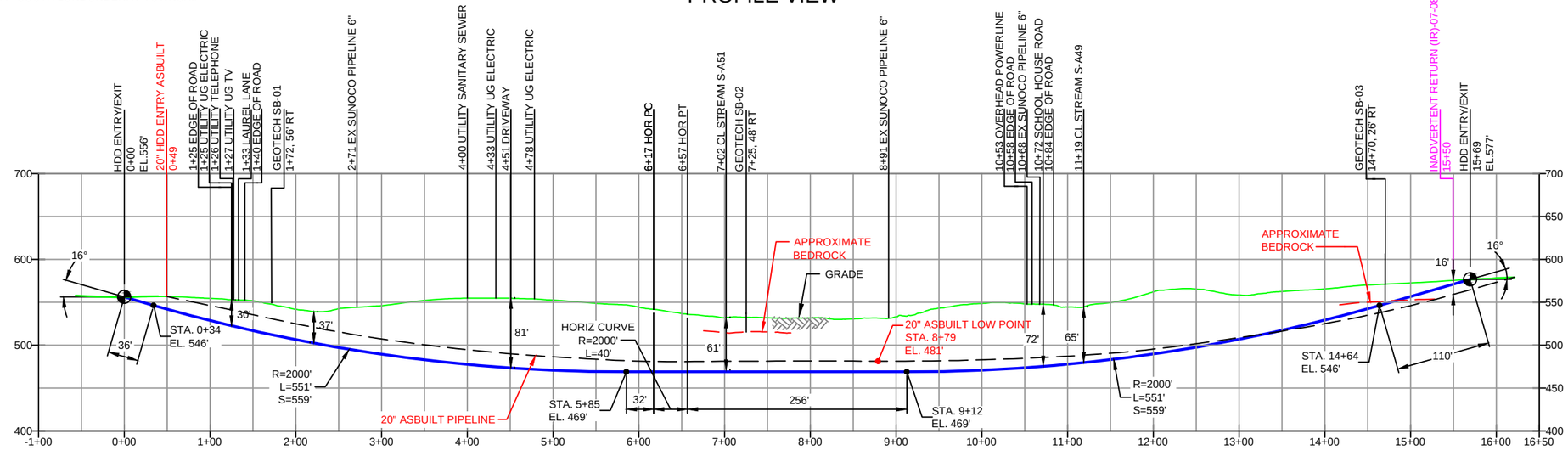
RETTEW

ATTACHMENT 1
REVISED 16-INCH HDD PROFILE AND GEOTECHNICAL BORINGS



LEBANON COUNTY, PENNSYLVANIA - SOUTH LONDONDERRY TOWNSHIP
S3-0091-16

PROFILE VIEW



GEOTECH SB-01
-NG EL. 550'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 19.0')
-WEATHERED SHALE (19.0' - 28.7')
-COMPLETION DEPTH EL. 521.3'

GEOTECH SB-02
-NG EL. 538'
-TOPSOIL (0' - 0.4')
-SM (0.4' - 17.5')
-SM/ML (17.5' - 19.0')
-AUGER REFUSAL (19.0')
-SHALE (19.0' - 20.0')
-LIMESTONE (20.0' - 22.5')
-SANDSTONE (22.5' - 29.0')
-COMPLETION DEPTH EL. 509.0'

GEOTECH SB-03
-NG EL. 570'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 14.0')
-SHALE (14.0' - 19.0')
-AUGER REFUSAL (19.0')
-COMPLETION DEPTH EL. 521.3'

NOTE: REFER TO TEST BORING LOG S3-0091 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-2
-NG EL. 550'
-RESIDIUUM-SANDY SILT ML (0.0' - 3.0')
-RESIDIUUM-SILTY SAND SM (3.0' - 12.0')
-WEATHERED SANDSTONE SILTY SAND SM (12.0' - 16.5')
-WEATHERED SANDSTONE SANDY SILT ML (16.5' - 22.0')
-WEATHERED SANDSTONE SILTY SAND SM (22.0' - 25.0')
-AUGER REFUSAL (25.0')
-GROUNDWATER (36.7')
-SANDSTONE/SILTSTONE (25.0' - 200.0')
-BORING TERMINATED EL.350'

NOTE: REFER TO TEST BORING LOG B-2 INTERTEK PROJECT #04911458 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=): 1569'
   HDD PIPE LENGTH (S=): 1592'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 2100 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 2625 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-5.04	TO	ES-5.05	EROSION & SEDIMENT PLAN
SHEET 24	TO	SHEET 24	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP5	ADDED IR INFORMATION	MRS	02/13/19	RMB	02/13/19	AMC	02/13/19
EP4	DESIGN CHANGE - EXTENDED DRILL AND ADDED GEOTECH INFORMATION	MRS	11/16/18	RMB	11/16/18	AMC	11/16/18
EP3	UPDATED TO MATCH 16" IFC DESIGN AND NOTE 5 AND 10 PER INCREASED 16" MOP	MRS	05/10/18	RMB	05/10/18	AMC	05/10/18
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/10/16	RMB	05/10/16	AAW	05/10/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
SCHOOL HOUSE RD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'

DWG. NO: PA-LE-0005.0000-RD-16

LEGEND:

◎ Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
SCHOOL HOUSE ROAD
LEBANON COUNTY, SOUTH LONDONDERRY TWP, 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:	LAUREL LANE, LEBANON COUNTY, PA			Page 1 of 1	
HDD No.:	SCHOOL HOUSE ROAD	Dates(s) Drilled: 10/26/16		Inspector:	M. ESPOSITO
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED		Total Depth (ft):	28.7
Boring Location Coordinates:		40°15'15.99"N		76°35'22.52"W	

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.3			TOPSOIL (4")					
1	3.0	5.0	0.3		24	SM	DARK REDDISH BROWN SILTY FINE SAND (USCS: SM).	5	9	7	10	**16**
2	8.0	10.0			20		SAME	2	4	3	6	**7**
3	13.0	15.0			19		SAME (USCS: SM).	7	19	25	35	**44**
				19.0								
4	18.0	19.3	19.0		11	PARTIALLY WEATHERED SHALE	PARTIALLY WEATHERED DARK REDDISH BROWN SHALE.	13	50	50/3"		**>50**
5	23.0	23.8			9		SAME	11	50/4"			**>50**
6	28.0	28.7		28.7	8		SAME	25	50/3"			**>50**
							CAVED AND DRY AT 28'.					

Notes/Comments:
Pocket Pentrometer Testing

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

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

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TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406	
Project Location:	SCHOOL HOUSE ROAD, LEBANON COUNTY, PA			Page 1 of 1	
HDD No.:	SCHOOL HOUSE ROAD	Dates(s) Drilled: 10/26/16		Inspector:	M. ESPOSITO
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): SEE NOTES.		Total Depth (ft):	29.0
Boring Location Coordinates:		40°15'17.89"N		76°35'15.84"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	0.4			TOPSOIL (5")					
1	3.0	5.0	0.4		20	SM	DARK REDDISH BROWN FINE SAND WITH SOME FINE TO COARSE	2	7	11	12	**18**
							GRAVEL, WITH A LITTLE SILT.					
2	8.0	10.0			20		DARK REDDISH BROWN FINE SAND WITH SOME FINE GRAVEL, SOME	3	12	20	25	**32**
							SILT (USCS: SM).					
3	13.0	15.0			24		SAME	5	10	14	18	**24**
				17.5								
4	18.0	18.4	17.5		5	SM/ ML	DARK REDDISH BROWN FINE SAND AND SILT, WITH A LITTLE FINE	50/5"				**>50**
				18.4			GRAVEL (USCS: SM/ML).					
							AUGER REFUSAL AT 19'. COMMENCE ROCK CORING.					
							ROCK CORING					
RUN 1	19.0	20.0	19.0		11	SHALE	REDDISH BROWN HIGHLY FRACTURED SHALE.	TCR: 92%, SCR: 81%, RQD: 36%				
				20.0								
RUN 2	20.0	22.5	20.0		30	LIME-STONE	REDDISH GRAY SLIGHTLY FRACTURED LIMESTONE	TCR: 100%, SCR: 90%, RQD: 86%				
				22.5								
RUN 3	22.5	25.0	22.5		30	SANDSTONE	REDDISH BROWN SANDSTONE WITH CONGLOMERATE LENSES.	TCR: 100%, SCR: 100%, RQD: 58%				
RUN 4	25.0	29.0		29.0	44		SAME.	TCR: 92%, SCR: 92%, RQD: 79%				
							CAVED AND DRY AT 18'.					
							CORE TESTING RESULTS (DEPTH 20'-21'):					
							COMPRESSIVE STRENGTH: 8,120 PSI					
							UNIT WEIGHT: 157.1 PCF					
							CORE TESTING RESULTS (DEPTH 23'-23.5'):					
							COMPRESSIVE STRENGTH: 2,940 PSI					
							UNIT WEIGHT: 165.2 PCF					

Notes/Comments:

Pocket Pentrometer Testing

WATER LEVEL ENCOUNTERED AT 19'. MAY BE PERCHED WATER ON TOP OF BEDROCK.

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.

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TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406	
Project Location:	KREIDER ROAD, LEBANON COUNTY, PA			Page 1 of 1	
HDD No.:	SCHOOL HOUSE ROAD	Dates(s) Drilled: 10/26/16		Inspector:	M. ESPOSITO
Boring No.:	SB-03	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED		Total Depth (ft):	19.0
Boring Location Coordinates:		40°15'20.55"N		76°35'6.87"W	

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.3			TOPSOIL (3")					
1	3.0	5.0	0.3		24	SM	DARK REDDISH BROWN FINE SAND WITH SOME SILT, WITH SOME	3	3	12	20	**15**
							FINE TO COARSE GRAVEL.					
2	8.0	9.5			17		DARK REDDISH BROWN FINE SAND AND SILT, WITH SOME F-C	6	35	50		**85**
				14.0			GRAVEL. (USCS: SM).					
3	13.0	14.3	14.0		11		DARK REDDISH BROWN PARTIALLY WEATHERED SILTSTONE OR	4	50	50/3"		**>50**
							SHALE.					
4	18.0	18.8		19.0	7		SAME.	50	50/3"			**>50**
							AUGER REFUSAL AT 19'.					
							CAVED AND DRY AT 17'.					

Notes/Comments:

Pocket Pentrometer Testing

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

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

ROCK CORE DESCRIPTION SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
SCHOOL HOUSE ROAD

Location	Boring No.	Core Run	Core Depth (ft)		TCR (%)	SCR (%)	RQD (%)	Depth (ft)		Weathering	Classification	Bedding Thickness (ft)	Color	Discontinuity Data
			From	To				From	To					
School House Road	SB-02	1	19	20	92	81	36	19	19.5	Highly	Shale	Very thin	Reddish brown	Rubble, very broken up
		2	20	22.5	100	90	86	19.5	23.5	Moderate	Limestone	Massive	Reddish gray	Fractures ranging from 15° to 30°, Avg. 21°
		3	22.5	24	100	100	58	23.5	29	Slight	Sandstone w/ Conglomerate Lenses	Massive	Red	Fractures ranging from 8° to 72°, Avg. 30°
		4	25	29	92	93	79							

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
SCHOOL HOUSE ROAD

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)
School House Road	SB-01	1	3.0	5.0	14.0	47.7	32	26	6	SM
		2	8.0	10.0	13.1	42.3	-	-	-	-
		3	13.0	15.0	7.7	38.2	31	25	6	SM
		4	18.0	19.3	9.6	21.8	-	-	-	-
		5	23.0	23.8	6.0	23.8	-	-	-	-
	SB-02	1	3.0	5.0	9.4	17.5	-	-	-	-
		2	8.0	10.0	9.2	24.9	NV	NP	NP	SM
		3	13.0	15.0	10.0	24.3	-	-	-	-
		4	18.0	18.4	17.6	48.0	32	25	7	SM/ML
	SB-03	1	3.0	5.0	13.0	32.0	-	-	-	-
		2	8.0	9.5	10.1	47.5	33	26	11	SM
		3	13.0	14.3	10.7	22.4	-	-	-	-
		4	18.0	18.8	14.2	42.4	-	-	-	-

Rock Core Testing Results				
Boring No.	Core Run	Approximate Depth (ft)	Compressive Strength (psi)	Unit Weight (pcf)
SB-02	2	20.0-21.0	8,120	157.1
SB-02	3	23.0-23.5	2,940	165.2

Notes:

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

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
SCHOOL HOUSE ROAD

HDD IDENTIFICATION	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
School House Road	SB-01 SB-02 SB-03	Gettysburg Fm - reddish-brown to maroon silty mudstone and shale and soft, red-brown, medium- to fine-grained sandstone, with minor amounts of yellowish-brown shale and sandstone and thin beds of impure limestone. Diabase - occurs primarily as dikes and sheets and forms a complex igneous network that extensively intrudes sedimentary rocks in the Gettysburg basin.	Rolling hills, sloping E-W	Gettysburg Fm	Silty mudstone-shale-sandstone w/ some impure limestone	16,000	7-35	High yield zones present

