SUNOCO PIPELINE
An ENERGY TRANSFER Company

535 Fritztown Road
Sinking Spring, PA 19608

June 17, 2019

Via Electronic Mail
Mr. Scott R. Williamson
Program Manager, Waterways & Wetlands Program
Pennsylvania Department of Environmental Protection
Southcentral Regional Office
909 Elmerton Avenue
Harrisburg, PA 17110-8200

Re: Response to DEP Request for Additional Information
Hydrogeological HDD Re-Evaluation Report – Interstate 81 Crossing 16"
Horizontal Directional Drill Location (S2-0220-16)
Permit No. E21-449
Middlesex Township, Cumberland County

Dear Mr. Williamson:

In compliance with the Corrected Stipulated Order (Order) dated August 10, 2017 a Re-Evaluation Report on the above-referenced horizontal directional drill (HDD) was submitted to the Pennsylvania Department of Environmental Protection (Department) on February 26, 2019. In a letter dated April 11, 2019, the Department requested further information. Please accept this letter as a response. Department requests are bolded below followed by Sunoco Pipeline, LP (SPLP) responses. A revised Re-Evaluation Report accompanies this response.

1. **Examination of the drilling record for the 20-inch pipeline boring indicates a persistent and significant loss of circulation (LOC) and inadvertent return (IR) that began approximately 500 feet from the east of the bore. It continued for most of the duration of drilling. The s-wave seismic profile (figure 4 of 7, Geophysical Report) indicates that a deeper pathway of 20 additional feet would place the bore in a zone of higher velocity bedrock underneath the persistent IR location and interval to the east of that IR location. Please discuss the possibility of designing the profile even deeper to pass beneath the low velocity feature on figure 4, Geophysical Report.**

The overall depth of the redesigned 16-inch HDD profile has been increased to nearly the maximum amount achievable within the 16-inch product pipe stress tolerance limits. The depth beneath the wetlands has been increased by approximately 36 feet (ft) compared to the 20-inch pipeline installation, which places the profile in bedrock having higher seismic velocities (i.e., higher density) as identified in the geophysical survey. The new profile depth under wetland W-I30 is approximately 80 feet which places it approximately 10 feet beneath the low velocity bedrock interval identified in the seismic survey.

As illustrated on Figure 2 in Attachment 3 of the Revised Re-Evaluation Report, the entry and exit angles are at 16 degrees which is at the “break over” stress threshold for the 16-inch pipeline, and due to the orientation of the conventionally laid pipeline, custom pipe bends are required at both ends of the HDD. The 2000 ft radius into and out of the profile bottom is below the pipeline stress limits; however tightening the radius will increase entry and exit angles unacceptably. The HDD horizontal run is only 41 ft in length and leaves no room for corrections before commencing into the exit radius.

The redesigned profile alone will not prevent LOCs or IRs, but taken in conjunction with the following site-specific best management practices, should decrease the potential for IRs during the installation of the 16-inch HDD:

- Advancing the pilot tooling at the lowest possible drilling fluid pressure to reduce the fluid pressure buildup within the borehole and reduce the potential for hydrofracturing of the pilot hole;
- Increasing the frequency of tripping the pilot tooling out of the pilot hole to remove any buildup of drilling cuttings in the annulus as a result of the lower drilling fluid pressure;
- Conditioning the boring (i.e., adjusting the drilling fluid viscosity and swabbing the borehole) in the event of unexpected pressure changes or evidence of diminished drilling fluid returns;
- In the event of an LOC, the drilling contractor will trip the pilot tool out of the boring and advance a 14-inch reamer to increase the diameter of the borehole resulting in a corresponding decrease in annular pressure;
- In conjunction with the reaming of the pilot hole, the drilling contractor will install a loss control material (LCM) plug at the interval(s) in which the drilling fluid was lost. The LCM plug will be given enough time to setup before the continuation of pilot hole advancement;
- In the event the LCM plug does not adequately seal off the zone of loss, the pilot tool will be tripped out of the borehole, a packer assembly will be tripped into the pilot hole and the zone of loss will be pressure grouted with either a neat-cement or a cement and sand mixture. The grout will be given a minimum of 24 hours to setup before the pilot tool is tripped back into the boring and the advancement of the pilot hole is resumed;
- An on-site, full time drilling specialist will be employed for the duration of the HDD with the authority to make recommendations to the drilling contractor and/or shut down the HDD should conditions warrant this action.

2. Once the items discussed above are developed by using the geophysical profiles, please attempt to predict where any operational provisions or changes may be necessary for the intervals where the previous LOCs or IRs occurred. Also, discuss any drilling intervals along the proposed 16-inch drill path where increased vigilance may be warranted, i.e.: the P.G. working in concert with the HDD contractor as sensitive geologic zones are approached by the drill bit.

Because of this HDD's setting within a karst formation, enhanced monitoring of all aspects of the HDD will be implemented from initiation to completion. Prior to initiating the 16-inch pilot hole, the drilling contractor, environmental inspector and professional geologist (PG) will review the revised 16-inch profile and the 20-inch as-built profile to pinpoint areas of potential concern. Further, SPLP will provide the drilling contractor and the inspectors with locations of potential areas of concern for fluid loss and IRs based on previous areas of loss and IRs, as well as areas identified by the geophysical survey (e. g., low density areas identified in the seismic survey). As those areas of concern are approached, additional efforts will be made to include increased monitoring of pressure changes and increasing the frequency of drill path surveys to identify any surfacing of air, groundwater or drilling fluid in the event of a loss of drilling fluids. Further, the drilling contractor will evaluate the need to modify the characteristics of the drilling fluid (i.e., viscosity) and increase the frequency of swabbing the borehole to reduce the potential for cuttings to accumulate within the borehole. Finally, during HDD operations the site-specific best management practices referenced is response to Item #1 will be implemented to decrease the potential for IRs.

3. **In the re-evaluation report, please further discuss SPLP's monitoring procedure for detecting an IR and the standard operating procedures that are implemented upon the loss of circulation with special emphasis on how these provisions will minimize the occurrence and magnitude of an inadvertent return.**

An IR event is typically, but not always, preceded by an LOC and usually noted by a loss of pressure at the Annular Pressure Monitor (APM) simultaneously. Some loss of fluids to the surrounding formation is a normal occurrence while advancing an HDD as it is absorbed into the annulus of the borehole as well as filling microfractures within the annulus and the formation, with no changes noted by the APM. As noted in the HDD Inadvertent Return Assessment, Preparedness Prevention and Contingency Plan (Revised April 2018), notifications are made (based on occurrence) to the PADEP, public water suppliers within 450 feet, and every landowner with a private water supply located within 450 feet of the HDD alignment that an LOC occurred and that their water supply may be impacted. If a significant LOC (i.e., greater than 30%) occurs, the drilling contractor will attempt to condition the borehole by modifying the drilling fluids and by swabbing the borehole. This process will aid in the removal of any cuttings which may have accumulated in the borehole which could result in an increased annular pressure and can lead to fracturing the formation or increasing the magnitude of fractures already present. Further, the drilling contractor will modify the advancement rates (i.e., penetration rate and travel speed) to prevent a plunger effect from occurring and will reduce the drilling fluid pumping pressures to the minimum necessary to maintain the borehole and allow transport of the cuttings back to the surface. Finally, the drilling contractor will amend the drilling fluid by adding LCMs to seal off any fractures, voids or zones of lost circulation.

In the event the LOC continues, the drilling contractor will trip out of the boring and initiate a push ream from the entry side to increase the size of the annulus and regain fluid circulation. By initiating a push ream, the size of the borehole and annular space will be increased resulting in a corresponding decrease in annular pressure.

Should the LOCs continue to be recorded at above-normal levels subsequent to completing the push ream, the drilling contractor will trip in a packer assembly to the area of the LOC and install a cement-grout (either neat-cement or a cement-sand mixture) or LCM plug under pressure in an attempt to "squeeze" the grout/LCM into the formation and seal off the boring annulus. This will seal/fill any fractures or karst features in immediate communication with the borehole.

These procedures, along with the other site-specific procedures identified in the response to comment #1 will be utilized to minimize the occurrence and magnitude of LOCs and IRs.

4. **SPLP is reminded that drilling of any sort in a karst environment can induce subsidence sinkholes. The site geologist should be reminded to exercise vigilance for surface indications of sinkhole formation.**

The site geologist (PG) will be reminded to be vigilant and to look for evidence of sinkhole formation while conducting drill path surveys as required by the HDD Inadvertent Returns Assessment, Preparedness, Prevention and Contingency Plan. Further the Lead Geologist (PG) for Spread 4 will also periodically conduct surveys looking for evidence of subsidence features while the 16-inch HDD is being advanced.

5. **Relating to the Analysis of well production zones and use of information obtained during construction of the 20-inch pipeline:**

   The re-evaluation report fails to include an evaluation of the information and data collected from the water supply located within 450 feet of the HDD, or the other nearby water supply identified in the report (>450 feet from the HDD).

   Any private or public water supply data obtained within 450 feet or otherwise obtained in the vicinity of the 20-inch or proposed 16-inch HDD should be used and discussed as part of this HDD re-evaluation. This information and data should include, but not be limited to, any applicable water supply sampling data that SPLP may have obtained and any water supply complaints that SPLP may have received for water supplies within 450 feet of the HDD or the general vicinity during construction of the 20-inch pipeline. The results of the SPLP's water supply sampling program, investigation, disposition of the complaint, and any correlation or non-correlation to SPLP's construction activities should be evaluated and discussed in the HDD re-evaluation report. Use the report to demonstrate how the proposed 16-inch HDD activity will minimize the potential for IRs and impacts to water supplies. Please revise the re-evaluation report to include this information.

Per the Order, SPLP conducted an inventory of water supply wells located within 450 feet of the Interstate 81 Crossing HDD. One water well (WL-09122017-615-01) was identified and is represented on Attachment 3 of the Hydrogeologic Re-Evaluation Report. One additional well (WL-10022017-632-01) was identified 655 feet from the western entry/exit point of the Interstate 81 Crossing HDD location. Both wells are located on the same parcel and water well WL-1002017-632-01 supplies a separate dwelling that is rented. Water quality samples were collected on five separate occasions from both wells both during and follow the completion of the 20-inch HDD. With the exception of dissolved solids, none of the analyzed parameters identified in these samples were detected at concentrations exceeding the Department's established primary and secondary drinking water standards (MCLs/SMCLs). Based on the lack of other parameters typically associated with drilling fluid impacts (i.e., turbidity, iron, manganese) being detected at levels above laboratory reporting limits or their respective drinking water standards (MCLs/SMCLs), the elevated levels of dissolved solids are deemed representative of natural groundwater quality. As a result of these findings, no impacts to groundwater quality were identified that can be attributed to installation of the I-81 Crossing 20-inch HDD. Summary tables containing the analytical results from the various water quality sampling events are attached.

On August 17, 2018, a complaint was received by the Department regarding water quality impacts resulting from pipeline activities to the water well supplying the Dehart residence located at 134 Horners Road, in Carlisle, Cumberland County, Pennsylvania. The complaint was based on an increase in cloudiness and a greenish tint to their water supply source. Because the residence is located approximately 7,000 feet from the Interstate 81 Crossing HDD location, a desktop evaluation was completed prior to conducting a site inspection and collection of water quality samples. Results of the desktop evaluation completed by a Pennsylvania-licensed PG determined that the Interstate 81 Crossing HDD did not impact the Dehart water well. This conclusion is based on the distance between the HDD and the Dehart residential well, the length of time between the completion of the 20-inch HDD, the Department's receipt of the complaint (approximately 9 months), the location of the water well topographically upgradient of the HDD location, and direction of groundwater flow away from the Dehart property relative to the HDD site. This information was summarized in the S2-0220 I-81 HDD Dehart Water Well Complaint Investigation Report submitted to the Department on September 5, 2018. On January 4, 2019, the Department concurred there was no evidence that SPLP's Mariner East 2 construction activities caused pollution as alleged in the complaint.

SPLP submits that we have been, and are, in complete compliance with the agreed terms and analysis requirements of the Order, as agreed to by the Department, and that no further analysis is required for the Department to consent to the start of this HDD. SPLP therefore requests that the Department approve the Re-Evaluation Report for the Interstate 81 Crossing Horizontal Directional Drill (S2-0220) as soon as possible.

Sincerely,

Larry J. Gremminger, CWB
Vice-President – Environmental, Health & Safety
Energy Transfer Partners
Mariner East 2 Pipeline Project

Pertaining to the practice of geology and information conveyed.

6/17/2019

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

Date

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
DOUGLAS JAY HESS
GEOLOGIST
PG000186G

Attachment as stated.

Sunday Water Sample Analytical Results Summary

Parcel ID: 21-07-0465-012 (40 South Middlesex Road)

Well Location Map ID: WL-09122017-615-01 and WL-10022017-632-01

Parameter	Units	Sample Date: 9/12/2017 Well 1 Sample I.D.: 09122017-615-01	Sample Date: 10/2/2017 Well 1 Sample I.D.: 10022017-632-01	Sample Date: 10/2/2017 Well 2 Sample I.D.: 10022017-632-02	Sample Date: 4/27/2018 Well 1 Sample I.D.: 04272018-639-01	Sample Date: 4/27/2018 Well 2 Sample I.D.: 04272018-639-02	PA DEP Drinking Water MCL/SMCL
Coliform, fecal	col/100ml	6.00	~826	5.00	2.00	1.00	-
E. Coli	MPN/100ml	4.10	>2419.6	4.10	1.00	4.10	-
Coliform, total	MPN/100ml	313	>2419.6	55.7	194	127	-
Dissolved Solids	mg/l	**525**	**521**	**518**	**530**	**537**	500
Suspended Solids	mg/l	ND	3.60	ND	ND	ND	-
Hardness (colorimetric) as CACO3	mg/l	369	348	348	348	397	-
Turbidity	NTU	0.395	0.902	ND	ND	0.864	-
Alkalinity	mg/l	291	299	297	250	253	-
pH	SU	7.28	7.26	7.22	7.25	7.23	-
Specific Conductance	umhos/cm	281	947	938	978	991	-
Bromide	mg/l	ND	ND	ND	ND	ND	-
Chloride	mg/l	97.7	105	100	124	124	250
Sulfate	mg/l	31.9	33.8	31.8	30.1	30.6	250
Barium	mg/l	0.0614	0.0638	0.0625	0.0600	0.0622	2
Calcium	mg/l	113	118	116	110	110	-
Iron	mg/l	ND	ND	ND	ND	0.107	0.3
Magnesium	mg/l	19.7	20.7	19.8	19.5	19.5	-
Manganese	mg/l	0.0167	ND	ND	ND	ND	0.05
Potassium	mg/l	3.74	2.40	2.83	3.77	3.02	-
Sodium	mg/l	50.4	50.8	52.3	63.9	69.7	-
Methane	mg/l	ND	ND	ND	ND	ND	-
Ethane	mg/l	ND	ND	ND	ND	ND	-
Ethene	mg/l	ND	ND	ND	ND	ND	-
Propane	mg/l	ND	ND	ND	ND	ND	-
Benzene	mg/l	ND	ND	ND	ND	ND	0.005
Toluene	mg/l	ND	ND	ND	ND	ND	1
Ethylbenzene	mg/l	ND	ND	ND	ND	ND	0.7
Total Xylenes	mg/l	ND	ND	ND	ND	ND	10
Residual Bentonite	-	NA	NA	NA	NA	NA	-

20-inch HDD construction dates: April 27, 2017 through November 2, 2017

16-inch HDD construction dates: Awaiting PA DEP authorization to start

Notes:

1. MCL - Maximum Primary Contaminant Level
2. SMCL - Maximum Secondary Contaminant Level
3. NA - Not Analyzed
4. ND - Not Detected
5. col/100ml - colonies per 100 milliliters
6. MPN/100ml - most probable number per 100 milliliters
7. mg/l - milligrams per liter
8. NTU - nephelometric turbidity units
9. SU - standard units
10. umhos/cm - micro ohms per centimeter

Concentrations that are bolded exceed or are equivalent to their respective PA DEP MCL/SMCL

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

This reanalysis of the horizontal directional drill (HDD) installation of a 16-inch diameter pipeline that traverses Interstate Highway 81 (I-81), Middlesex Road, Wetland W-I30, and Stream S-I47 in Middlesex Township, Cumberland 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 9 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 HDD had two inadvertent returns (IR) with multiple flow events for these locations during installation of the 20-inch pipeline. The combined IR location was remediated after completion of the pipeline installation.

The 16-inch pipeline HDD is referred to herein as HDD S2-0220-16.

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.

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

Ductility of the steel used for pipelines is determined by the percentage of carbon within the steel. Generally steel pipe is categorized as "low carbon" having less than 0.3% carbon content within the steel, and "high carbon" having greater than 3% carbon within the steel. As the carbon content within the steel used to make the pipe increases, the flexibility of the pipe is decreased. The X70 16-inch pipe utilized on the Mariner project is a low carbon steel pipe.

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

All of the information and the stress assessment procedures discussed above are incorporated into the profile design and implemented in analysis of the drilling profile to ensure the integrity of the pipeline as installed.

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

Specifics for the original permitted 16-inch HDD plan and profile are discussed in the original permitted HDD design summary below. Specifics for the revised 16-Inch HDD plan and profile are discussed in the Redesigned Horizontal Directional Drill Design Summary at the end of this report.

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 1,215 feet (ft)
- Entry/Exit angle: 10-11 degrees
- Maximum depth of cover: 73 ft
- Depth below wetlands: 55-58 ft
- Depth below stream: 47 ft
- Pipe design radius: 1,600 ft

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

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

The occurrence of the IR events in Wetland W-I30 during the installation of the 20-inch diameter pipeline resulted from the shallow depth of the profile while drilling through dissolved and fractured limestone/dolomite bedrock. This is evidenced by the documented losses of circulation at several points in the profile during the pilot hole drilling and reaming phase. No attempts at controlling fluid losses were made during the pilot or reaming phases.

GEOLOGIC ANALYSIS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (PABTGS), the site is in the Great Valley Section of the Ridge and Valley Physiographic Province of Pennsylvania and is underlain by very finely crystalline limestone with minor occurrences of dolomite and chert. The site geology for the redesigned 16-inch HDD profile is mapped as the Ordovician-age St. Paul Group (Osp) as shown on Figure 2 (Socolow, 1980). This geologic unit is described as buff-colored, finely crystalline magnesium limestone containing numerous layers of chert, high calcium limestone in part, with a thickness of approximately 900 feet (Root, 1978). The lower and upper parts of the St. Paul Group are predominantly pure limestone except for minor amounts of dolomite. The middle part consists of darker, impure limestone and abundant interbanded dolomite and some dolomite interbeds. This Group is considered difficult to excavate, due to the degree and extent of bedrock pinnacle development; however, drilling rates are classified as moderate.

RETTEW completed a multi-technique geophysical survey at the I-81 HDD on between October 24 and November 17, 2018. The purpose of the survey was to provide supplemental information for the geotechnical drilling programs and to detect and delineate subsurface voids or low-density zones that could contribute to IRs and/or loss of returns (LORs) and to determine the rock profile and rock rippability for ease of excavation along the HDD path. Results from the geophysical surveys are consistent with each other, and with the geology as mapped by the PA Geological Survey; all suggesting that the local bedrock is only mildly karstified, with a few potential anomalous zones of concern. In the limestone zone, the top-of-rock is expected to be slightly pinnacled (highly irregular) with interfingered competent rock and residual clay soils.

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

HYDROGEOLOGY, GROUNDWATER, AND WELL PRODUCTION ZONES

Groundwater at the site occurs in a fractured, solution-prone, carbonate bedrock aquifer system within the St. Paul Group. In carbonate rocks, water-bearing zones generally occur in solution-enhanced secondary openings that form along bedding planes, joints, faults and fractures. Most of the water-bearing zones penetrated by supply wells occur in individual fractures or groups of interconnected fractures that are sufficiently enlarged by dissolution of bedrock to provide pathways for the transport of groundwater.

The median depth of water supply wells in the St. Paul Group is reported to be 178 feet bgs with a median depth to water of 38 feet bgs (Becher and Root, 1981). Rocks of the St. Paul Group have a reported median sustained yield of 82 gallons per minute (gpm) attributed to well-developed fractures and solution openings. Sustained yields of large capacity production wells are reportedly between 105 and 260 gpm. Although the maximum density of water-bearing zones is developed at shallow depths, these zones are nearly as abundant to depths of 250 feet bgs. Between 251 and 550 feet, water yielding zones are rare. However, in the 551- to 600-foot depth bgs range, the number of zones per 100 feet of hole evaluated is almost as great as in the shallower zone (Becher and Root, 1981).