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

FIELD DESCRIPTION AND LOGGING SYSTEM FOR SOIL EXPLORATION

GRANULAR SOILS

(Sand, Gravel & Combinations)

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

Relative Proportions

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

Particle Size Identification

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

COHESIVE SOILS

(Silt, Clay & Combinations)

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

Plasticity

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

ROCK

(Rock Cores)

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

RQD: Rock Quality Designation
TCR: Total Core Recovery
SCR: Solid Core Recovery

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

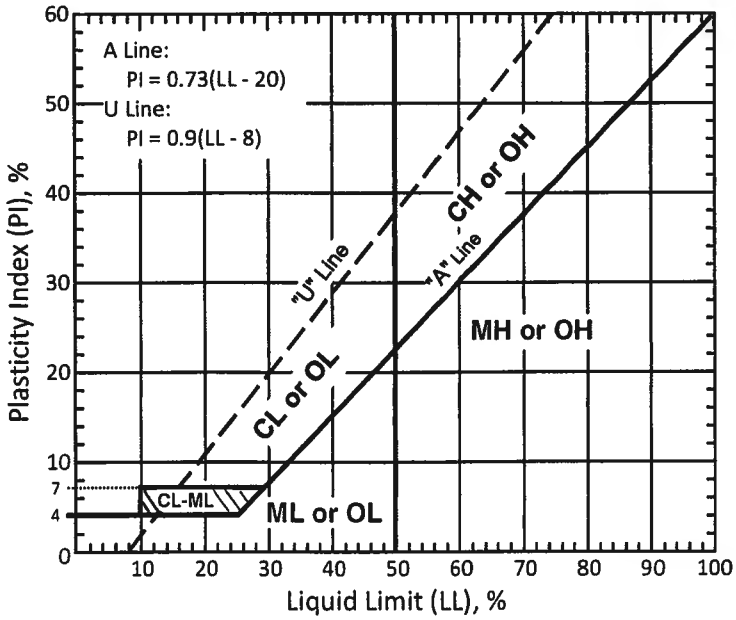
Groundwater observations were made at the times indicated. Groundwater elevations fluctuate throughout a given year, depending on actual field porosity and variations in seasonal and annual precipitation.

UNIFIED SOIL CLASSIFICATION SYSTEM [Casagrande (1948)]

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

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

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



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

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Figure 1: Site Vicinity Map

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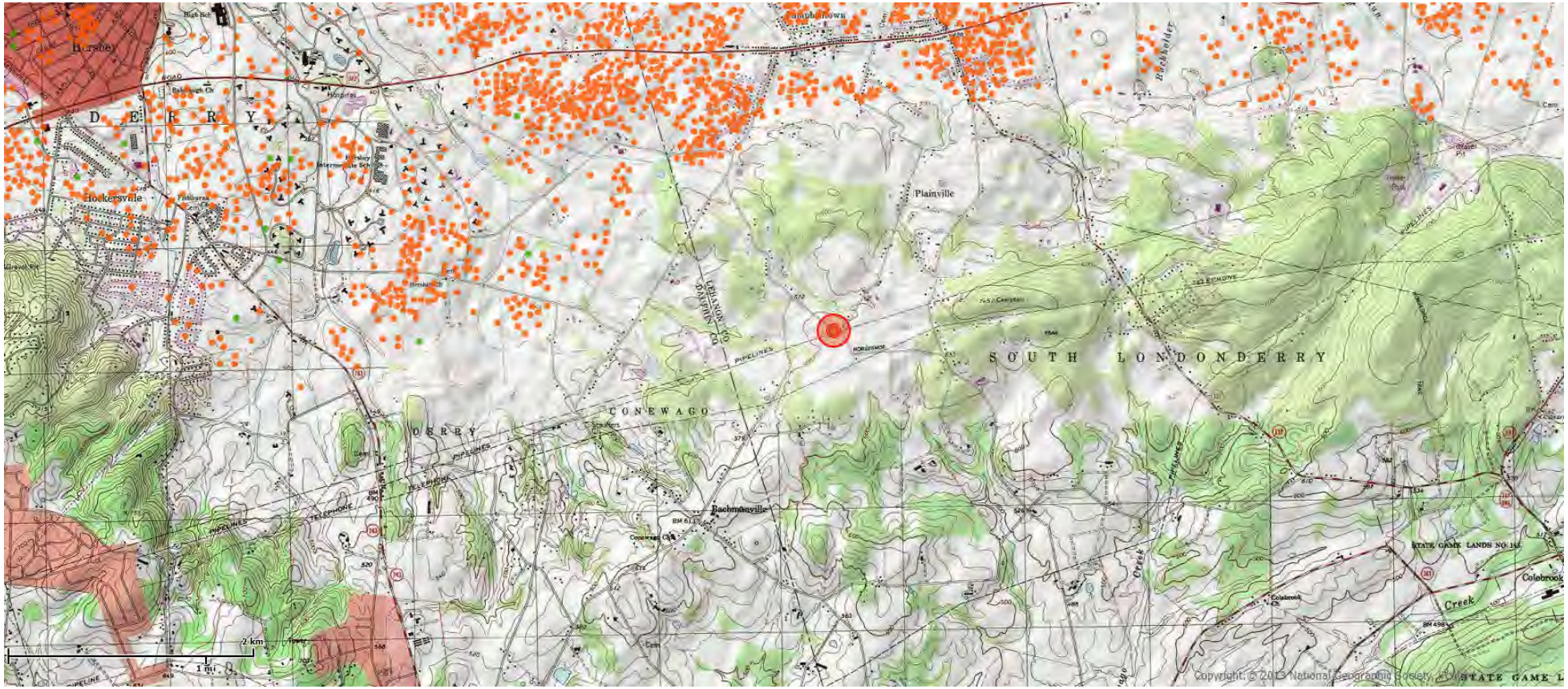
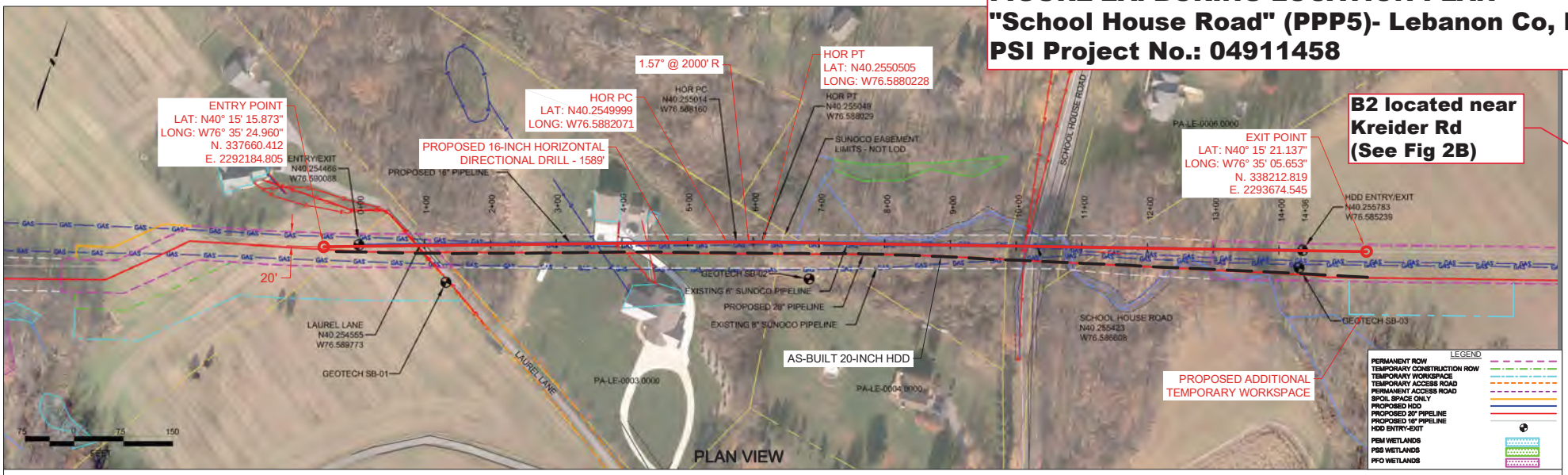


Created using PA DCNR Map Viewer

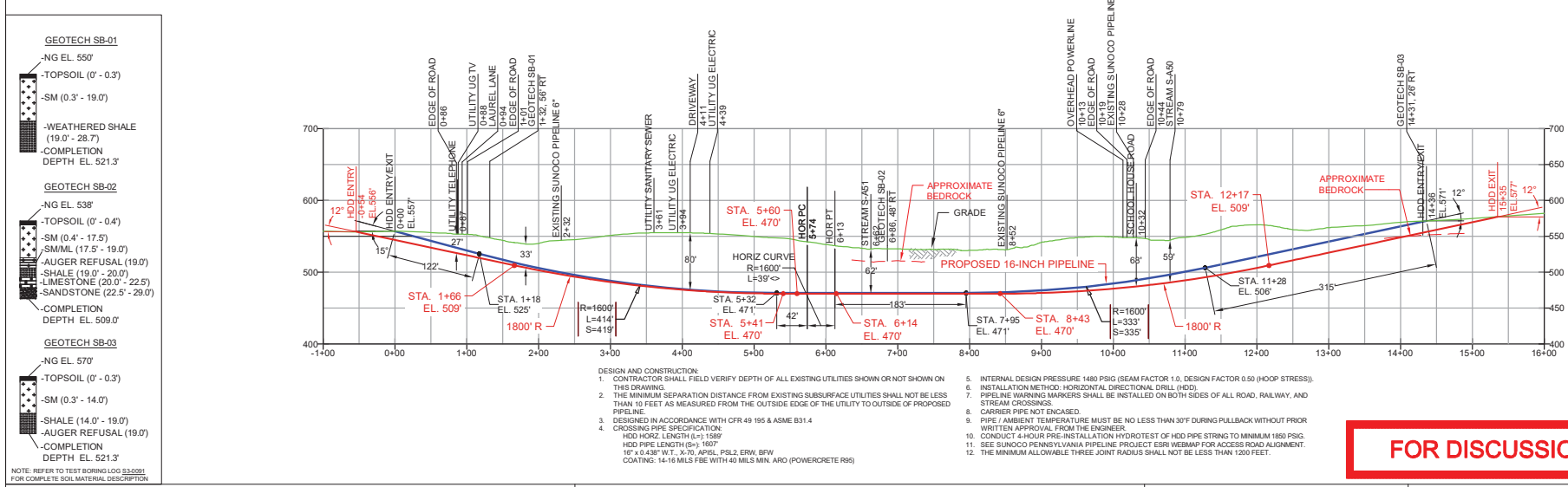
Map created on Tue Dec 19 2017

FIGURE 2A: BORING LOCATION PLAN
"School House Road" (PPP5)- Lebanon Co, PA
PSI Project No.: 04911458



LEBANON COUNTY, PENNSYLVANIA - SOUTH LONDONDERRY TOWNSHIP S3-0091-16

PROFILE VIEW



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=): 1589'
   HDD PIPE LENGTH (S=): 1607'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. THE MINIMUM ALLOWABLE THREE JOINT RADIUS SHALL NOT BE LESS THAN 1200 FEET.

FOR DISCUSSION 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
11	LANEY DESIGN CHANGE - ADDED 20-INCH AS-BUILT ALIGNMENT	KBP	09/15/17				
10	LANEY DESIGN CHANGE	KBP	09/13/17				
9	LANEY DESIGN CHANGE	KBP	06/15/17				
8	DESIGN CHANGE - ADDED HORIZONTAL CURVE	MRS	03/14/17	RMB	03/14/17	AMC	03/14/17
7	REVISED PROFILE WITH 201 LIDAR	MRS	02/15/17	RMB	02/15/17	AAW	02/15/17
6	ADDED GEOTECH INFO	MRS	11/29/16	RMB	09/28/16	AAW	11/29/16

Sunoco Logistics Partners L.P.

laney

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
SCHOOL HOUSE RD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' | DWG. NO: PA-LE-0005.0000-RD-16