Well records for 29 individual water supply wells within a 0.5-mile radius of the I-81 HDD were obtained from the Pennsylvania Groundwater Information System (PaGWIS, 2019). The 29 wells identified within a 0.5-mile radius of the HDD consist of 8 commercial/industrial water supply wells, 16 domestic water supply wells, 3 irrigation wells, and 2 with other/unknown use. The well locations are shown on Figures 2 and 3. Well construction details were not reported for all of the wells; however, the majority of the identified wells were completed as 6-inch-diameter open-rock wells with total depths ranging from 80 to 875 feet bgs. Reported well yields range from 1 to 100 gpm, while the reported depth to water ranges from 15.9 to 100 feet bgs with an average of 51 feet bgs.

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

INADVERTENT RETURN (IR) DISCUSSION

As introduced previously, the occurrence of the IR events in Wetland W-I30 during the installation of the 20-inch diameter pipeline resulted from the shallow depth of the profile while drilling through dissolved and fractured limestone/dolomite bedrock. This is evidenced by the documented losses of circulation (LOC) at several points in the profile during the pilot hole drilling and reaming phase. During drilling, the IR points were combined, lined with controls, and used as an unconventional relief hole for the remainder of the pilot phase and during the initial reaming stages. Once a 22-inch diameter reaming tool had completed the profile run, the discharge of fluids to the IR containment stopped, and no flows occurred during the 30-inch ream and pipe pull.

No attempts at controlling fluid losses were made during the pilot or reaming phases.

As discussed in the Revised Horizontal Directional Drill section below, SPLP drilling specialists have redesigned the 16-inch HDD profile to near the maximum limits of the pipe free stress tolerances to maximize the depth of profile, and increased the entry/exit angles.

These changes alone are unlikely to prevent LOC during the 16-inch HDD, and proactive response measures will be implemented to seal the HDD annulus as LOCs are observed during the HDD phases.

ADJACENT FEATURES ANALYSIS

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

The crossing of I-81 is located in Cumberland County, approximately 0.4 miles south-southwest of the township of Middlesex, Pennsylvania, and approximately 4.0 miles northeast of the borough of Carlisle, Pennsylvania.

This HDD location traverses under one stream and one wetland. Stream S-I47 is designated as a high quality coldwater fishery under Chapter 93 and drains to a Class A naturally-reproducing trout stream, according to the Pennsylvania Fish and Boat Commission. Wetland I30 is designated as exceptional value for being in the floodplain of a stream that either is classified or drains to a stream classified as having naturally-reproducing trout populations. This HDD avoids surficial impacts to stream S-I47, a high quality stream, and wetland I30, an exceptional value wetland. Additionally, this HDD avoids surficial impacts to the floodway of stream S-I47, a Federal Emergency Management Agency (FEMA) 100-year floodplain (Chapter 106), I-81, existing underground utilities (e.g., water line, sewage line), an overhead powerline, and South Middlesex Road.

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, one water supply well was identified within the 450-foot radius and one additional water well was identified outside the search radius. The total depth of the well inside the 450-foot search radius is reported to be greater than 100 feet bgs. Information was not available pertaining to the depth to water or pump setting. The water well identified outside the 450-foot search radius is located approximately 650 feet northwest of the western HDD entry/exit point. This well was reported to have a total depth of 180 feet bgs and pump setting depth of approximately 100 feet bgs.

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 the revised HDD alignment.

ALTERNATIVES ANALYSIS

As stated in the Order, the second (16-inch-diameter) HDD pipeline installation at Interstate Highway 81 (I-81) is characterized as a "High Risk" HDD activity, and therefore PADEP has requested an enhanced alternatives analysis for this HDD. As required by the Order, the reevaluation of HDD S2-0220 includes an analysis of alternatives, including open cut, conventional auger bore (CAB), FlexBor, Direct Pipe Bore, and potential re-routes. As part of the PADEP Chapter 105 permit process for the Pennsylvania Pipeline Project, SPLP developed and submitted for review a project-wide Alternatives Analysis. During the development and siting of the Project, SPLP considered several different routings, locations, and designs to determine whether there was a practicable alternative to the proposed impact. SPLP performed this determination through a sequential review of routes and design techniques, which concluded with an alternative that has the least environmental impacts, taking into consideration cost, existing technology, and logistics. The baseline route provided for the pipeline construction was to cross every wetland and stream on the project by open cut construction procedures. The Alternatives Analysis submitted to PADEP conceptually analyzed the potential feasibility of any alternative to baseline route trenched resource crossings (e.g., reroute, conventional bore, HDD). The decision-making processes for selection of the HDD instead of an open cut crossing methodology is discussed thoroughly in the submitted alternatives analysis and was an important part of the overall PADEP approval of HDD plans as currently permitted. As described below, the analyses of potential open cut, CAB, FlexBor, Direct Pipe Bore, and re-route alternatives have confirmed the conclusions reached in the previously submitted Alternatives Analysis.

HDD Alternative

Use of the originally-proposed HDD construction method across the entire current 1,221-foot-long crossing alignment (encompassing all workspace limits of disturbance for pipeline installation, not including additional temporary workspace [ATWS] to accommodate the HDD pullback string) is a technically feasible and practicable alternative taking into consideration cost, existing technology, and logistics. At this HDD location, I-76, commercial buildings, paved parking areas, and driveways are to the south; I-81 and commercial buildings, paved parking areas, and driveways are to the north and northwest; and South Middlesex Road, a driveway, and commercial facility are to the east. The presence of these existing structures necessitated the HDD to avoid effects to public infrastructure (I-81 and South Middlesex Road), existing underground utilities, and commercial developments at this location. Accordingly, use of the originally-proposed HDD construction method avoids potential significant impacts to these other (non-wetland) environmental (infrastructure) resources. Alteration of the current permitted route and plans for installation would require major modifications of the state Chapter 102 and Chapter 105 permits, and authorization issued by the U.S. Army Corps of Engineers.

The originally-proposed HDD construction method results in the second largest total land impact (3.25 acres) compared to the other alternatives evaluated in this analysis. However, the majority of this area involves only temporary surface use (no grading) associated with the 2.28-acre ATWS to accommodate the HDD pullback string on the west side of the HDD alignment (see Figure 1 in Attachment 2). As a result, the originally-proposed HDD construction method actually minimizes the total area of land disturbed by grading and/or excavation (approximately 0.97 acre). Moreover, the HDD method avoids direct impacts to the bed, banks, and floodway of an unnamed tributary to LeTort Spring Run (stream S-I47) which is a PADEP Chapter 93 designated High Quality-Cold Water Fishery (HQ-CWF); and exceptional value (EV) wetland W-I30 (palustrine emergent and palustrine forested [PFO] wetland) (Tables 1a, 1b). This includes avoidance of PFO cover type conversion of EV wetland W-I30 and associated potential requirements for compensatory mitigation.

Table 1a. Horizontal Directional Drill (HDD) Alternative Impacts on Wetlands.

Wetland	Crossing Method	Cowardin Classification [1]	Exceptional Value (EV) Designation	Wetland Temp Impact (acres) [3]	Wetland Perm Impact (acres) [3]	PFO Cover Type Conversion [1,2] (acres)
W-I30	HDD	PEM	Yes	0 (0)	0 (0.006)	n/a
W-I30	HDD	PFO	Yes	0 (0)	0 (0)	0

[1] PEM = palustrine emergent, PSS = palustrine scrub-scrub, PFO = palustrine forested, n/a = not applicable.

[2] Permanent conversion of PFO cover type to PEM cover type due to maintenance of permanent ROW.

[3] Use of the HDD construction method avoids direct wetland impacts, therefore impacts are denoted as zero (“0”). Parentheses denote PADEP impact calculations for the area of pipeline installed beneath the wetlands.

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

Table 1b. Horizontal Directional Drill (HDD) Alternative Impacts on Waterbodies.

Stream	Crossing Method	Stream Dist. Length in Perm ROW (feet) [1]	Stream Dist. Length in Temp ROW (feet) [1]	Stream Perm Impact (sq. feet) [1]	Stream Temp Impact (sq. feet) [1]	PADEP Perm Floodway Impact (acres) [1]	PADEP Temp Floodway Impact (acres) [1]	Ch. 106 Perm Floodplain Impact (acres) [1]	Ch. 106 Temp Floodplain Impact (acres) [1]
S-I47	HDD	0 (10)	0 (0)	0 (13)	0 (0)	0 (0.004)	0 (0)	n/a	n/a
S-I48	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.291

[1] Use of the HDD construction method avoids direct stream impacts, therefore impacts are denoted as zero (“0”). Parentheses denote PADEP impact calculations for the area of pipeline installed beneath the streams and clearing workspaces that impacts the streams’ floodways.

Additionally, as required by the Order, follow-up restoration monitoring of the previous IR events in wetland W-I30 is being conducted. Based on monitoring performed in May 2019, restoration of aquatic resources impacted by IRs is trending rapidly toward success (see enclosed photographs of restoration progress at wetland W-I30 in Attachment 2). In the event an IR should occur in the aquatic resources above this HDD, restoration activities will occur immediately such that temporary impacts will be minimized to the greatest extent practicable.

Based on the results of this reevaluation, use of the originally-proposed HDD construction method for the I-81 crossing area: 1) is a technically feasible alternative; 2) is a practicable alternative taking into consideration cost, existing technology, and logistics; 3) avoids potential significant impacts to other (non-wetland) environmental resources; and 4) results in the least environmental impact (including the least acreage disturbed by grading and/or excavation) compared to the other technically-feasible and practicable alternatives analyzed. Therefore, the originally-proposed HDD construction method is the preferred and selected alternative for this crossing location.

Open Cut Alternative

Use of the open cut construction method across the entire current 1,221-foot-long crossing alignment, is neither a technically feasible nor practicable alternative due to the requirement to use horizontal directional drill (or alternative trenchless) construction methods to install the 16-inch-diameter pipeline beneath the I-81 and South Middlesex Road. Any open cut alternative crossing of I-81 or South Middlesex Road would not be permitted by PennDOT due to the impact to use of a major roadway by the public. Therefore, any open cut alternative would require the use of horizontal directional drill (or potentially other trenchless) construction methods to cross I-81 and South Middlesex Road at a minimum (see combination open cut/bore alternatives analyses below).