FIGURE 2B: BORING LOCATION PLAN

School House Rd (PPP5)-Lebanon Co, PA
PSI Project No.:04911458

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Figure 3: Site Geology Map

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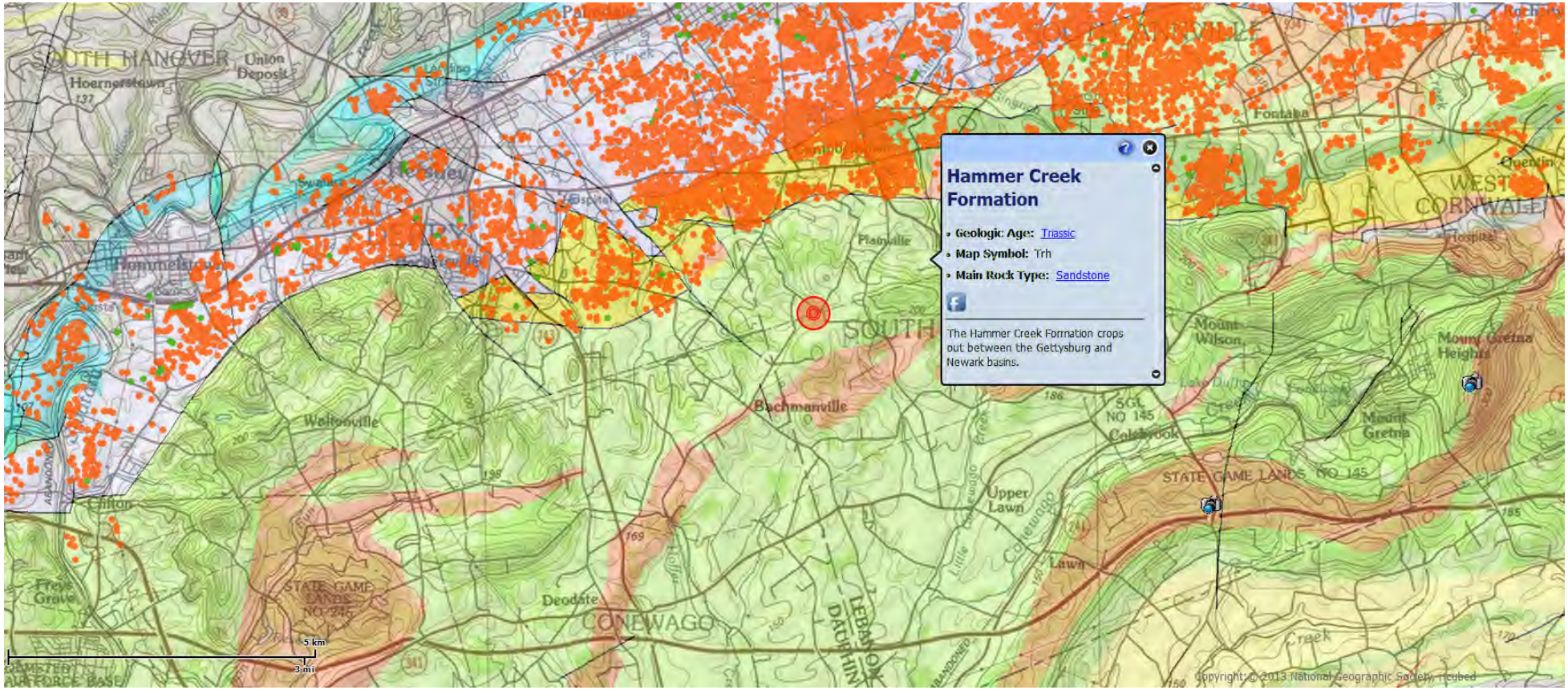

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Map created on Tue Dec 19 2017

BORING B-2

DATE STARTED:	12/6/17	**DRILL COMPANY:**	Eichelbergers
DATE COMPLETED:	12/8/17	**DRILLER:** L. Trimble	**LOGGED BY:** Eicher/Frederick/Eshelma
COMPLETION DEPTH	200.0 ft	**DRILL RIG:**	Track Rig
BENCHMARK:	N/A	**DRILLING METHOD:**	HSA/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS2.000-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water

While Drilling	None Enc.
Upon Completion	36.7 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			S-1	23	**RESIDUUM**-Stiff to Very Stiff, Dark brown, Sandy SILT, moist	ML	5-5-5-6 N=10	14		
	5			S-2	6	**RESIDUUM**-Medium Dense, Dark brown, Silty SAND, moist	SM	14-50/5"	12	>>	Non-Plastic Fines=48.0%
	10			S-3	24			10-12-17-31 N=29	10		
	15			S-4	10	**Highly Weathered SANDSTONE Sampled As:**-Very Dense, Dark brown, Silty SAND, moist	SM	8-50/4"	13	>>	Fines=37.4%
	20			S-5	24	**Highly Weathered SANDSTONE Sampled As:**-Hard, Dark brown, Sandy SILT, moist	ML	22-29-39-43 N=68	13	>>	Non-Plastic Fines=54.0%
	25			S-6	3	**Highly Weathered SANDSTONE Sampled As:**-Very Dense, Dark brown, Silty SAND, moist	SM	50/3"	11	>>	
				R-1	60	Auger refusal @ 25 feet **SANDSTONE** - Red-brown to dark gray-brown, Slightly Weathered, very broken to massive, hard to very hard, flat medium to thick bedded, random, moderate to very steep, moderately to widely spaced fractures with tight joints Broken layer @ 28.6 feet (~ 3 inches thick)		RQD=10 Rec=100%		>>	2 min. 2 min. Q_u = 203.0 tsf 153.8 pcf 1 min. 1 min.
	30										

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

PROJECT NO.: 04911458
PROJECT: Energy Transfer HDD (DPS)
LOCATION: School House Rd (PPP5) Lebanon Co., PA
PA-LE-0005.0000-RD/PO#20171129-2

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

BORING B-2

DATE STARTED:	12/6/17	**DRILL COMPANY:**	Eichelbergers
DATE COMPLETED:	12/8/17	**DRILLER:** L. Trimble	**LOGGED BY:** Eicher/Frederick/Eshelma
COMPLETION DEPTH	200.0 ft	**DRILL RIG:**	Track Rig
BENCHMARK:	N/A	**DRILLING METHOD:**	HSA/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS2.000-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

Water — While Drilling: None Enc.; Upon Completion: 36.7 feet

BORING LOCATION: See Boring Location Plan

REMARKS:

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
	30			R-2	60	**SANDSTONE** - Red-brown to dark gray-brown, Slightly Weathered, very broken to massive, hard to very hard, flat medium to thick bedded, random, moderate to very steep, moderately to widely spaced fractures with tight joints Weathered/broken layer @ 30 feet (~ 3-1/4 inches thick) Weathered/broken layer from 30.9 to 32.2 feet.		RQD=35 Rec=100%			2 min. >> Qu = 439.7 tsf 3 min. 156.9 pcf
	35			R-3	60			RQD=87 Rec=100%			2 min. 2 min. 3 min. 3 min. 3 min. 3 min.
	40			R-4	60			RQD=100 Rec=100%			3 min. >> Qu = 770.8 tsf 3 min. 163.8 pcf 4 min. 3 min.
	45			R-5	60	Weathered layer @ 45.3 feet (~ 15 inches thick)		RQD=37 Rec=100%			2 min. 2 min. 3 min. 2 min. 2 min. 2 min.
	50			R-6	60	Broken layer @ 49.5 feet (~ 3-3/4 inches thick) With Siltstone and Conglomeratic Sandstone interbeds of varying thickness from 50 to 65 feet.		RQD=75 Rec=100%			2 min. 5 min. 5 min. >> Qu = 405.0 tsf 4 min. 150.1 pcf 4 min.
	55			R-7	60			RQD=48 Rec=100%			4 min. 4 min. 3 min. >> Qu = 410.2 tsf 4 min. 164.7 pcf
	60										

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

PROJECT NO.: 04911458
PROJECT: Energy Transfer HDD (DPS)
LOCATION: School House Rd (PPP5) Lebanon Co., PA
PA-LE-0005.0000-RD/PO#20171129-2

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

BORING B-2

DATE STARTED:	12/6/17	**DRILL COMPANY:**	Eichelbergers
DATE COMPLETED:	12/8/17	**DRILLER:** L. Trimble	**LOGGED BY:** Eichelberger/Frederick/Eshelma
COMPLETION DEPTH	200.0 ft	**DRILL RIG:**	Track Rig
BENCHMARK:	N/A	**DRILLING METHOD:**	HSA/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS2.000-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

Water: While Drilling — None Enc.; Upon Completion — 36.7 feet

BORING LOCATION: See Boring Location Plan

REMARKS:

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
	60					**SANDSTONE** - Red-brown to dark gray-brown, Slightly Weathered, very broken to massive, hard to very hard, flat medium to thick bedded, random, moderate to very steep, moderately to widely spaced fractures with tight joints					8 min.
				R-8	54	Weathered/broken layer @ 63.4 feet (~ 2-1/4 inches thick)		RQD=25 Rec=90%			4 min.
						Broken layer @ 63.9 feet (~ 9-1/2 inches thick)					6 min.
	65					**SILTSTONE with Interbedded Sandstone** - Red-brown to red-gray-brown, Slightly Weathered, very broken to massive, moderately hard to hard, laminated flat to shallow bedding, closely to moderately spaced, shallow to moderate angled fractures, mostly bedding joints with tight joints					2 min.
											2 min.
											3 min.
				R-9	60			RQD=37 Rec=100%			3 min.
											4 min.
											4 min.
										>> Q_u = 531.3 tsf	4 min.
										166.4 pcf	4 min.
	70					Weathered layer @ 67.1 feet (~ 5-1/2 inches thick)					4 min.
						Broken layer @ 69.8 feet (~ 2-1/4 inches thick)					4 min.
				R-10	60	Highly Weathered layer @ 70.7 feet (~ 3-1/4 inches thick)		RQD=80 Rec=100%			4 min.
											5 min.
											6 min.
	75										3 min.
				R-11	60			RQD=67 Rec=100%		>> Q_u = 619.6 tsf	
										166.5 pcf	
						SANDSTONE - Red-brown to light gray, Slightly Weathered, very broken to massive, moderately hard to very hard, flat medium to thick bedding, random, moderate to very steep, moderately to widely spaced fractures with tight joints					
	80					Broken layer @ 78.6 feet (~ 3-3/4 inches thick)					2 min.
				R-12	60	Highly Weathered/very broken layer @ 81.3 feet (~ 2 inches thick)		RQD=60 Rec=100%			1 min.
						Broken layer @ 82.5 feet (~ 6-1/4 inches thick)					3 min.
						Weathered/broken layer with soil @ 85 feet (~ 13-1/2 inches thick)					2 min.
	85										2 min.
											2 min.
										>> Q_u = 559.9 tsf	2 min.
				R-13	60			RQD=82 Rec=100%		167.5 pcf	2 min.
											2 min.
	90										

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Professional Service Industries, Inc.
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Telephone: (717) 230-8622

PROJECT NO.: 04911458
PROJECT: Energy Transfer HDD (DPS)
LOCATION: School House Rd (PPP5) Lebanon Co., PA
PA-LE-0005.0000-RD/PO#20171129-2

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

BORING B-2

DATE STARTED:	12/6/17	**DRILL COMPANY:**	Eichelbergers
DATE COMPLETED:	12/8/17	**DRILLER:** L. Trimble	**LOGGED BY:** Eichler/Frederick/Eshelma
COMPLETION DEPTH	200.0 ft	**DRILL RIG:**	Track Rig
BENCHMARK:	N/A	**DRILLING METHOD:**	HSA/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS2.000-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

Water

While Drilling	None Enc.
Upon Completion	36.7 feet

BORING LOCATION:
See Boring Location Plan

REMARKS:

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
	90					**SANDSTONE** - Red-brown to light gray, Slightly Weathered, very broken to massive, moderately hard to very hard, flat medium to thick bedding, random, moderate to very steep, moderately to widely spaced fractures with tight joints					2 min.
											2 min.
				R-14	60			RQD=100 Rec=100%			2 min.
											3 min.
											3 min. >> Q_u = 470.8 tsf 163.8 pcf
	95					Weathered/broken layer @ 95 feet (~ 4-1/4 inches thick)					2 min.
											2 min.
											2 min.
				R-15	60			RQD=95 Rec=100%			3 min.
											2 min.
						Weathered/broken layer @ 98.9 feet (~ 2-1/2 inches thick)					2 min.
	100										2 min.
											2 min.
				R-16	60			RQD=85 Rec=100%			2 min.
											2 min.
											2 min.
	105										2 min. >> Q_u = 454.9 tsf 163.9 pcf
											2 min.
											2 min.
				R-17	60			RQD=100 Rec=100%			2 min.
											2 min.
											2 min.
	110					Weathered/Highly Weathered layer @ 110 feet (~ 17-1/2 inches thick)					2 min.
											2 min.
											3 min.
				R-18	59			RQD=58 Rec=98%			4 min. >> Q_u = 427.2 tsf 167.3 pcf
						SILTSTONE with Interbedded Sandstone - Red-brown, Slightly Weathered, very broken to massive, moderately hard, laminated, flat to shallow bedding, closely to moderate spaced, shallow to moderate dip fractures, bedding joints, tight					5 min.
	115										3 min.
											3 min.
											5 min.
				R-19	60			RQD=100 Rec=100%			3 min.
											5 min.
	120										

Continued Next Page

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Professional Service Industries, Inc.
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Harrisburg, PA 17104
Telephone: (717) 230-8622

PROJECT NO.: 04911458
PROJECT: Energy Transfer HDD (DPS)
LOCATION: School House Rd (PPP5) Lebanon Co., PA
PA-LE-0005.0000-RD/PO#20171129-2