If a theoretical open cut construction method were practicable (see Figure 2 in Attachment 2), then use of this method would result in direct but temporary impacts to the bed, banks, and floodway of an unnamed tributary to LeTort Spring Run (stream S-I47) which is a PADEP Chapter 93 designated HQ-CWF; the floodplain fringe of HQ-CWF stream S-I48 (LeTort Spring Run); and exceptional value (EV) wetland W-I30 (palustrine emergent wetland); as well as permanent wetland cover type conversion of EV wetland W-I30 (palustrine forested wetland) and associated potential requirements for compensatory mitigation (Tables 2a, 2b). SPLP specifications require a minimum of 48 inches of cover between the installed pipeline and the bottom of the watercourse. To meet this cover requirement, during trenched construction through stream S-I47 (open water) and wetland W-I30, an open cut workspace with a minimum width of 75 feet would be required to accommodate the 16-inch-diameter pipeline and provide sufficient space for trench excavation, spoil storage, pipeline installation, and sufficient separation between pipelines (for integrity management). The assessed area of impact by this open cut plan would directly affect approximately 2.10 acres of land (primarily forested land, emergent wetland, existing paved roadways, and open/agricultural lands), 61 feet at the unnamed tributary to LeTort Spring Run (stream S-I47), and 186 feet (at centerline) of emergent and 13 feet (of workspace) of forested wetland (wetland W-I30) adjacent to stream S-I47. The assessed area of impact by this open cut plan would directly affect 0.02 acre of state water bottom, 0.36 acre of EV wetland (including 0.004 acre of forested wetland conversion), 0.23 acre of floodway, and 0.052 acre of floodplain fringe.

Table 2a. Open Cut Alternative Impacts on Wetlands.

Wetland	Crossing Method	Cowardin Classification [1]	Exceptional Value (EV) Designation	Wetland Temp Impact (acres)	Wetland Perm Impact (acres)	PFO Cover Type Conversion [1,2] (acres)
W-I30	Open Cut	PEM	Yes	0.138	0.221	n/a
W-I30	Open Cut	PFO	Yes	0	0.004	0.004

[1] PEM = palustrine emergent, PSS = palustrine scrub-scrub, PFO = palustrine forested, n/a = not applicable.

[2] Permanent conversion of PFO cover type to PEM cover type due to maintenance of permanent ROW.

Table 2b. Open Cut Alternative Impacts on Waterbodies.

Stream	Crossing Method	Stream Dist. Length in Perm ROW (feet)	Stream Dist. Length in Temp ROW (feet)	Stream Perm Impact (sq. feet)	Stream Temp Impact (sq. feet)	PADEP Perm Floodway Impact (acres)	PADEP Temp Floodway Impact (acres)	Ch. 106 Perm Floodplain Impact (acres)	Ch. 106 Temp Floodplain Impact (acres)
S-I47	Open Cut	61	30	610	300	0.151	0.080	n/a	n/a
S-I48	Open Cut	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0.051

As mentioned above, use of the open cut crossing method through this area would result in impacts to EV wetland W-I30, including approximately 0.36 acre and 0.004 acre of impacts to emergent and forested wetland vegetative cover types, respectively. The HDD will largely avoid surface impacts to biological features, and as currently proposed results in no surface impacts to wetlands (impact avoidance) compared to the open cut alternative.

Open cut impacts to these resources would require modification of the state and federal permits. PADEP likely would require use of an approved dry open cut crossing method – such as the dam-and-pump construction method – as a best management practice to prevent downstream turbidity during construction activities across the unnamed tributary to LeTort Spring Run (stream S-I47). PADEP also likely would require that fisheries biologists monitor the bypass section of the crossing area to ensure it is free of fish prior to and for the duration of open cut construction activities; and that captured fish species are handled through Pennsylvania Fish and Boat Commission (PAFBC) approved capture, handling, and reporting procedures and conditions. Based on the PAFBC classification for stream S-I47 (Drains to Class A, wild trout-natural reproduction [TNR]), this stream requires a construction moratorium between October 1 – April 1; a PAFBC waiver would be required if construction activities would occur during this construction moratorium period. In addition, a portage may be required to provide waterway navigation users access around the crossing area, which in turn would require an activity-specific aids to navigation (ATON) permit from PAFBC.

The open cut crossing of the unnamed tributary to LeTort Spring Run (stream S-I47) would require damming the stream using an upstream and downstream geotube, while simultaneously pumping around all stream flows, and pumping out of all produced groundwater discharge from the excavated shallow soil horizons and water seepage below the geotube dams installed in the channel for the entire duration of the open cut crossing event. Moreover, any produced groundwater in the open excavations would be pumped to a discharge filtration structure. The current feasible filtration ability, however, does not exceed 50 microns. Therefore, cloudy water (from suspended fine clay and silt particles) would be discharged downstream regardless of all control methods employed for the entire duration of the use of open cut construction techniques.

Although the above surface disturbances to the subject wetland and stream resources would be controlled and managed using the measures in SPLP's Impact Avoidance, Minimization, and Mitigation Plan and E&S Plan to a level that is temporary and minor, the open cut construction method is not technically feasible (I-81 and South Middlesex Road must be crossed by trenchless construction methods) and therefore not practicable, such that the required and preferred method would be to use a horizontal directional drill (or potentially an alternative trenchless) construction method to avoid these surface disturbances.

Based on the results of this reevaluation, use of the open cut construction method for the I-81 crossing area: 1) is not a technically feasible alternative (is not permittable); 2) is not a practicable alternative taking into consideration cost, existing technology, and logistics (is not permittable); 3) would not comply with required regulations and would result in potential significant impacts to other (non-wetland) environmental (infrastructure) resources; and 4) results in greater environmental impacts compared to the originally-proposed HDD construction method. Therefore, the open cut construction method is not the preferred or selected alternative for this crossing location.

Conventional Auger Bore (CAB) Alternative

Use of the conventional auger bore (CAB) construction method across the entire 1,221-foot-long (I-81 HDD crossing area) alignment is neither technically feasible nor practicable due to the length limitations of this construction technology, as discussed below.

As discussed in the original Alternatives Analysis (Section 4.1.2 – Practicability Constraints in the Trenchless Construction Feasibility Analysis [TCFA]), auger boring was initially developed to cross under two-lane roadways with an average length of 40 feet and a maximum length of 70 feet. However, with demand for longer installations increasing, the current maximum extent for a CAB installation of a 16-inch-diameter pipeline is approximately 390 feet (note that 390 feet was used as an initial screening criterion in the TCFA). Accordingly, this crossing methodology should only be considered for avoidance of obstacles of somewhat less than 390 feet in length, and therefore would be considered not technically feasible for the current 1,221-foot-long crossing alignment. Based on experience gained during construction of the Mariner II Pipeline project, conventional auger bores should be limited to approximately 200 linear feet at a time, or less, varying by the underlying substrate. Conventional auger bores for the 16- and 20-inch pipelines, attempted at longer distances, have at times had alignment drift and elevation deflections which have complicated installation. Drift and deflection are safety concerns when boring adjacent to in-service pipelines and other utilities.

Finally, given use of the CAB construction method is technically limited to less than 200 linear feet at a time (and varying by the underlying substrate), due to the resource and other obstacle spacing constraints at the location of this HDD, there are no subset locations across the current 1,221-foot-long crossing alignment to feasibly employ this type of installation method.

Based on the results of this reevaluation, use of the CAB construction method for the I-81 crossing area: 1) is not a technically feasible alternative; and 2) is not a practicable alternative taking into consideration cost, existing technology, and logistics. Therefore, the CAB construction method is not the preferred or selected alternative for this crossing location.

Combination Open-Cut/CAB Alternatives

Given neither an open cut nor a CAB construction method alone is technically feasible nor practicable (see above), SPLP developed two theoretical combination open cut/CAB crossing alternatives across the entire I-81 HDD crossing alignment. These combination open cut/CAB crossing alternatives were developed with consideration and incorporation of:

- best engineering design practices;
- requirements to use trenchless construction methods to install the 16-inch-diameter pipeline beneath I-81 and South Middlesex Road;
- known areal extent and classification of existing PADEP-regulated wetlands, waterbodies, and floodplains/floodways, and objective to avoid or minimize surface disturbance to these resources;
- known areal extent and protection requirements of existing agency-regulated significant land use, cultural, and human environment resources, and objective to avoid or minimize surface disturbance to these resources;
- known existing topographic, geologic, and hydrogeologic conditions and constraints at and below the ground surface along and adjacent to the current 1,221-foot-long crossing alignment based on the ***HDD Hydrogeologic Reevaluation Report***; and
- given these conditions and constraints, the objective to use the minimum linear extent of the CAB construction method (potentially) practicable.

Therefore, these theoretical alternatives represent the most (potentially) practicable combination open cut/CAB crossing alternatives available based on existing technology, logistics, and cost. Plan view drawings depicting these combination alternatives are provided as Figures 3 and 4 in Attachment 2.

Description and Analysis of Alternatives

These theoretical combination alternatives along the current 1,221-foot-long alignment cross multiple surface and subsurface features, including from west to east: I-81 southbound lane, I-81 northbound lane, EV wetland W-I30 (palustrine emergent and palustrine forested wetland), the floodway and bed/banks of stream S-I47 (a PADEP Chapter 93 designated HQ-CWF), a public water line, two sanitary sewer lines, South Middlesex Road, a fenceline, and an overhead electric distribution line. As depicted on the plan view drawings in Figures 3 and 4 in Attachment 2, these alternatives would necessarily include two (2) CAB crossings (one of I-81 and one of South Middlesex Road), whereas the remaining portions of the current pipeline alignment theoretically could be installed using the open cut construction method.