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

BORING B-2

DATE STARTED:	12/6/17	**DRILL COMPANY:**	Eichelbergers
DATE COMPLETED:	12/8/17	**DRILLER:** L. Trimble	**LOGGED BY:** Eichelberger/Frederick/Eshelma
COMPLETION DEPTH	200.0 ft	**DRILL RIG:**	Track Rig
BENCHMARK:	N/A	**DRILLING METHOD:**	HSA/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS2.000-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water: While Drilling — None Enc.; Upon Completion — 36.7 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
	120					**SILTSTONE with Interbedded Sandstone** - Red-brown, Slightly Weathered, very broken to massive, moderately hard, laminated, flat to shallow bedding, closely to moderate spaced, shallow to moderate dip fractures, bedding joints, tight					4 min. 3 min. 3 min. 4 min.
				R-20	60			RQD=100 Rec=100%			>> Q_u = 531.0 tsf 164.1 pcf 4 min.
	125										2 min. 7 min. 3 min. 4 min.
				R-21	58			RQD=90 Rec=97%			>> Q_u = 642.8 tsf 162.2 pcf 5 min.
	130					**SANDSTONE** - Dark red-brown to gray-brown, Slightly Weathered, broken to massive, hard, flat medium to thick bedding, random, moderate to very steep, moderately to widely spaced fractures with tight joints					4 min.
				R-22	60			RQD=88 Rec=100%			5 min. 4 min. 4 min.
						Weathered/Highly Weathered layer @ 133.4 feet (~ 7-1/2 inches thick)					
	135										2 min. 4 min.
				R-23	58			RQD=88 Rec=97%			4 min. >> Q_u = 249.0 tsf 167.0 pcf 3 min.
	140										3 min. 3 min.
				R-24	60			RQD=100 Rec=100%			4 min. 3 min. >> Q_u = 474.8 tsf 170.3 pcf 5 min.
	145										4 min.
				R-25	60			RQD=72 Rec=100%			3 min. 4 min. >> Q_u = 88.8 tsf 145.5 pcf 5 min.
						Soil layer @ 148 feet (~ 1 inch thick)					
	150										

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

PROJECT NO.: 04911458
PROJECT: Energy Transfer HDD (DPS)
LOCATION: School House Rd (PPP5) Lebanon Co., PA
PA-LE-0005.0000-RD/PO#20171129-2

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

BORING B-2

DATE STARTED:	12/6/17	**DRILL COMPANY:**	Eichelbergers
DATE COMPLETED:	12/8/17	**DRILLER:** L. Trimble	**LOGGED BY:** Eichler/Frederick/Eshelma
COMPLETION DEPTH	200.0 ft	**DRILL RIG:**	Track Rig
BENCHMARK:	N/A	**DRILLING METHOD:**	HSA/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS2.000-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water: While Drilling — None Enc.; Upon Completion — 36.7 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
	150			R-26	60	**CONGLOMERATE** - Tan to light gray to dark brown, Weathered to Slightly Weathered, broken to slightly broken, hard to very hard, cross bedded, crypto crystalline, flat to moderate, indistinct, tight joints, bedded joints Weathered/Highly Weathered layer @ 150 feet (~ 11-1/4 inches thick)		RQD=57 Rec=100%			2 min. 3 min. 3 min. 3 min. 4 min. >> Q_u = 179.6 tsf 149.4 pcf
	155			R-27	60	**SILTSTONE with Interbedded Sandstone** - Red-gray-brown to dark brown, Slightly Weathered, very broken to massive, moderately hard to hard, laminated, flat to shallow bedding, very close to moderate spaced, shallow to moderate tight fractures, bedding joints, tight, calcareous, conglomerate interbeds		RQD=90 Rec=100%			3 min. 4 min. 3 min. 4 min. 4 min. 4 min.
	160			R-28	43			RQD=72 Rec=72%			4 min. 4 min. 3 min. >> Q_u = 330.7 tsf 167.4 pcf 4 min.
	165			R-29	60			RQD=95 Rec=100%			4 min. 3 min. 3 min. 3 min. 3 min.
	170			R-30	60	**SANDSTONE with Interbedded Siltstone** - Dark red-brown to gray-brown, Slightly Weathered, broken to massive, moderately hard, medium bedding, flat to moderate, moderate to wide fractures, tight joints		RQD=95 Rec=100%			2 min. >> Q_u = 698.6 tsf 162.3 pcf 4 min. 3 min. 3 min. 4 min.
	175			R-31	60	Weathered/broken layer @ 177.4 feet (~ 3-1/4 inches thick) Broken layer @ 178.2 feet (~ 10-1/4 inches thick)		RQD=62 Rec=100%			3 min. 3 min. 3 min. 4 min.
	180					*Continued Next Page*					

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

PROJECT NO.: 04911458
PROJECT: Energy Transfer HDD (DPS)
LOCATION: School House Rd (PPP5) Lebanon Co., PA
PA-LE-0005.0000-RD/PO#20171129-2

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

BORING B-2

DATE STARTED:	12/6/17	**DRILL COMPANY:**	Eichelbergers
DATE COMPLETED:	12/8/17	**DRILLER:** L. Trimble	**LOGGED BY:** Eicher/Frederick/Eshelma
COMPLETION DEPTH	200.0 ft	**DRILL RIG:**	Track Rig
BENCHMARK:	N/A	**DRILLING METHOD:**	HSA/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS2.000-in Core
LATITUDE:	n/a°	**HAMMER TYPE:**	Automatic
LONGITUDE:	n/a°	**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	F. Hoffman

REMARKS:

Water

While Drilling	None Enc.
Upon Completion	36.7 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
	180					**SANDSTONE** - Dark red-brown to light gray-brown, Weathered to Slightly Weathered, very broken to massive, moderately hard to very hard, flat to medium bedding, moderately to highly weathered, medium hard, steep to moderate dip, closed, spaced fractures, tight to open joints					4 min.
						Soil layer @ 180.3 feet (~ 1-1/2 inches thick)					>> Qu = 459.7 tsf
						Broken layer @ 180.7 feet (~ 1-3/4 inches thick)					155.0 pcf
				R-32	60	Highly Weathered/very broken layer @ 183.6 feet (~ 5-1/2 inches thick)		RQD=30 Rec=100%			2 min.
											2 min.
											2 min.
	185										2 min.
						SANDSTONE with Interbedded Conglomeratic Sandstone - Light red-brown to dark gray-brown, Slightly Weathered, broken to massive, moderately hard to very hard, shallow bedding, moderate to thick, moderately to widely spaced, shallow to steep random fractures with tight joints					4 min.
											5 min.
				R-33	60			RQD=80 Rec=100%			>> Qu = 416.5 tsf
											154.0 pcf
											4 min.
											4 min.
											4 min.
	190										4 min.
											3 min.
						Weathered/Highly Weathered layer with soil from 191.9 to 194 feet.					3 min.
				R-34	60			RQD=10 Rec=100%			3 min.
											5 min.
											4 min.
	195										4 min.
											4 min.
											4 min.
				R-35	60			RQD=100 Rec=100%			>> Qu = 158.7 tsf
											163.9 pcf
											4 min.
	200										4 min.
						Test boring terminated @ 200 feet					

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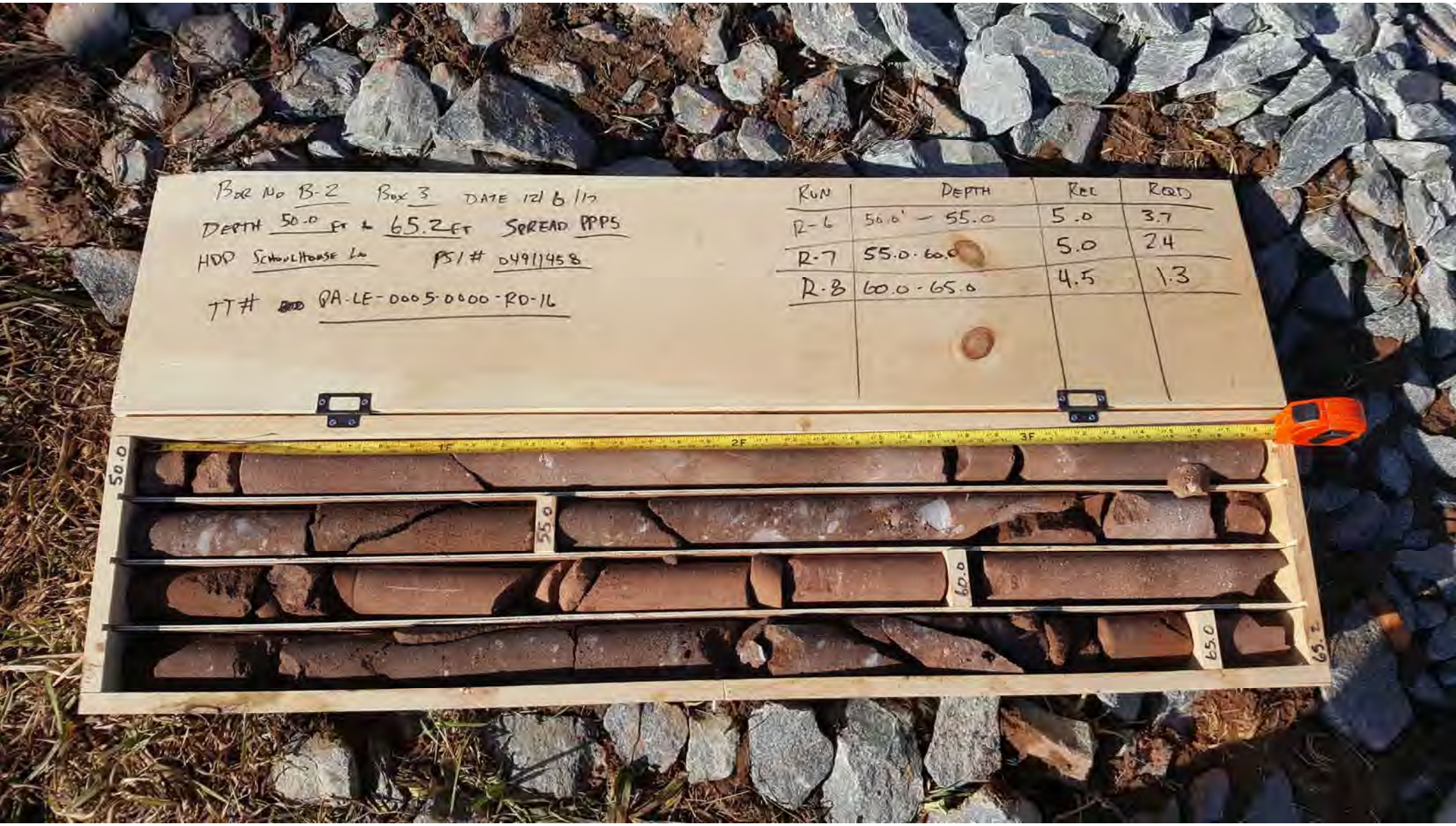
PROJECT NO.: 04911458
PROJECT: Energy Transfer HDD (DPS)
LOCATION: School House Rd (PPP5)
Lebanon Co., PA
PA-LE-0005.0000-RD/PO#20171129-2

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


BOR NO B-2 DATE 12/5/17 BOX 1
DEPTH 0.0 FT to 36.0 FT SPREAD PPP5
HDD SCHOOL HOUSE LN PSI # 04911458
TT DRAWING # PA-LE-0005,0000-RD-16
RUN | DEPTH | REC | RQD
R-1 | 25.0' - 30.0 | 5.0 | 0.5
R-2 | 30.0' - 35.0 | 5.0 | 1.7
R-3 | 35.0 - 40.0 | 5.0 | 4.3
1F
2F
3F
0.0
25.0
30.0
35.0
36.0


BOR NO B-2 DATE 12/5/17 Box 2
DEPTH 36.0 FT to 50.0 FT SPREAD PPP 5
HOP SCHOOLHOUSE LN PSI # 04911458
TT# PA-LE-0005.0000-RD-16
RUN | DEPTH | REC | RQD
R-3 | 35.0 - 40.0 | 5.0 | 4.3
R-4 | 40.0 - 45.0 | 5.0 | 5.0
R-5 | 45.0 - 50.0 | 5.0 | 1.8
36.0
40.0
45.0
50.0


Bor No B-2 Box 3 DATE 12/6/17
DEPTH 50.0 FT & 65.2 FT SPREAD PPPS
HDD Schoolhouse Ln PSI # 04911458
TT# RDD QA-LE-0005-0000-RD-16
RUN | DEPTH | REC | RQD
R-6 | 50.0' - 55.0 | 5.0 | 3.7
R-7 | 55.0 - 60.0 | 5.0 | 2.4
R-8 | 60.0 - 65.0 | 4.5 | 1.3
1F
2F
3F
50.0
55.0
60.0
65.0
65.2


BOR No B-2 Box 4 Date 12/6/17
DEPTH 65.2 FT to 80.0 FT SPREAD PPPS
HOD SCHOOLHOUSE LN PS/# 0411458
TT# PA.CE.005.0000.RD-16
RUN | DEPTH | REC | RQD
R-9 | 65.0 - 70.0 | 5.0 | 1.8
R-10 | 70.0 - 75.0 | 5.0 | 4.0
R-11 | 75.0 - 80.0 | 5.0 | 3.3
65.2
70.0
75.0
80.0


BOR No B-2 Box 5 DATE 12/6/17
DEPTH 80.0ft to 95.0 FT SPREAD PPP5
HDD SchoolHouse Ln PSIH 491145B
HT USD
TT# PALE 0005 0000 RD-16
RUN | DEPTH | REC | RQD
R-12 | 80.0 - 85.0 | 5.0 | 3.0
R-13 | 85.0 - 90.0 | 5.0 | 4.1
R-14 | 90.0 - 95.0 | 5.0 | 5.0
80.0
1F
2F
3F
85.0
90.0
95.0


Bor No B-2 Box 6 DATE 12/6/17
DEPTH 95.0 Ft to 110.0 Ft 5 DREAD PPPS
HOD SCHOOLHOUSE LN PSI# 4911458
TT# PA-LE-0005-0000-RD-16
RUN | DEPTH | REC | RQD
R-15 | 95.0 – 100.0 | 5.0 | 4.7
R-16 | 100.0 - 105.0 | 5.0 | 4.2
R-17 | 105.0 - 110.0 | 5.0 | 5.0
95.0
100.0
105.0
110.0

TT# PA-LE-0005-0000-RD-16

Bor No B-2 Box 7 DATE 12/6/17 - 12/7/17

DEPTH 110.0 FT to 124.1 FT SPREAD PPP5

HDD Schoolhouse Ln PSI# 4911458

TT# PA-LE-0005.0000-RD-16

RUN	DEPTH	REC	RQD
R-18	110.0 – 115.0	4.9	2.9
R-19	115.0 - 120.0	5.0	5.0
R-20	120.0 - 126.0	5.0	5.0


BOR NO. B-2 BOX 8 DATE 12-7-17
Depth 124.1 to 139.0 SPREAD PPP-5
HDD SCHOOL HOUSE LN. PSI # 4911458
TT # PA-LE-0005-0000-RD-16
RUN | DEPTH | REC | RQD
R21 | 125-130 | 4.8 | 4.5
R-22 | 130-135 | 5.0 | 4.4
R-23 | 135-140 | 4.4 | 4.0
124.1
125.0
130.0
SCHOOL HOUSE LN


BOR NO. B-2 BOX 4 DATE 12/7/17
DEPTH 139.0 to 153.5 SPREAD PPP-5
HDD SCHOOLHOUSE LN. PSI # 4911458
TT# PA-LE-0005-0000-RD-16
RUN | DEPTH | REC | RQD
R-23 | 135.0-140.0 | 4.8 | 4.4
R-24 | 140.0 145.0 | 5.0 | 5.0
R-25 | 145.0 150.0 | 5.0 | 3.6
R-26 | 150.0 155.0 | 5.0 | 2.8
139.0
148
153.5


BOR NO B-2 Box 10 of Date 12/7/17
Depth 153.5 to 168.9 Spread PPP-5
HDD School House Ln. PSI # 4911458
TT# PA-LE-0005-0000-RD-16
RUN | Depth | REC | RQD
R26 | 150.0-155.0 | 5.0 | 2.8
R-27 | 155.0-160.0 | 5.0 | 4.5
R-28 | 160.0-165.0 | 3.6 | 3.6
R-29 | 165.0-170.0 | 5.0 | 4.7
153.5
155.0
160.0
165.0
168.9


BOR NO. B-2 BOX 11 DATE 12/7/17
DEPTH 168.9 to 182.3 SPREAD PPP-5
HDD SCHOOLHOUSE LN. PSI # 4911458
TT # PA-LE-0005-0000-RD-16
RUN | DEPTH | REC | RQD
R29 | 165.0-170 | 5.0 | 4.7
R30 | 170.0-175.0 | 5.0 | 4.7
R-31 | 175.0-180.0 | 5.0 | 3.1
R-32 | 180.0-185.0 | 5.0 | 1.5
168.9
170.0
175.0
180.0
182.3


Bor No B-2 Box 8
PPP-5 SCHOOLHOUSE LN
Bor No B-2 Box 7
PPP-5 SCHOOLHOUSE LN
BOR NO. B-2 BOX 12 DATE 12/7-/17
DEPTH 182.3ft to 194.0ft SPREAD PPP-5
HDD SCHOOLHOUSE LN PSI 4911458
TT# PA-LE-0005-0000-RD-16
RUN | DEPTH | REC | RQD
R-32 | 180.0-185.0 | 5.0 | 1.5
R-33 | 185.0-190.0 | 5.0 | 4.0
R-34 | 190.0-195.0 | 5.0 | 0.5
182.3
185.0
190.0
194.0


BOR NO B-2
BOX 13
DATE 12/8/17
DEPTH 194.0 FT to 200.0 FT
SPREAD PPP5
HOD SCHOOLHOUSE LN
PSI# 4911458
TT# 0005.0000-RD-16
RUN | DEPTH | REC | RQD
R-34 | 190.0-195.0 | 5.0 | 0.5
R-35 | 195.0-200.0 | 5.0 | 5.0
194.0
195.0
200.0

GENERAL NOTES

SAMPLE IDENTIFICATION

The Unified Soil Classification System (USCS), AASHTO 1988 and ASTM designations D2487 and D-2488 are used to identify the encountered materials unless otherwise noted. Coarse-grained soils are defined as having more than 50% of their dry weight retained on a #200 sieve (0.075mm); they are described as: boulders, cobbles, gravel or sand. Fine-grained soils have less than 50% of their dry weight retained on a #200 sieve; they are defined as silts or clay depending on their Atterberg Limit attributes. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size.

DRILLING AND SAMPLING SYMBOLS

SFA: Solid Flight Auger - typically 4" diameter flights, except where noted.
HSA: Hollow Stem Auger - typically 3¼" or 4¼ I.D. openings, except where noted.
M.R.: Mud Rotary - Uses a rotary head with Bentonite or Polymer Slurry
R.C.: Diamond Bit Core Sampler
H.A.: Hand Auger
P.A.: Power Auger - Handheld motorized auger

SS: Split-Spoon - 1 3/8" I.D., 2" O.D., except where noted.
ST: Shelby Tube - 3" O.D., except where noted.
RC: Rock Core
TC: Texas Cone
BS: Bulk Sample
PM: Pressuremeter
CPT-U: Cone Penetrometer Testing with Pore-Pressure Readings

SOIL PROPERTY SYMBOLS

N: Standard "N" penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2-inch O.D. Split-Spoon.
N_{60}: A "N" penetration value corrected to an equivalent 60% hammer energy transfer efficiency (ETR)
Q_u: Unconfined compressive strength, TSF
Q_p: Pocket penetrometer value, unconfined compressive strength, TSF
w%: Moisture/water content, %
LL: Liquid Limit, %
PL: Plastic Limit, %
PI: Plasticity Index = (LL-PL),%
DD: Dry unit weight, pcf
▼,▽,▼ Apparent groundwater level at time noted

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Relative Density	N - Blows/foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	50 - 80
Extremely Dense	80+

ANGULARITY OF COARSE-GRAINED PARTICLES

Description	Criteria
Angular:	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular:	Particles are similar to angular description, but have rounded edges
Subrounded:	Particles have nearly plane sides, but have well-rounded corners and edges
Rounded:	Particles have smoothly curved sides and no edges

GRAIN-SIZE TERMINOLOGY

Component	Size Range
Boulders:	Over 300 mm (>12 in.)
Cobbles:	75 mm to 300 mm (3 in. to 12 in.)
Coarse-Grained Gravel:	19 mm to 75 mm (¾ in. to 3 in.)
Fine-Grained Gravel:	4.75 mm to 19 mm (No.4 to ¾ in.)
Coarse-Grained Sand:	2 mm to 4.75 mm (No.10 to No.4)
Medium-Grained Sand:	0.42 mm to 2 mm (No.40 to No.10)
Fine-Grained Sand:	0.075 mm to 0.42 mm (No. 200 to No.40)
Silt:	0.005 mm to 0.075 mm
Clay:	<0.005 mm

PARTICLE SHAPE

Description	Criteria
Flat:	Particles with width/thickness ratio > 3
Elongated:	Particles with length/width ratio > 3
Flat & Elongated:	Particles meet criteria for both flat and elongated

RELATIVE PROPORTIONS OF FINES

Descriptive Term	% Dry Weight
Trace:	< 5%
With:	5% to 12%
Modifier:	>12%

GENERAL NOTES

(Continued)

CONSISTENCY OF FINE-GRAINED SOILS

Q_U - TSF	N - Blows/foot	Consistency
0 - 0.25	0 - 2	Very Soft
0.25 - 0.50	2 - 4	Soft
0.50 - 1.00	4 - 8	Firm (Medium Stiff)
1.00 - 2.00	8 - 15	Stiff
2.00 - 4.00	15 - 30	Very Stiff
4.00 - 8.00	30 - 50	Hard
8.00+	50+	Very Hard

MOISTURE CONDITION DESCRIPTION

Description	Criteria
Dry:	Absence of moisture, dusty, dry to the touch
Moist:	Damp but no visible water
Wet:	Visible free water, usually soil is below water table

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term	% Dry Weight
Trace:	< 15%
With:	15% to 30%
Modifier:	>30%

STRUCTURE DESCRIPTION

Description	Criteria
Stratified:	Alternating layers of varying material or color with layers at least ¼-inch (6 mm) thick
Laminated:	Alternating layers of varying material or color with layers less than ¼-inch (6 mm) thick
Fissured:	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided:	Fracture planes appear polished or glossy, sometimes striated
Blocky:	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed:	Inclusion of small pockets of different soils
Layer:	Inclusion greater than 3 inches thick (75 mm)
Seam:	Inclusion 1/8-inch to 3 inches (3 to 75 mm) thick extending through the sample
Parting:	Inclusion less than 1/8-inch (3 mm) thick

SCALE OF RELATIVE ROCK HARDNESS

Q_U - TSF	Consistency
2.5 - 10	Extremely Soft
10 - 50	Very Soft
50 - 250	Soft
250 - 525	Medium Hard
525 - 1,050	Moderately Hard
1,050 - 2,600	Hard
>2,600	Very Hard

ROCK BEDDING THICKNESSES

Description	Criteria
Very Thick Bedded	Greater than 3-foot (>1.0 m)
Thick Bedded	1-foot to 3-foot (0.3 m to 1.0 m)
Medium Bedded	4-inch to 1-foot (0.1 m to 0.3 m)
Thin Bedded	1¼-inch to 4-inch (30 mm to 100 mm)
Very Thin Bedded	½-inch to 1¼-inch (10 mm to 30 mm)
Thickly Laminated	1/8-inch to ½-inch (3 mm to 10 mm)
Thinly Laminated	1/8-inch or less "paper thin" (<3 mm)

ROCK VOIDS

Voids	Void Diameter
Pit	<6 mm (<0.25 in)
Vug	6 mm to 50 mm (0.25 in to 2 in)
Cavity	50 mm to 600 mm (2 in to 24 in)
Cave	>600 mm (>24 in)

GRAIN-SIZED TERMINOLOGY

(Typically Sedimentary Rock)

Component	Size Range
Very Coarse Grained	>4.76 mm
Coarse Grained	2.0 mm - 4.76 mm
Medium Grained	0.42 mm - 2.0 mm
Fine Grained	0.075 mm - 0.42 mm
Very Fine Grained	<0.075 mm

ROCK QUALITY DESCRIPTION

Rock Mass Description	RQD Value
Excellent	90 -100
Good	75 - 90
Fair	50 - 75
Poor	25 -50
Very Poor	Less than 25

Degree of Brokeness

Characteristic	Description
Less than 1 inch	Very Broken
1 inch to 3 inches	Broken
3 inches to 6 inches	Slightly Broken
Greater than 6 inches	Massive

DEGREE OF WEATHERING

Slightly Weathered: Rock generally fresh, joints stained and discoloration extends into rock up to 25 mm (1 in), open joints may contain clay, core rings under hammer impact.

Weathered: Rock mass is decomposed 50% or less, significant portions of the rock show discoloration and weathering effects, cores cannot be broken by hand or scraped by knife.

Highly Weathered: Rock mass is more than 50% decomposed, complete discoloration of rock fabric, core may be extremely broken and gives clunk sound when struck by hammer, may be shaved with a knife.

Table 4–3 Hardness and unconfined compressive strength of rock materials

Hardness category	Typical range in unconfined compressive strength (MPa)	Strength value selected (MPa)	Field test on sample	Field test on outcrop
Soil*	< 0.60		Use USCS classifications	
Very soft rock or hard, soil-like material	0.60–1.25		Scratched with fingernail. Slight indentation by light blow of point of geologic pick. Requires power tools for excavation. Peels with pocket knife.	
Soft rock	1.25–5.0		Permits denting by moderate pressure of the fingers. Handheld specimen crumbles under firm blows with point of geologic pick.	Easily deformable with finger pressure.
Moderately soft rock	5.0–12.5		Shallow indentations (1–3 mm) by firm blows with point of geologic pick. Peels with difficulty with pocket knife. Resists denting by the fingers, but can be abraded and pierced to a shallow depth by a pencil point. Crumbles by rubbing with fingers.	Crumbles by rubbing with fingers.
Moderately hard rock	12.5–50		Cannot be scraped or peeled with pocket knife. Intact handheld specimen breaks with single blow of geologic hammer. Can be distinctly scratched with 20d common steel nail. Resists a pencil point, but can be scratched and cut with a knife blade.	Unfractured outcrop crumbles under light hammer blows.
Hard rock	50–100		Handheld specimen requires more than one hammer blow to break it. Can be faintly scratched with 20d common steel nail. Resistant to abrasion or cutting by a knife blade, but can be easily dented or broken by light blows of a hammer.	Outcrop withstands a few firm blows before breaking.
Very hard rock	100–250		Specimen breaks only by repeated, heavy blows with geologic hammer. Cannot be scratched with 20d common steel nail.	Outcrop withstands a few heavy ringing hammer blows but will yield large fragments.
Extremely hard rock	> 250		Specimen can only be chipped, not broken by repeated, heavy blows of geologic hammer.	Outcrop resists heavy ringing hammer blows and yields, with difficulty, only dust and small fragments.