Combination Open-Cut/CAB Alternative 1 (Avoid Stream/Wetland Resources)

Due to practicability constraints related to spacing of resources (stream S-I47 and wetland W-I30) located between the major infrastructure obstacles (I-81 and South Middlesex Road), the Combination Open Cut/CAB Alternative 1 alignment is designed to use a single central CAB entry pit for both CAB crossings to avoid open cut construction across these (stream S-I47 and wetland W-I30) resources (see Figure 3 in Attachment 2). Specifically, this alternative includes from west to east:

- A 60-foot-long (including 16-foot-long CAB receiving pit) open cut construction method crossing of uplands (open land) that immediately abuts the start of the CAB pipeline installation to the east;
- A 680-foot-long CAB crossing of I-81 southbound lane, I-81 northbound lane, EV wetland W-I30 (palustrine emergent and palustrine forested wetland), and the floodway and bed/banks of stream S-I47;
- A 56-foot-long open cut (CAB entry pit) construction method crossing of uplands (open land);
- A 280-foot-long CAB crossing of a public water line, two sanitary sewer lines, South Middlesex Road, a fenceline, and an overhead electric distribution line; and

- A 145-foot-long (including 16-foot-long CAB receiving pit) open cut construction method crossing of uplands (active agricultural land).

This theoretical Combination Open Cut/CAB Alternative 1 was determined to be neither technically feasible nor practicable due to multiple constraints related to the CAB crossings of I-81 and South Middlesex Road, including but not necessarily limited to technical limitations on maximum practicable CAB length, safety concerns related to CAB bore/receiving pit depth, and suboptimal access and constrained workspace due to the juxtaposition of obstacles intended to be avoided, as discussed below.

As noted previously due to pipeline installation requirements, I-81 and South Middlesex Road cannot be open cut and require use of the horizontal directional drill (or an alternative trenchless) construction method. Based on best engineering design parameters (and the objective of this alternative to avoid open cut impacts on stream and wetland resources), the shortest practicable CAB crossing of I-81 is 680 feet and of South Middlesex Road is 280 feet (see Figure 3 in Attachment 2). As discussed above (see Conventional Auger Bore (CAB) Alternative), from a practicability standpoint, a CAB typically is technically limited to 200 feet in length varying by the underlying substrate (as opposed to the 390-foot length used as an initial screening criterion in the TCFA). Given the minimum lengths of the I-81 and South Middlesex Road CAB crossings are 680 feet and 280 feet, respectively, use of the CAB construction method is not technically feasible at these locations.

Based on existing topography and use of the minimum CAB lengths, the depths of the west receiving pit (15 feet), CAB entry pit (16-19 feet), and east receiving pit (11-15 feet) present significant safety concerns for construction equipment, materials, and personnel, as pit walls would require extensive shoring and diligent monitoring to prevent failure or collapse during the lengthy boring process. In addition, the CAB entry pit workspace is constrained to the west by wetland W-I30, to the south by the I-76/Pennsylvania Turnpike right-of-way, to the east by existing buried infrastructure (public water line and two sanitary sewer lines) and South Middlesex Road, and to the north by wetland W-I30 and infrastructure. Due to these constraints, the 16- to 19-foot-deep CAB entry pit has the potential to encounter the groundwater table (of wetland W-I30) and experience flooding, resulting in significant safety concerns for construction equipment, materials, and personnel. Therefore, use of the CAB construction method is suboptimal at best with regard to safety of construction equipment, materials, and personnel at this location.

Finally, available access and workspace are substantively constrained, and therefore suboptimal, due to the juxtaposition of existing obstacles (infrastructure and resources) that are intended to be avoided by use of the CAB construction method. Specifically as noted above, due to practicability constraints related to spacing of resources (stream S-I47 and wetland W-I30) located between the major infrastructure obstacles (I-81 and South Middlesex Road), this Combination Open Cut/CAB Alternative 1 is designed to use a single central CAB entry pit for both CAB crossings to avoid open cut construction across these (stream S-I47 and wetland W-I30) resources. This central CAB entry pit is essentially isolated, located within a triangular area bounded by I-81 to the west, I-76/Pennsylvania Turnpike to the south, and South Middlesex Road to the east. Because of access restrictions associated with the two interstate highway rights-of-way, available access to the central CAB entry pit is only available via South Middlesex Road, which is to the east of stream S-I47 and wetland W-I30. Accordingly, to avoid direct impacts (via open cut construction method, temporary access road) to these stream and wetland resources, the CAB entry pit and associated ATWS is necessarily located between South Middlesex Road (to the east) and the resources (to the west) in a very constrained workspace area.

If this theoretical Combination Open Cut/CAB Alternative 1 were technically feasible (see Figure 3 in Attachment 2), then use of this method would avoid the direct but temporary and minor impacts to the bed, banks, and floodway of one stream (stream S-I47) that is a PADEP Chapter 93 designated HQ-CWF, and one EV wetland (wetland W-I30, palustrine emergent and palustrine forested wetland). SPLP specifications require a minimum of 48 inches of cover between the installed pipeline and the bottom of the watercourse.

To meet this cover requirement during CAB construction beneath stream S-I47 and wetland W-I30, deep entry and receiving pits would be required resulting in a suboptimal CAB construction method design at best with regard to safety of construction equipment, materials, and personnel at this location.

The assessed area of impact by this combination open cut/CAB construction method plan would directly affect approximately 2.58 acres of land (primarily open land, active agricultural land, and forested land), <0.01 acre of state water bottom, 0.06 acre of floodway, and <0.01 acre of floodplain fringe. The alternative combination open cut/CAB construction method crossings of these resources would require modification of the state and federal permits.

Table 3a. Combination Open Cut/CAB Alternative 1 Impacts on Wetlands.

Wetland	**Crossing Method**	**Cowardin Classification [1]**	**Exceptional Value (EV) Designation**	**Wetland Temp Impact (acres) [3]**	**Wetland Perm Impact (acres) [3]**	**PFO Cover Type Conversion [1,2] (acres)**
W-I30	CAB	PEM	Yes	0 (0)	0 (0.006)	n/a
W-I30	CAB	PFO	Yes	0 (0)	0 (0)	0

[1] PEM = palustrine emergent, PSS = palustrine scrub-scrub, PFO = palustrine forested, n/a = not applicable.

[2] Permanent conversion of PFO cover type to PEM cover type due to maintenance of permanent ROW.

[3] Use of the CAB construction method avoids direct wetland impacts, therefore impacts are denoted as zero ("0"). Parentheses denote PADEP impact calculations for the area of pipeline installed beneath the wetlands.

Table 3b. Combination Open Cut/CAB Alternative 1 Impacts on Waterbodies.

Stream	**Crossing Method**	**Stream Dist. Length in Perm ROW (feet)**	**Stream Dist. Length in Temp ROW (feet)**	**Stream Perm Impact (sq. feet)[1]**	**Stream Temp Impact (sq. feet) [1]**	**PADEP Perm Floodway Impact (acres) [1]**	**PADEP Temp Floodway Impact (acres) [1]**	**Ch. 106 Perm Floodplain Impact (acres) [1]**	**Ch. 106 Temp Floodplain Impact (acres) [1]**
S-I47	CAB	0 (10)	0 (0)	0 (13)	0 (0)	0.008 (0.004)	0.052 (0)	n/a	n/a
S-I48	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0

[1] Use of the CAB construction method avoids direct stream impacts, therefore impacts are denoted as zero ("0"). Parentheses denote PADEP impact calculations for the area of pipeline installed beneath the streams and clearing workspaces that impacts the streams' floodways.

Based on the results of this reevaluation, use of the Combination Open Cut/CAB Alternative 1 construction method for the I-81 crossing area: 1) is not a technically feasible alternative; and 2) is not a practicable alternative taking into consideration cost, existing technology, and logistics. Therefore, the Combination Open Cut/CAB Alternative 1 construction method is not the preferred or selected alternative for this crossing location.

Combination Open-Cut/CAB Alternative 2 (Open Cut Stream/Wetland Resources)

The Combination Open Cut/CAB Alternative 2 is designed such that the CAB entry and receiving pits avoid direct affects to the stream and wetland resources (stream S-I47 and wetland W-I30) located in the center of the 1,221-foot-long crossing area (see Figure 4 in Attachment 2). However, these CAB construction method crossings of I-81 and South Middlesex Road are suboptimal and subject to failure. In addition, this plan of construction would require use of the open cut construction method to cross the EV wetland and HQ-CWF stream with the resulting direct temporary and permanent impacts and permit modification requirements as discussed above (see Open Cut Alternative). Specifically, this alternative includes from west to east:

- A 56-foot-long (including 56-foot-long CAB entry pit) open cut construction method crossing of uplands (open land) that immediately abuts the start of the CAB pipeline installation to the east;
- A 338-foot-long CAB crossing of I-81 southbound lane and I-81 northbound lane;
- A 462-foot-long (including 16-foot-long CAB receiving pit and 56-foot-long CAB entry pit) open cut construction method crossing of uplands (open land), EV wetland W-I30 (palustrine emergent and palustrine forested wetland), the floodway and bed/banks of stream S-I47, and uplands (open land);
- A 216-foot-long CAB crossing of a public water line, two sanitary sewer lines, South Middlesex Road, a fenceline, and an overhead electric distribution line; and
- A 149-foot-long (including 16-foot-long CAB receiving pit) open cut construction method crossing of uplands (active agricultural land).

This theoretical Combination Open Cut/CAB Alternative 2 was determined to be suboptimal and subject to failure due to multiple constraints related to the CAB crossings of I-81 and South Middlesex Road, including but not necessarily limited to technical limitations on maximum practicable CAB length, safety concerns related to CAB bore/receiving pit depth, and suboptimal access and constrained workspace due to the juxtaposition of obstacles intended to be avoided, as discussed below.

As noted previously due to pipeline installation requirements, I-81 and South Middlesex Road cannot be open cut and require use of the horizontal directional drill (or an alternative trenchless) construction method. Based on best engineering design parameters (and with the allowance of this alternative to open cut stream and wetland resources), the shortest practicable CAB crossing of I-81 is 338 feet and of South Middlesex Road is 216 feet (see Figure 4 in Attachment 2). As discussed above (see Conventional Auger Bore (CAB) Alternative), from a practicability standpoint, a CAB typically is technically limited to 200 feet in length varying by the underlying substrate (as opposed to the 390-foot length used as an initial screening criterion in the TCFA). Based on experience gained during construction of the Mariner II Pipeline project, CABs for the 16- and 20-inch pipelines, attempted at longer distances, have at times had alignment drift and elevation deflections which have complicated installation. Drift and deflection are safety concerns when boring adjacent to in-service pipelines and other utilities. Given the minimum lengths of the I-81 and South Middlesex Road CAB crossings are 338 feet and 216 feet, respectively, use of the CAB construction method is considered suboptimal and subject to failure at these locations.