Method used to determine consistency or hardness (check one):
Field assessment: _____ Uniaxial lab test: _____ Other: _____ Rebound hammer (ASTM D5873): _____
* See NEH631.03 for consistency and density of soil materials. For very stiff soil, SPT N values = 15 to 30. For very soft rock or hard, soil-like material, SPT N values exceed 30 blows per foot.

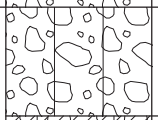
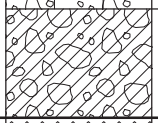
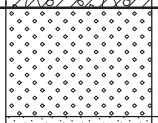
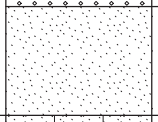
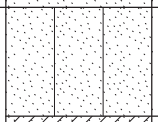
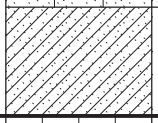
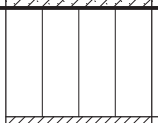
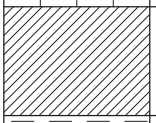
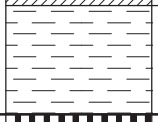
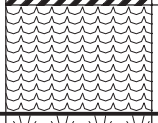
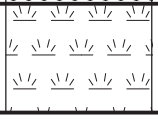
Bedding/ Discontinuity Dip (Abbrev.)	Description
Flat Dip (**Fld**)	Beds/Discontinuities dipping < 5 degrees
Shallow Dip (**Sld**)	Beds/Discontinuities dipping from 5 to 15 degrees
Moderate Dip (**Mdd**)	Beds/Discontinuities dipping from 15 to 30 degrees
Steep Dip (**Std**)	Beds/Discontinuities dipping from 30 to 45 degrees
Very Steep Dip (**Vsd**)	Beds/Discontinuities dipping from 45 to 60 degrees
Sheer Dip (**Srd**)	Beds/Discontinuities dipping > 60 degrees

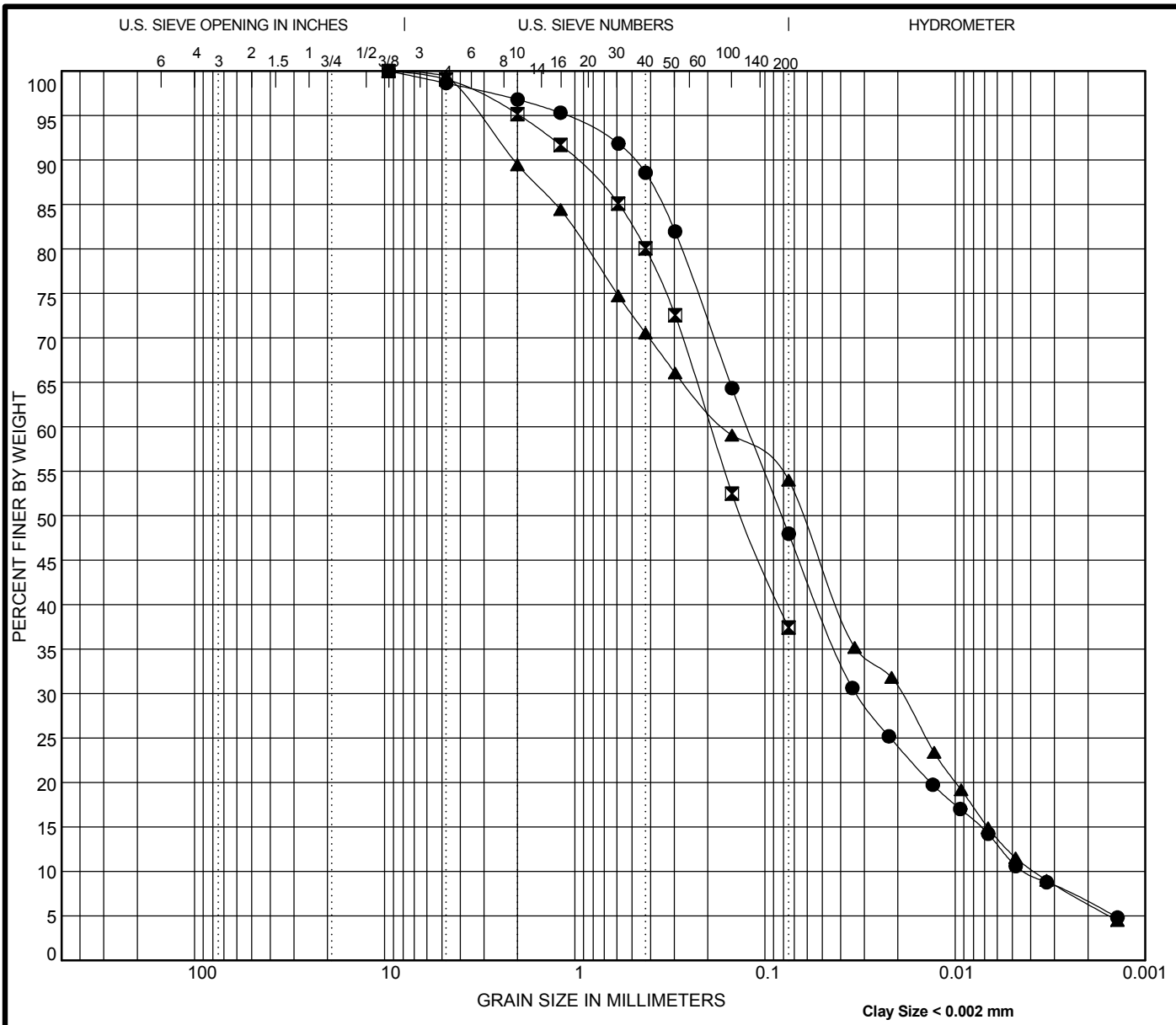
Table 29 - Bedding/Discontinuity Dip Descriptors

From PADOT Publication 222 “Geotechnical Investigations Manual”

SOIL CLASSIFICATION CHART

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		(LITTLE OR NO FINES)		GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
		(APPRECIABLE AMOUNT OF FINES)		GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	SAND AND SANDY SOILS	CLEAN SANDS		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		(LITTLE OR NO FINES)		SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	SANDS WITH FINES		SM	SILTY SANDS, SAND - SILT MIXTURES
		(APPRECIABLE AMOUNT OF FINES)		SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

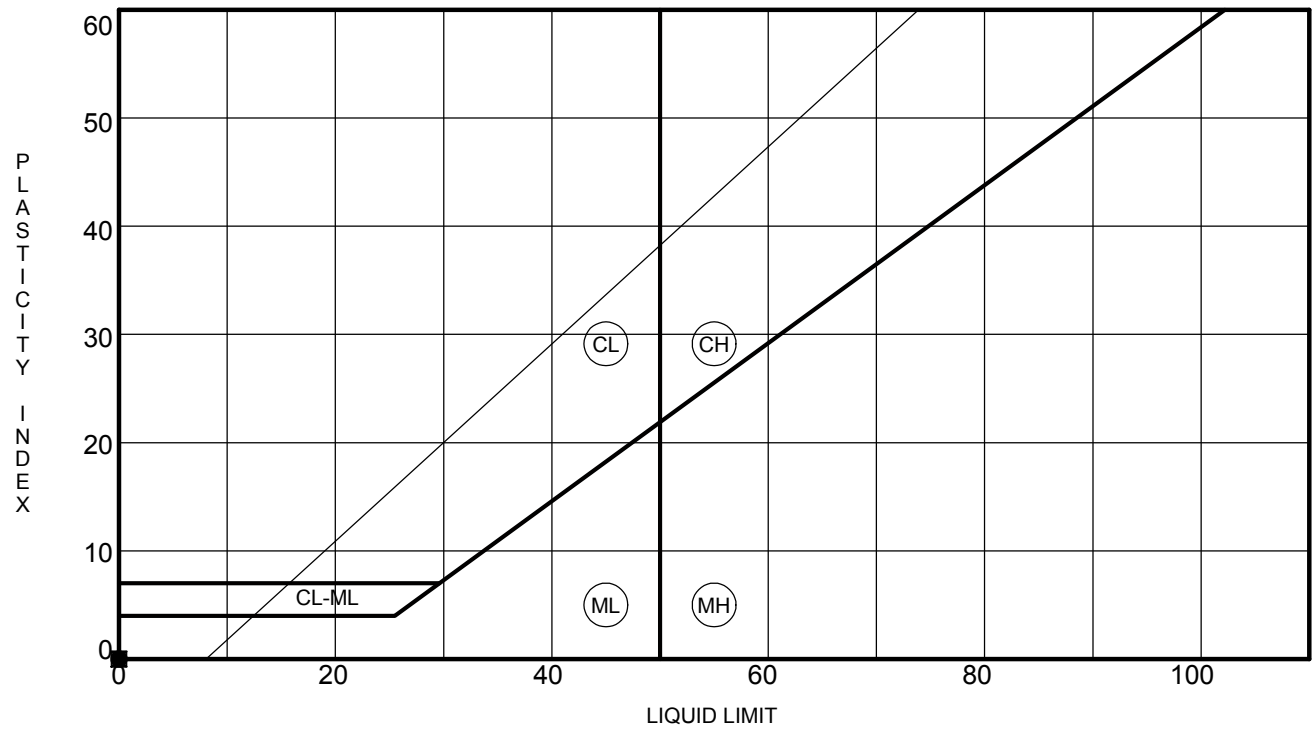
	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	B-2	4.5	Silty SAND (SM)	NP	NP	NP	2.06	29.30
⊠	B-2	14.0	Silty SAND (SM)					
▲	B-2	19.5	Sandy SILT (ML)	NP	NP	NP	0.60	42.75

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	B-2	4.5	9.525	0.124	0.033	0.004	1.4	50.7	41.5	6.5
⊠	B-2	14.0	9.525	0.193			0.9	61.7	37.4	
▲	B-2	19.5	9.525	0.164	0.019	0.004	0.6	45.4	47.6	6.4

Professional Service Industries, Inc.
1707 S. Cameron Street, Suite B
Harrisburg, PA 17104
Telephone: (717) 230-8622
Fax: (717) 230-8626

GRAIN SIZE DISTRIBUTION

Project: Energy Transfer HDD (DPS)
PSI Job No.: 04911458
Location: School House Rd (PPP5)
Lebanon Co., PA



	Boring	Depth (ft)	LL	PL	PI	Fines	Classification (*Visual)
●	**B-2**	**4.5**	**NP**	**NP**	**NP**	**48.0**	**Silty SAND (SM)**
⊠	**B-2**	**19.5**	**NP**	**NP**	**NP**	**54.0**	**Sandy SILT (ML)**

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ATTERBERG LIMIT RESULTS

PSI Job No.: 04911458
Project: Energy Transfer HDD (DPS)
Location: School House Rd (PPP5)
Lebanon Co., PA

Laboratory Summary Sheet

Borehole	Approx. Depth	Liquid Limit	Plastic Limit	Plasticity Index	Qu (tsf)	%<#200 Sieve	Est. Specific Gravity	Water Content (%)	Dry Density (pcf)	Satur-ation (%)	Void Ratio
B-2	1							14			
B-2	4.5	0	0	0		48.0%		12			
B-2	9.5							10			
B-2	14					37.4%		13			
B-2	19.5	0	0	0		54.0%		13			
B-2	23.5							11			
B-2	27.5				202.96						
B-2	33.9				439.73						
B-2	42.2				770.78						
B-2	53.3				404.99						
B-2	58.9				410.23						
B-2	68.4				531.33						
B-2	77.3				619.62						
B-2	86.9				559.91						
B-2	94.1				470.82						
B-2	105.2				454.91						
B-2	113.3				427.24						
B-2	123.4				530.95						
B-2	129				642.81						
B-2	137.7				249.01						
B-2	144				474.84						
B-2	148.8				88.82						
B-2	154				179.65						
B-2	163.4				330.67						
B-2	170.8				698.58						
B-2	181.1				459.74						
B-2	187.3				416.55						
B-2	198.1				158.69						

intertek PSI

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Summary of Laboratory Results

PSI Job No.: 04911458
Project: Energy Transfer HDD (DPS)
Location: School House Rd (PPP5)
Lebanon Co., PA
PA-LE-0005.0000-RD/PO#20171129-2

ATTACHEMENT 2
SOIL RESOURCES MAP AND PROFILE DESCRIPTIONS

United States Department of Agriculture

Natural Resources Conservation Service

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

Custom Soil Resource Report for Lebanon County, Pennsylvania

February 6, 2019

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil

scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and

identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map

Map Scale: 1:2,830 if printed on A landscape (11" x 8.5") sheet.

N

Meters
0 40 80 160 240

Feet
0 100 200 400 600

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

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

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

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

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

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

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

Soil Survey Area: Lebanon County, Pennsylvania
Survey Area Data: Version 14, Sep 19, 2018

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

Date(s) aerial images were photographed: Jun 29, 2011—Mar 16, 2017

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

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ro	Rowland silt loam	4.5	26.4%
UnB	Ungers loam, 3 to 8 percent slopes	0.2	1.3%
UnC	Ungers loam, 8 to 15 percent slopes	8.3	48.8%
UnD	Ungers loam, 15 to 25 percent slopes	4.0	23.5%
Totals for Area of Interest		**17.1**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate

pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Lebanon County, Pennsylvania

Ro—Rowland silt loam

Map Unit Setting

National map unit symbol: l597
Elevation: 150 to 1,000 feet
Mean annual precipitation: 36 to 50 inches
Mean annual air temperature: 48 to 57 degrees F
Frost-free period: 150 to 200 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Rowland and similar soils: 82 percent
Minor components: 14 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Rowland

Setting

Landform: Flood plains
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Head slope, base slope
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Parent material: Alluvium derived from sandstone and shale

Typical profile

A - 0 to 12 inches: silt loam
B - 12 to 34 inches: silty clay loam
Cg - 34 to 46 inches: silty clay loam
2Cg - 46 to 61 inches: stratified gravel to sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: 60 to 99 inches to lithic bedrock
Natural drainage class: Moderately well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: About 12 to 36 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: C
Hydric soil rating: No

Minor Components

Knauers

Percent of map unit: 8 percent
Landform: Flood plains

Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Hydric soil rating: Yes

Abbottstown

Percent of map unit: 6 percent
Landform: Hillslopes
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Base slope, head slope
Down-slope shape: Concave, linear
Across-slope shape: Linear, concave
Hydric soil rating: No

UnB—Ungers loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: l59g
Elevation: 250 to 1,500 feet
Mean annual precipitation: 36 to 50 inches
Mean annual air temperature: 46 to 57 degrees F
Frost-free period: 160 to 200 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Ungers and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Ungers

Setting

Landform: Mountain slopes
Landform position (two-dimensional): Backslope, shoulder
Landform position (three-dimensional): Mountainflank
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from sandstone and siltstone

Typical profile

H1 - 0 to 11 inches: loam
H2 - 11 to 40 inches: gravelly sandy clay loam
H3 - 40 to 60 inches: very channery sandy loam
H4 - 60 to 64 inches: bedrock

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: 40 to 80 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Medium

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 6.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: B
Hydric soil rating: No

Minor Components

Penn

Percent of map unit: 7 percent
Hydric soil rating: No

Readington

Percent of map unit: 5 percent
Hydric soil rating: No

Bucks

Percent of map unit: 3 percent
Hydric soil rating: No

UnC—Ungers loam, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: l59h
Elevation: 250 to 1,500 feet
Mean annual precipitation: 36 to 50 inches
Mean annual air temperature: 46 to 57 degrees F
Frost-free period: 160 to 200 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Ungers and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Ungers

Setting

Landform: Mountain slopes
Landform position (two-dimensional): Shoulder, backslope
Landform position (three-dimensional): Mountainflank
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from sandstone and siltstone

Typical profile

H1 - 0 to 9 inches: loam
H2 - 9 to 40 inches: gravelly sandy clay loam
H3 - 40 to 60 inches: very channery sandy loam
H4 - 60 to 64 inches: bedrock

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: 40 to 80 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 6.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: B
Hydric soil rating: No

Minor Components

Penn

Percent of map unit: 7 percent
Hydric soil rating: No

Readington

Percent of map unit: 5 percent
Hydric soil rating: No

Bucks

Percent of map unit: 3 percent
Hydric soil rating: No

UnD—Ungers loam, 15 to 25 percent slopes

Map Unit Setting

National map unit symbol: l59j
Elevation: 250 to 1,500 feet
Mean annual precipitation: 36 to 50 inches
Mean annual air temperature: 46 to 57 degrees F
Frost-free period: 160 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Ungers and similar soils: 85 percent
Minor components: 15 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Ungers

Setting

Landform: Mountain slopes
Landform position (two-dimensional): Shoulder, backslope
Landform position (three-dimensional): Mountainflank
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from sandstone and siltstone

Typical profile

H1 - 0 to 9 inches: loam
H2 - 9 to 40 inches: gravelly sandy clay loam
H3 - 40 to 60 inches: very channery sandy loam
H4 - 60 to 64 inches: bedrock

Properties and qualities

Slope: 15 to 25 percent
Depth to restrictive feature: 40 to 80 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 6.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Hydric soil rating: No

Minor Components

Penn

Percent of map unit: 7 percent
Landform: Hillslopes
Landform position (two-dimensional): Shoulder, backslope
Landform position (three-dimensional): Side slope, nose slope
Down-slope shape: Linear, convex
Across-slope shape: Convex, linear
Hydric soil rating: No

Readington

Percent of map unit: 5 percent
Landform: Hillslopes
Landform position (two-dimensional): Footslope, backslope
Landform position (three-dimensional): Base slope, head slope, side slope
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: No

Bucks

Percent of map unit: 3 percent

Landform: Hillslopes
Landform position (two-dimensional): Shoulder, summit
Landform position (three-dimensional): Side slope, interfluve
Down-slope shape: Linear, convex
Across-slope shape: Convex, linear
Hydric soil rating: No

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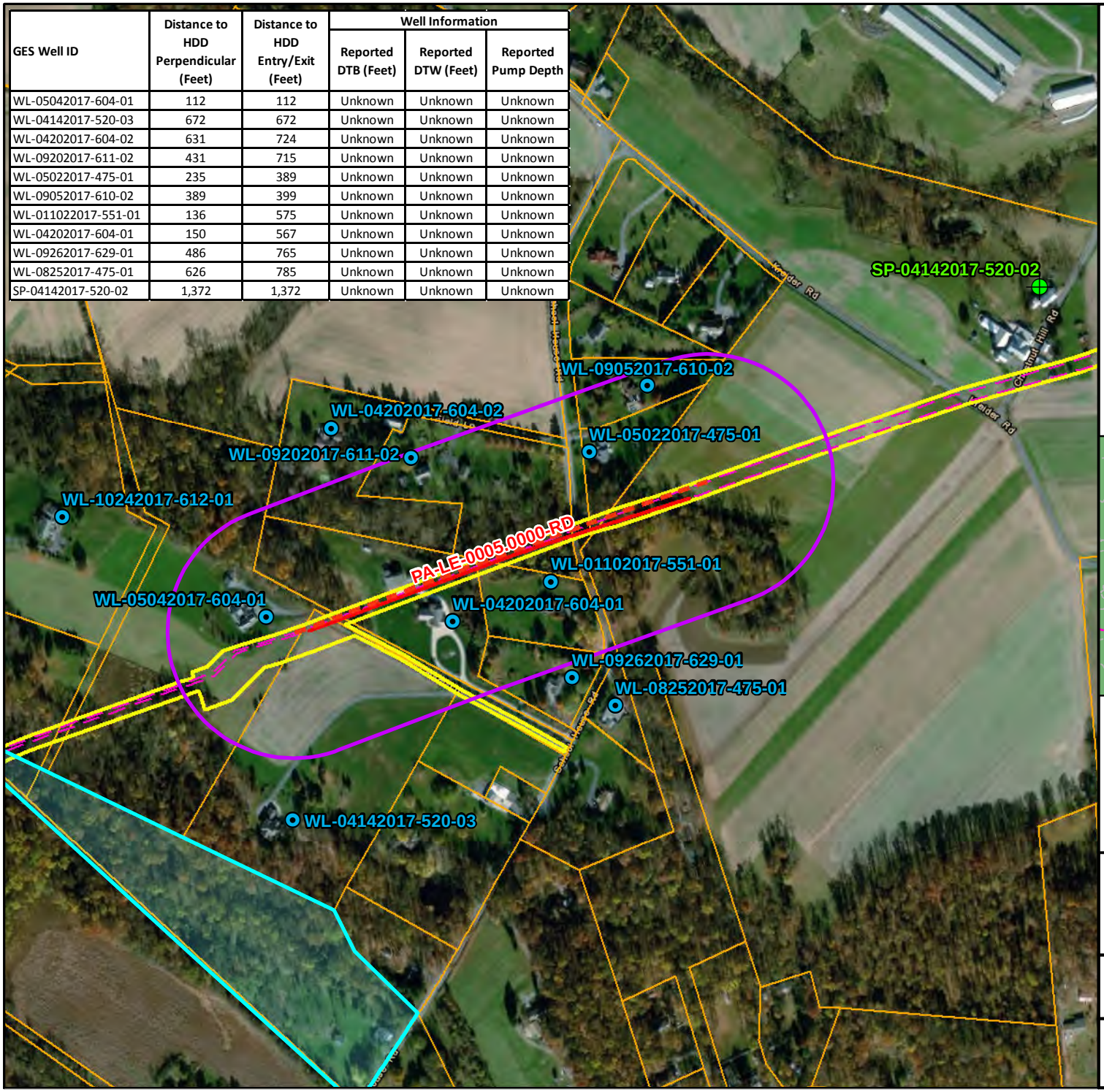
ATTACHMENT 3
450-FOOT WELL SURVEY

GES Well ID	Distance to HDD Perpendicular (Feet)	Distance to HDD Entry/Exit (Feet)	Well Information		
			Reported DTB (Feet)	Reported DTW (Feet)	Reported Pump Depth
WL-05042017-604-01	112	112	Unknown	Unknown	Unknown
WL-04142017-520-03	672	672	Unknown	Unknown	Unknown
WL-04202017-604-02	631	724	Unknown	Unknown	Unknown
WL-09202017-611-02	431	715	Unknown	Unknown	Unknown
WL-05022017-475-01	235	389	Unknown	Unknown	Unknown
WL-09052017-610-02	389	399	Unknown	Unknown	Unknown
WL-011022017-551-01	136	575	Unknown	Unknown	Unknown
WL-04202017-604-01	150	567	Unknown	Unknown	Unknown
WL-09262017-629-01	486	765	Unknown	Unknown	Unknown
WL-08252017-475-01	626	785	Unknown	Unknown	Unknown
SP-04142017-520-02	1,372	1,372	Unknown	Unknown	Unknown



Legend

- LOD
- Parcel
- PPP Centerline
- PPP 1 HDD
- Proposed PPP 2 HDD Redesign
- 450 foot buffer of HDD alignment
- Public Water Supply/Landowner Confirmed No Well

****Testing locations current as of 02/07/2019**

- GES Testing Location
- GES Spring Testing Location

Location

N

0 250 500 Feet

Well Location Map
HDD# PA-LE-0005.0000-RD
Lebanon County, PA.

Prepared By: TETRA TECH

Date: 2/7/2019

Base Map;
ESRI World Imagery, 09/24/2015

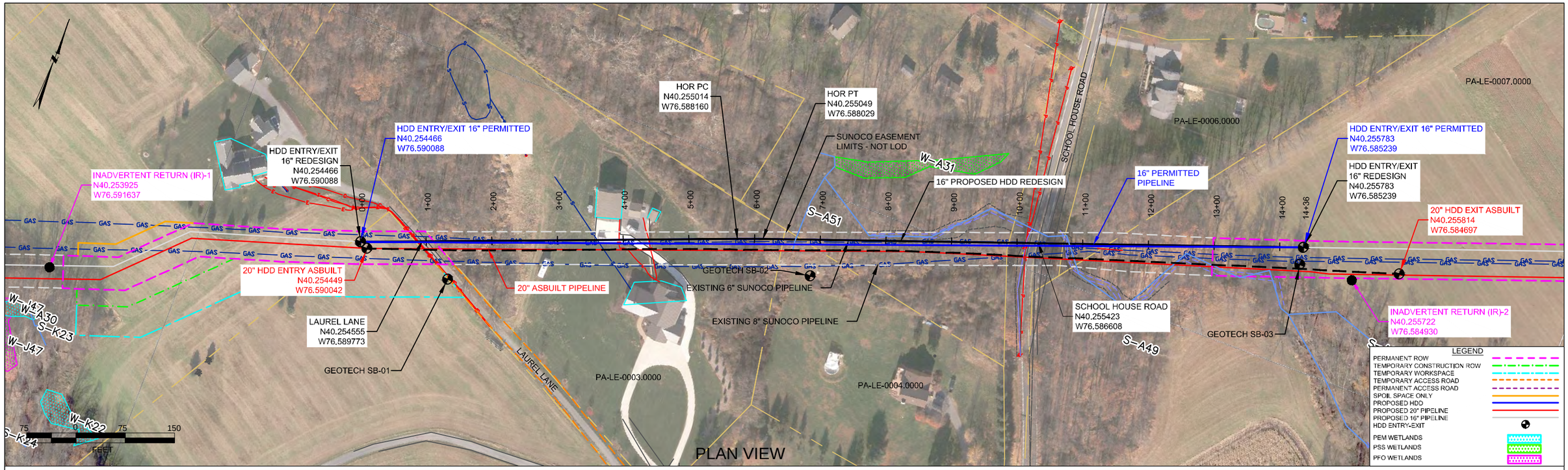
Coordinate System: NAD 83 Stateplane, PA South, Feet