Based on existing topography and use of the minimum CAB lengths, the depths of the I-81 CAB entry (15-16 feet) and receiving (18-19 feet) pits, and the South Middlesex Road entry (15-17 feet) and receiving (11-15 feet) pits, present significant safety concerns for construction equipment, materials, and personnel, as pit walls would require extensive shoring and diligent monitoring to prevent failure or collapse during the lengthy boring process. In addition, the I-81 CAB receiving pit workspace is constrained to the east by wetland W-I30, to the south by the I-76/Pennsylvania Turnpike right-of-way, to the west by the I-81 right-of-way boundary, and to the north by both wetland W-I30 and I-81 right-of-way boundary. Also, the South Middlesex Road CAB entry pit workspace is constrained to the west by wetland W-I30, to the south by the I-76/Pennsylvania Turnpike right-of-way, to the east by existing buried infrastructure (public water line and two sanitary sewer lines) and South Middlesex Road, and to the north by wetland W-I30 and infrastructure. Due to these constraints, these 11- to 19-foot-deep CAB pits have the potential to encounter the groundwater table (of wetland W-I30) and experience flooding in the event of heavy rain events/flooding, resulting is significant safety concerns for construction equipment, materials, and personnel. Therefore, use of the CAB construction method is suboptimal at best with regard to safety of construction equipment, materials, and personnel at this location.

Finally, available access and workspace are substantively constrained, and therefore suboptimal, due to the juxtaposition of existing obstacles (infrastructure and resources) in this crossing area. Specifically, this crossing area is isolated within a triangular area bounded by I-81 to the west, I-76/Pennsylvania Turnpike to the south, and South Middlesex Road to the east. Because of access restrictions associated with the two interstate highway rights-of-way, available access to the interior of the triangular area is only available via South Middlesex Road. This singular access represents a pinch point that substantively constrains access for construction equipment, materials, and personnel to the I-81 CAB receiving pit, open cut construction of stream S-I47 and wetland W-I30, and the South Middlesex Road CAB entry pit. In addition, because this singular access is located to the east of stream S-I47 and wetland W-I30, an equipment travel lane is required across these resources to access the I-81 CAB receiving pit (located to the west of these resources) for the duration of the I-81 CAB construction period. Finally, as described above, to minimize direct impacts on stream S-I47 and wetland W-I30, the ATWS required for these three (CAB, open cut, CAB) construction activities is constrained in all four cardinal directions by infrastructure and resource obstacles. Therefore, use of the CAB construction method is suboptimal at best with regard to constrained access and workspace at this location.

If this theoretical Combination Open Cut/CAB Alternative 2 were not suboptimal and subject to failure (see Figure 4 in Attachment 2), then use of this method would result in direct but temporary impacts to the bed, banks, and floodway of an unnamed tributary to LeTort Spring Run (stream S-I47) which is a PADEP Chapter 93 designated HQ-CWF; the floodplain fringe of HQ-CWF stream S-I48 (LeTort Spring Run); and EV wetland W-I30 (palustrine emergent wetland); as well as permanent wetland cover type conversion of EV wetland W-I30 (palustrine forested wetland) and associated potential requirements for compensatory mitigation (Tables 4a, 4b). SPLP specifications require a minimum of 48 inches of cover between the installed pipeline and the bottom of the watercourse. To meet this cover requirement, during trenched construction through stream S-I47 (open water) and wetland W-I30, an open cut workspace with a minimum width of 75 feet (in this case, 50-foot-wide permanent workspace and overlapping use of 25-foot-wide portions of the adjacent I-81 and South Middlesex Road CAB ATWS areas) would be required to accommodate the 16-inch-diameter pipeline and provide sufficient space for trench excavation, spoil storage, pipeline installation, and sufficient separation between pipelines (for integrity management).

The assessed area of impact by this combination open cut/CAB construction method plan would directly affect approximately 4.14 acres of land (primarily open/agricultural lands, forested land, and emergent and forested wetland), 61 feet at the unnamed tributary to LeTort Spring Run (stream S-I47), and 186 feet (at centerline) of emergent and 13 feet (of workspace) of forested wetland (wetland W-I30) adjacent to stream S-I47. The assessed area of impact by this combination open cut/CAB construction method would directly affect 0.01 acre of state water bottom, 0.23 acre of EV wetland (including 0.004 acre of forested wetland conversion), 0.19 acre of floodway, and <0.01 acre of floodplain fringe.

Table 4a. Combination Open Cut/CAB Alternative 2 Impacts on Wetlands.

Wetland	Crossing Method	Cowardin Classification [1]	Exceptional Value (EV) Designation	Wetland Temp Impact (acres)	Wetland Perm Impact (acres)	PFO Cover Type Conversion [1,2] (acres)
W-I30	Open Cut	PEM	Yes	0	0.221	n/a
W-I30	Open Cut	PFO	Yes	0	0.004	0.004

[1] PEM = palustrine emergent, PSS = palustrine scrub-scrub, PFO = palustrine forested, n/a = not applicable.

[2] Permanent conversion of PFO cover type to PEM cover type due to maintenance of permanent ROW.

Table 4b. Combination Open Cut/CAB Alternative 2 Impacts on Waterbodies.

Stream	Crossing Method	Stream Dist. Length in Perm ROW (feet)	Stream Dist. Length in Temp ROW (feet)	Stream Perm Impact (sq. feet)	Stream Temp Impact (sq. feet)	PADEP Perm Floodway Impact (acres) [1]	PADEP Temp Floodway Impact (acres)	Ch. 106 Perm Floodplain Impact (acres)	Ch. 106 Temp Floodplain Impact (acres)
S-I47	Open Cut	61	0	610	0	0.151	0.041	n/a	n/a
S-I48	Open Cut	n/a	n/a	n/a	n/a	n/a	n/a	0.001	0

As mentioned above, use of the open cut crossing method through this area would result in impacts to EV wetland W-I30, including approximately 0.23 acre and 0.004 acre of impacts to emergent and forested wetland vegetative cover types, respectively. The HDD will largely avoid surface impacts to biological features, and as currently proposed results in no surface impacts to wetlands (impact avoidance) compared to this open cut/CAB alternative. Finally, open cut impacts to the stream and wetland resources would require modification of the state and federal permits, as well as use of a dry crossing method for construction across stream S-I47, as described in the Open Cut Alternative.

Based on the results of this reevaluation, use of the Combination Open Cut/CAB Alternative 2 construction method for the I-81 crossing area: 1) is a technically feasible alternative, but suboptimal and subject to failure; 2) is not a practicable alternative taking into consideration cost, existing technology, and logistics; and 3) results in greater environmental impacts compared to the originally-proposed HDD construction method. Therefore, the the Combination Open Cut/CAB Alternative 2 construction method is not the preferred or selected alternative for this crossing location.

FlexBor Alternative

Use of the FlexBor construction method across the entire current 1,221-foot-long crossing alignment, or as separate I-81 (approximately 680- or 338-foot-long) and South Middlesex Road (approximately 280- or 216-foot-long) trenchless crossing alternatives, is neither technically feasible nor practicable due to the limitations of this existing technology, as discussed below.

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

Based on the results of this reevaluation, use of the FlexBor construction method for the I-81 crossing area: 1) is not a technically feasible alternative; and 2) is not a practicable alternative taking into consideration cost, existing technology, and logistics. Therefore, the FlexBor construction method is not the preferred or selected alternative for this crossing location.

Direct Pipe Bore Alternative

Use of the Direct Pipe Bore construction method across the entire current 1,221-foot-long crossing alignment, or as separate I-81 (approximately 680- or 338-foot-long) and South Middlesex Road (approximately 280- or 216-foot-long) trenchless crossing alternatives, is neither technically feasible nor practicable due to the limitations of this existing technology, as discussed below.

The Direct Pipe Bore method is also known as "microtunneling". This method of pipeline installation is a remote-controlled, continuously supported pipe jacking method. During the direct pipe installation, operations are managed by an operator in an above-ground control room alongside of the installation pit. Rock and soil cutting and removal occurs by drilling fluid injection through the cutting tool during rotation at the face of the bore, and the cuttings are forced into inlet holes in the crushing cone at the tool face for circulation to a recycling plant through a closed system. The entire operating system for this method of pipeline installation, including the cutting tool drive hydraulics, fluid injection, fluid return, and operating controls are enclosed inside the outside diameter bore pipe (or casing pipe) being installed. At the launching point/entry pit, the bore pipe is attached to a "jacking block" that hammers the bore pipe while the tool is cutting through the substrate or geology. The cutting tool face is marginally larger in diameter than the pipe to which it is attached. As a result, there is minimal annulus space, which minimizes the potential for drilling fluid returns or the production of groundwater returning back to the point of entry.

SPLP's construction contractors have successfully completed one (1) Direct Pipe Bore approximately 925 feet in length on the Pennsylvania Pipeline Project. However, the entire current HDD crossing alignment is approximately 1,221 feet in length, which exceeds the limits of Direct Pipe Bore technology.

SPLP also analyzed the option to employ a Direct Pipe Bore for an approximately 680- or 338-foot-long trenchless crossing of I-81 and an approximately 280- or 216-foot-long trenchless crossing of South Middlesex Road. Although there is sufficient workspace outside of the stream/wetland to feasibly establish a Direct Pipe Bore entry rig setup, the variability in the near subsurface geology was determined to likely result in drifting off alignment of this type of boring unit which would ultimately result in the geologic binding of the rock against the pipe casing and result in a failed bore attempt. The geology here is similar to the geology at the attempted Piney Creek Direct Pipe Bore crossing which failed.

Based on the results of this reevaluation, use of the Direct Pipe Bore construction method for the I-81 crossing area: 1) is not a technically feasible alternative; and 2) is not a practicable alternative taking into consideration cost, existing technology, and logistics. Therefore, the Direct Pipe Bore construction method is not the preferred or selected alternative for this crossing location.

Major Route Alternatives

As noted above, as part of the PADEP Chapter 105 permit process for the Pennsylvania Pipeline Project, SPLP developed and submitted for review a project-wide Alternatives Analysis. As part of the Alternatives Analysis (Section 3.3), SPLP evaluated a Major Route Alternative – the North Middleton/Mechanicsburg Southern Bypass Alternative – covering the area of analysis for the subject I-81 crossing area. The initial planning route co-located with SPLP's 8-inch pipeline corridor was determined to not be practicable due to obvious constraints and impacts that would occur along an approximately 15-mile-long pipeline segment in North Middleton, Middlesex, Silver Spring, Hampden, and Lower Allen Townships, Cumberland County. Specifically, the initial planning route would have crossed a heavily developed and populated area including residential and commercial uses in North Middleton and Mechanicsburg (see Alternatives Analysis, Appendix A: Figure 4 depicting the initial planning route). Accordingly, SPLP evaluated potential major route alternative corridors in this area that would allow co-location with other existing utility or other developed corridors, and avoid potential significant impacts on other (non-wetland) environmental resources and the subject developed and populated area.

The North Middleton/Mechanicsburg Bypass Alternative route involved two segments totaling approximately 15 miles, including a reroute of the pipeline to the north of the initial planning route and parallel to the existing Buckeye pipeline and electric transmission utility lines, and a reroute to the south of the Mechanicsburg area to a crossing of the Pennsylvania Turnpike to reconnect with the existing SPLP maintenance corridor before Rossmoyne Road (see Alternatives Analysis, Appendix A: Figure 4). This re-route alternative is approximately 15.8 miles long, and would result in an approximately 0.5 mile increase in pipeline length. This route alternative is co-located with existing utility corridors for the majority of its length and to the maximum extent practicable along the subject alignment. In both segments, the reroute parallels existing utility corridors to avoid heavily developed and congested residential and commercial areas in North Middleton and in the Mechanicsburg area. In addition to avoidance of these constructability constraints and properties, this reroute avoided areas that were congested with existing pipelines, power lines, and drainage systems, paralleling the Pennsylvania Turnpike for approximately 2 miles. This route was determined to be practicable with regard to current technology, cost, and logistics, and was selected as the proposed route.

New Potential Reroute Alternative (South Side I-76/Pennsylvania Turnpike)

As noted above (see Major Route Alternatives), as part of the PADEP Chapter 105 permit process for the Pennsylvania Pipeline Project, SPLP's initial planning route was co-located with SPLP's 8-inch pipeline corridor (see green route on Figure 5 in Attachment 2), but this route was determined to not be practicable due to obvious constraints and impacts that would occur along an approximately 15-mile-long pipeline segment in North Middleton, Middlesex, Silver Spring, Hampden, and Lower Allen Townships, Cumberland County. Accordingly, SPLP evaluated and selected a Major Route Alternative – the North Middleton/Mechanicsburg Southern Bypass Alternative – covering the area of analysis for the subject I-81 crossing area.

As a result of adoption of this Major Route Alternative, the selected, proposed, and permitted route is largely co-located with I-76/Pennsylvania Turnpike, but an approximately 4.5-mile-long segment of this route in the vicinity of the I-81 crossing area diverts from co-location with I-76/Pennsylvania Turnpike largely to avoid obvious constraints and impacts, and to accommodate HDD crossings of sensitive resources (LeTort Spring Run, I-81) before ultimately reconnecting (being co-located) with SPLP's 8-inch pipeline corridor (see purple route on Figure 5 in Attachment 2). Specifically, after diverting from SPLP's 8-inch pipeline corridor for a short distance (0.14 mile) to the southeast to co-locate with I-76/Pennsylvania Turnpike, this approximately 4.5-mile-long segment of the permitted route (from east to west):

- Is co-located with I-76/Pennsylvania Turnpike for HDD crossings of LeTort Spring Run and I-81 for approximately 0.77 mile;
- Turns to the northeast a short distance (approximately 0.26 mile) to reconnect (co-locate) with SPLP's 8-inch pipeline corridor;
- Is co-located with SPLP's 8-inch pipeline corridor for approximately 1.20 miles;
- Turns to the southeast, east, and southeast to co-locate with an electric distribution line/roadway, railroad/electric distribution line, and two electric transmission lines, respectively, for a total of approximately 1.02 miles; and
- Traverses east generally co-located on the north side of I-76/Pennsylvania Turnpike along property lines, electric distribution lines, and/or roadways, and ultimately turns south to cross I-76/Pennsylvania Turnpike, for approximately 1.27 miles.

As required by the Order, the reevaluation of HDD S2-0210 includes an analysis of alternatives, including new potential re-route alternatives in the vicinity of the I-81 crossing area. Accordingly, SPLP considered new potential re-route alternatives that could replace the approximately 4.5-mile-long segment of the permitted route described above (see purple route on Figure 5 in Attachment 2). Specifically, SPLP evaluated a theoretical new re-route alternative that is approximately 3.7-miles long and entirely co-located on the south side of I-76/Pennsylvania Turnpike (see blue route on Figure 5 in Attachment 2).

It is important to note that given the general orientation of the Pennsylvania Pipeline Project in this area of the state is from west to east, and given the general north-south orientation of LeTort Spring Run and I-81, no practicable west-east oriented re-route alternative lies to the north or south of the proposed route that would not ultimately transect this stream and its associated Pennsylvania Scenic Rivers Corridor System, as well as I-81. Shifting the permitted route to the north or south would result in new “greenfield” corridor through existing woodlands along LeTort Spring Run. A shift north would traverse a high density commercial and residential area prior to it adjoining with an existing utility corridor. A shift south would significantly increase woodland impacts and require crossing I-76/Pennsylvania Turnpike twice. In addition, the geology across the broader area, miles in extent, is karst; therefore, no reasonable re-route alternative is available in the vicinity of the permitted route that would avoid these subsurface geologic conditions.

Therefore, SPLP’s evaluation and ultimate selection of a technically feasible and practicable route and construction methods in the vicinity of the I-81 crossing area was focused on:

- Use of HDD (as required by the Pennsylvania Department of Conservation and Natural Resources [PDCNR]) to avoid LeTort Spring Run, including potential significant direct and indirect impacts to the stream, as well as its associated Pennsylvania Scenic Rivers Corridor System characterized by PDCNR as, “related adjacent land areas, and associated outstanding aesthetic and recreational values of present and potential benefit to the citizens of Pennsylvania.”
- Use of HDD to avoid direct impacts to EV wetlands W-I30 (palustrine emergent wetland) and W-I31 (palustrine forested wetland), including PFO wetland cover type conversion;
- Use of HDD to avoid direct impacts to I-81 and South Middlesex Road;
- Use of a trenchless crossing method to avoid direct impacts to the Cumberland Valley Railroad Historic District and existing railroad tracks;
- Co-location with existing disturbed corridors to the maximum extent practicable;
- Avoiding and minimizing impacts on obvious constraints and impacts to existing industrial, commercial, and residential buildings and associated infrastructure to the maximum extent practicable; and
- Avoiding and minimizing impacts to other (non-wetland or significant) environmental resources to the maximum extent practicable.

The permitted route (see purple route on Figure 5 in Attachment 2) meets all of these routing and construction method objectives, including technically feasible and practicable HDD crossings and alignments of LeTort Spring Run and I-81.

- Compared to the new potential re-route alternative, the permitted route possesses the following certain advantages –
    - Foremost, it meets all of the above-listed routing and construction method objectives, and is a technically feasible and practicable alternative with regard to the HDD crossings and alignments of LeTort Spring Run and I-81.
    - It avoids crossing LeTort Spring Run Wildlife Management Area and County Natural Heritage Inventory (CNHI) core habitat area, has a shorter crossing of the LeTort Spring Run CNHI supporting habitat area, and thus avoids the clearing of forest and placement of an HDD entry/exit site within CNHI core and supporting areas adjacent to LeTort Spring Run.
    - It is in compliance with the Pennsylvania Scenic Rivers Act, including PDCNR specific conditions required for the proposed pipeline crossings of the LeTort Spring Run Pennsylvania Scenic Rivers Corridor System.
    - It crosses one less (total of three) National Hydrography Dataset (NHD) mapped water feature; and
    - It is entirely co-located with SPLP’s existing 20-inch-diameter (PPP 1) pipeline alignment, thus optimizing use of existing right-of-way (avoids creation of new right-of-way); and optimizes construction, restoration, and operational efficiency of both (20-inch and 16-inch diameter) pipelines.

- Compared to the new potential re-route alternative, the permitted route possesses the following certain disadvantages –
  - It is approximately 0.8 mile longer (total 4.5 miles long) and impacts approximately 5.0 acres of additional land (total 38.9 acres) based on a theoretical 75-foot-wide construction right-of-way along the entirety of both routes.
    - However, the entirety of the 16-inch-diameter pipeline impact area overlaps (is coincident with) the existing 20-inch-diameter (PPP 1) pipeline impact area, such that no new impact area would be required.
  - It crosses one additional (total of five) National Wetland Inventory (NWI) mapped feature; and
  - It has a longer crossing (but entirely co-located with existing disturbed corridors) of the Appalachian Trail Historic District buffer zone.

The new potential re-route alternative (see blue route on Figure 5 in Attachment 2) meets the majority of these routing and construction method objectives, however, it possesses certain fundamental disadvantages discussed below.

- Compared to the permitted route, the new potential re-route alternative possesses the following certain advantages –
  - It is approximately 0.8 mile shorter (total 3.7 miles long) and impacts approximately 5.0 acres less land (total 33.9 acres) based on a theoretical 75-foot-wide construction right-of-way along the entirety of both routes;
    - However, the entirety of the new potential re-route alternative impact area would be new, as it would not overlap the existing 20-inch-diameter (PPP 1) pipeline impact area.
  - It crosses one less (total of four) NWI feature; and
  - It has a shorter crossing (entirely co-located with existing disturbed corridors) of the Appalachian Trail Historic District buffer zone.
- Compared to the permitted route, the new potential re-route alternative possesses the following certain disadvantages –
  - Foremost, the theoretical HDD crossings and alignments of LeTort Spring Run and I-81 are potentially neither technically feasible nor practicable with regard to existing technology, cost, and logistics.
  - Specifically, the HDD alignment of LeTort Spring Run would cross the Wildlife Management Area associated with LeTort Spring Run, identified by the Pennsylvania Natural Heritage Program as a “locally significant area (that) consists of marshy floodplain habitat along this spring-fed tributary to the Conodoguinet Creek”, which provides “habitat for a variety of bird, reptile, and amphibian species.”
  - The HDD alignment crosses the LeTort Spring Run Wildlife Management Area and CNHI core habitat area, has a longer crossing of the LeTort Spring Run CNHI supporting habitat area, and thus results in the clearing of forest and placement of an HDD entry/exit site within CNHI core or supporting areas adjacent to LeTort Spring Run.
  - These direct impacts to the LeTort Spring Run Wildlife Management Area and CNHI core and supporting habitat areas is potentially in non-compliance with the Pennsylvania Scenic Rivers Act. Specifically, based on correspondence with the PDCNR dated August 13, 2015, the proposed pipeline crossings of the LeTort Spring Run Pennsylvania Scenic Rivers Corridor System require compliance with the following specific conditions:
    - “No tree clearing will occur on the banks of the creek(s).”
    - “All construction work areas will be set back from the creek as far as possible, and those work spaces that require tree/shrub clearing will be set back from the creek bank at least 250 feet.”