P:\GIS\projects\112\05958-PPP\MXD\WellLocations\WellLocation_PA_LE_0005_0000.mxd LN

SCHOOL HOUSE ROAD CROSSING
PADEP SECTION 105 PERMIT NO. E38-194
PA-LE-0005.0000-RD-16
(SPLP HDD No. S3-0091-16)

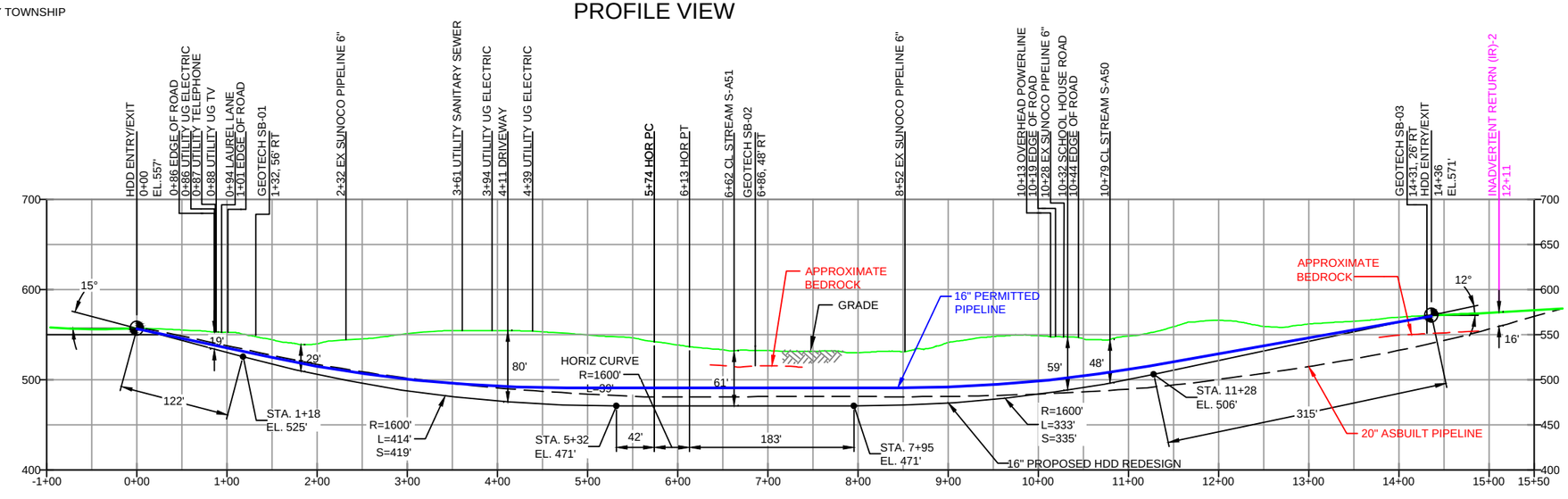
ATTACHMENT 2

HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



PLAN VIEW

PROFILE VIEW



LEBANON COUNTY, PENNSYLVANIA - SOUTH LONDONDERRY TOWNSHIP
S3-0091-16

GEOTECH SB-01
-NG EL. 550'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 19.0')
-WEATHERED SHALE (19.0' - 28.7')
-COMPLETION DEPTH EL. 521.3'

GEOTECH SB-02
-NG EL. 538'
-TOPSOIL (0' - 0.4')
-SM (0.4' - 17.5')
-SM/ML (17.5' - 19.0')
-AUGER REFUSAL (19.0')
-SHALE (19.0' - 20.0')
-LIMESTONE (20.0' - 22.5')
-SANDSTONE (22.5' - 29.0')
-COMPLETION DEPTH EL. 509.0'

GEOTECH SB-03
-NG EL. 570'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 14.0')
-SHALE (14.0' - 19.0')
-AUGER REFUSAL (19.0')
-COMPLETION DEPTH EL. 521.3'

NOTE: REFER TO TEST BORING LOG S3-0091 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=):1436'
   HDD PIPE LENGTH (S=):1455'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

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

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
8	DESIGN CHANGE - ADDED HORIZONTAL CURVE	MRS	03/14/17	RMB	03/14/17	AMC	03/14/17
7	REVISED PROFILE WITH 201 LIDAR	MRS	02/15/17	RMB	02/15/17	AAW	02/15/17
6	ADDED GEOTECH INFO	MRS	11/29/16	RMB	09/28/16	AAW	11/29/16
5	DESIGN CHANGE - HDD ENTRY RELOCATE	MRS	09/28/16	RMB	09/28/16	AAW	09/28/16
4	ADDED UTILITY CROSSINGS	MRS	09/19/16	RMB	09/19/16	AAW	09/19/16
3	REVISED PER ENGINEERING COMMENTS	MRS	08/19/16	RMB	08/19/16	AAW	08/19/16

Sunoco Logistics Partners L.P.

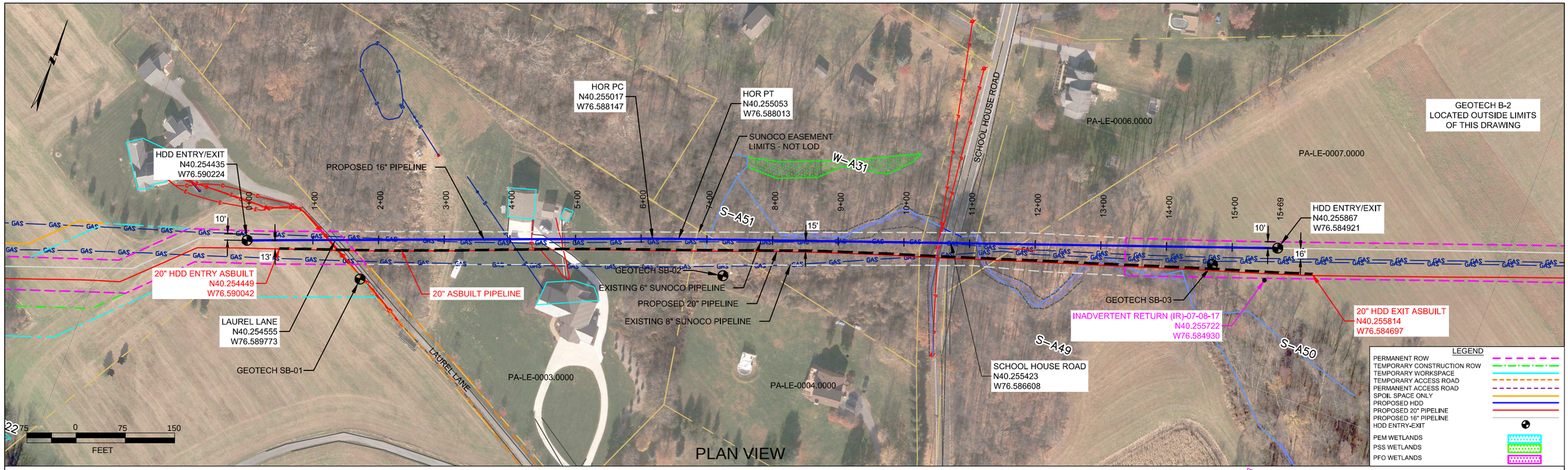
TETRA TECH ROONEY
(303) 792–5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
SCHOOL HOUSE RD
PENNSYLVANIA PIPELINE PROJECT

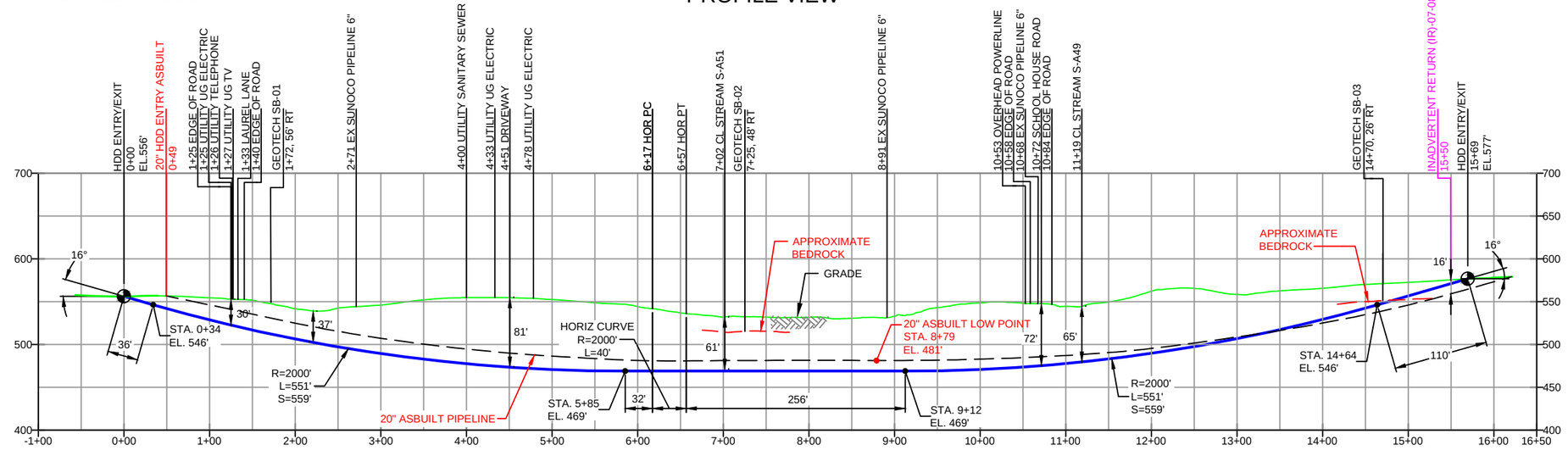
SCALE: 1"=150'

DWG. NO: PA-LE-0005.0000-RD-16 IR ASBUILT



LEBANON COUNTY, PENNSYLVANIA - SOUTH LONDONDERRY TOWNSHIP
S3-0091-16

PROFILE VIEW



GEOTECH SB-01
-NG EL. 550'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 19.0')
-WEATHERED SHALE (19.0' - 28.7')
-COMPLETION DEPTH EL. 521.3'

GEOTECH SB-02
-NG EL. 538'
-TOPSOIL (0' - 0.4')
-SM (0.4' - 17.5')
-SM/ML (17.5' - 19.0')
-AUGER REFUSAL (19.0')
-SHALE (19.0' - 20.0')
-LIMESTONE (20.0' - 22.5')
-SANDSTONE (22.5' - 29.0')
-COMPLETION DEPTH EL. 509.0'

GEOTECH SB-03
-NG EL. 570'
-TOPSOIL (0' - 0.3')
-SM (0.3' - 14.0')
-SHALE (14.0' - 19.0')
-AUGER REFUSAL (19.0')
-COMPLETION DEPTH EL. 521.3'

NOTE: REFER TO TEST BORING LOG S3-0091 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-2
-NG EL. 550'
-RESIDIUM-SANDY SILT ML (0.0' - 3.0')
-RESIDIUM-SILTY SAND SM (3.0' - 12.0')
-WEATHERED SANDSTONE SILTY SAND SM (12.0' - 16.5')
-WEATHERED SANDSTONE SANDY SILT ML (16.5' - 22.0')
-WEATHERED SANDSTONE SILTY SAND SM (22.0' - 25.0')
-AUGER REFUSAL (25.0')
-GROUNDWATER (36.7')
-SANDSTONE/SILTSTONE (25.0' - 200.0')
-BORING TERMINATED EL.350'

NOTE: REFER TO TEST BORING LOG B-2 INTERTEK PROJECT #04911458 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=):1569'
   HDD PIPE LENGTH (S=):1592'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 2100 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 2625 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 2. Redesigned 16-Inch HDD Plan and Profile

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

REF. DRAWING

ES-5.04	TO	ES-5.05	EROSION & SEDIMENT PLAN	
SHEET 24	TO	SHEET 24	AERIAL SITE PLAN	
DWG NO		DWG NO	DESCRIPTION	

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP5	ADDED IR INFORMATION	MRS	02/13/19	RMB	02/13/19	AMC	02/13/19
EP4	DESIGN CHANGE - EXTENDED DRILL AND ADDED GEOTECH INFORMATION	MRS	11/16/18	RMB	11/16/18	AMC	11/16/18
EP3	UPDATED TO MATCH 16" IFC DESIGN AND NOTE 5 AND 10 PER INCREASED 16" MOP	MRS	05/10/18	RMB	05/10/18	AMC	05/10/18
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/10/16	RMB	05/10/16	AAW	05/10/16
EP		MRS	03/15/16	RMB	03/15/16	AAW	03/15/16

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SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
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PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'

DWG. NO: PA-LE-0005.0000-RD-16