- o Additionally, the HDD alignment of I-81 would require a longer crossing, and require pipeline installation beneath an existing commercial building and parking lot which is not a practicable alignment.
- o It crosses one more (total of four) NHD mapped water feature;
- o It is not co-located with SPLP's existing 20-inch-diameter (PPP 1) pipeline alignment, and requires a new separate right-of-way, thus increasing the project-wide impact area by 33.9 acres. This in turn increases construction, restoration, and operational costs and inefficiencies (related to separation of the 20-inch and 16-inch diameter pipelines).

Based on the results of this reevaluation, use of the new potential re-route alternative to cross I-81: 1) is likely not a technically feasible alternative; 2) is likely not a practicable alternative taking into consideration cost, existing technology, and logistics; 3) likely would not comply with required regulations and would result in potential significant impacts to other (non-wetland) environmental resources; and 4) results in greater environmental impacts compared to the originally-proposed HDD construction method. Therefore, the new potential re-route alternative is not the preferred or selected alternative for this crossing location.

Alternatives Analysis Conclusion

The results of this reevaluation Alternatives Analysis conducted for the I-81 HDD crossing area confirms the conclusions reached in the previously submitted alternatives analysis. Specifically, use of the originally-proposed HDD construction method for the I-81 crossing area: 1) is a technically feasible alternative; 2) is a practicable alternative taking into consideration cost, existing technology, and logistics; 3) is in compliance with required regulations and avoids potential significant impacts to other (non-wetland) environmental resources; and 4) results in the least environmental impact compared to the other technically-feasible and practicable alternatives analyzed. Therefore, the originally-proposed HDD construction method is the preferred and selected alternative for this crossing location.

REVISED HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

Additional geologic investigation has been completed, and the "as built" record for the 20-inch pipeline has been utilized in the redesign of the planned 16-inch HDD. The redesign adjusts the HDD profile deeper into bedrock and increases the angles of to minimize the time required to enter into and exit out of bedrock. A summary of the redesign factors is provided below. The original and redesigned 16-inch HDD plan and profile drawings are provided in Attachment 2.

- Horizontal length: 1,215 feet (ft)
- Entry/Exit angle: 16 degrees
- Maximum depth of cover: 93 ft
- Depth below wetlands: 87-90 ft
- Depth below stream: 83 ft
- Pipe design radius: 2,000 ft

The overall depth of the redesigned 16-inch HDD profile has been increased to nearly the maximum amount achievable within the 16-inch product pipe stress tolerance limits. The depth beneath the wetlands has been increased by approximately 36 feet (ft) compared to the 20-inch pipeline installation, which places the profile in bedrock having higher seismic velocities (i.e., higher density) as identified in the geophysical survey. The new profile depth under wetland W-I30 is approximately 80 feet which places it approximately 10 feet beneath the low velocity bedrock interval identified in the seismic survey.

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

As illustrated on Figure 2 in Attachment 3 of the Revised Re-Evaluation Report, the entry and exit angles are at 16 degrees which is at the “break over” stress threshold for the 16-inch pipeline, and due to the orientation of the conventionally laid pipeline, custom pipe bends are required at both ends of the HDD. The 2000 ft radius into and out of the profile bottom is below the pipeline stress limits; however tightening the radius will increase entry and exit angles unacceptably. The HDD horizontal run is only 41 ft in length and leaves little room for corrections before commencing into the exit radius.

CONCLUSION

As shown on Figure 2 in Attachment 2, the redesigned HDD profile for the 16-inch pipeline increases the depth of cover, and exit/entry angles. 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 provide the drilling crew and company inspectors the location(s) data on potential zones of higher risk for fluid loss and IRs, including the area related to previous IRs, and potential zones of fracture concentration identified by the geophysics analysis, so that monitoring can be enhanced when drilling through these locations;

- SPLP will require and enforce the use of annular pressure (AP) monitoring during the drilling of the pilot holes, which assists in immediate identification of pressure changes indicative of loss of return flows or over pressurization of the annulus to manage development of pressures that can induce an IR;

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

- SPLP will implement short-tripping of the reaming tools as return flow monitoring indicates 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) or grouting 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. The AP below that depth can exceed the effective stabilization capability of LCMs. Additionally, using LCMs in the karstified geology at this HDD is less likely to effect a seal. Accordingly, the preferred corrective action needed to address the presence of fractures or LOCs at greater depths below ground will require grouting of the HDD annulus. Two types of grouting will be utilized for corrective actions to seal fractures and correct LOCs. 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.

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

FEASIBILITY DETERMINATION

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

2-25-2019
Date

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

Pertaining to the practice of geology

2-26-2019
Date

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

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
DOUGLAS JAY HESS
GEOLOGIST
PG000186G

Pertaining to the pipeline stress and HDD geometry

2/26/19
Date

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

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
JEFFREY A. LOWY
ENGINEER
PE082759
2/26/19

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

RETTEW

We answer to you.

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

Engineers

Environmental Consultants

Surveyors

Landscape Architects

Safety Consultants

February 21, 2019

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

RE: Sunoco Pipeline, LP Pipeline Project - Mariner East II
I-81 HDD (S2-0220), PA-CU-0136.0003-RD-16
Hydrogeologic Re-Evaluation Report for the 16-Inch Pipeline
Middlesex Township, Cumberland County, PA
RETTEW Project No. 096302011

EXECUTIVE SUMMARY

1. The 20-inch and 16-inch S3-0220 I-81 horizontal directional drill (HDD) locations are included in the Corrected Stipulated Order of August 10, 2017, requiring re-evaluation, including a geologic report. HDD S3-0220 is No. 9 of the HDDs listed in Exhibit 3. Due to the occurrence of inadvertent returns (IRs) during HDD operations for the 20-inch pipeline, this hydrogeologic re-evaluation was prepared to address the potential for IRs during the proposed 16-inch HDD operations.
2. The site is underlain by finely crystalline limestone and dolomite of the St. Paul Group which is characterized by good subsurface drainage and poor surface drainage where the occurrence of bedrock pinnacles and sinkhole development are common.
3. Water-bearing zones in the underlying geology generally occur in secondary openings along bedding planes, joints, faults, fractures, and solution openings. The permeability of these features is enhanced by dissolution of the limestone and dolomite bedrock.
4. The average depth of water supply wells in the St. Paul Group is 384 feet below ground surface (bgs) with an average depth to water of 32 feet bgs. Water bearing zones are abundant at shallow depths and typically extend to depths of approximately 250 feet bgs.
5. The HDD profile for the permitted 16-inch drill has been redesigned to increase its depth beneath the referenced stream and wetlands.
6. Based on hydro-structural characteristics of the underlying geology, information obtained from installation of the 20-inch pipe, the IRs that occurred during the installation of the 20-inch pipe, and the permitted 16-inch HDD profile within shallow unconsolidated soil materials and generally shallow bedrock, the proposed 16-inch HDD is susceptible to an IR of drilling fluids during HDD operations. The 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 I-81 S2-0220 HDD location on the Sunoco Pipeline, LP (SPLP) Pennsylvania Pipeline Project - Mariner East II (PPP-ME2) Project. The I-81 HDD is located in Middlesex Township, Cumberland County, Pennsylvania as shown on

Figure 1. The HDD will be drilled under Interstate I-81, Wetland W-I30, Stream S-I47, buried utilities, and Middlesex Road. This re-evaluation report is part of the response to the Corrected Stipulated Order dated August 10, 2017, related to the IRs of drilling fluids that occurred on May 6 through 10, 2017, during HDD operations for the 20-inch pipeline completed on November 2, 2017, and potential for IRs of drilling fluids during proposed 16-inch HDD operations.

The original 16-inch HDD profile was redesigned on February 4, 2019. The overall length of the proposed HDD profile was increased along with the inclination of the entry and exit angles to increase the amount of cover under the sensitive receptors described above and 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/exit is at a surface elevation of approximately 425 feet above mean sea level (AMSL) and the redesigned eastern entry/exit is at an elevation of approximately 427 feet AMSL. The inclination of the eastern and western entry/exit angles has been increased to approximately 16^{o} to install the pipe through the soils and bedrock in closer proximity to the entry and exit points, and to deepen the profile to approximately 83 feet below Stream S-I47 (approximately 36 feet deeper than the as-built 20-inch pipe). The locations of the as-built 20-inch and proposed 16-inch, I-81 HDD locations are shown on **Figure 1**, and the redesigned 16-inch profile detail is included as **Attachment 1.**

2.0 GEOLOGY AND SOILS

Based upon publications by the Pennsylvania Bureau of Topographic and Geologic Survey (PABTGS), the site is in the Great Valley Section of the Ridge and Valley Physiographic Province of Pennsylvania and is underlain by very finely crystalline limestone with minor occurrences of dolomite and chert. Local topography is characterized by rolling valleys of low relief and natural slopes that are gentle and relatively stable. Geologic structures are characterized as thrust sheets, nappes, overturned folds and steeply inclined faults (Sevon, 2000). Areas underlain by these rock units typically have good subsurface drainage and poor surface drainage where bedrock dissolution results in the development of bedrock pinnacles and solution cavities within the bedrock (e.g., sinkholes, voids, caves). Based on the United States Geological Survey (USGS) 7.5-Minute Carlisle and Mechanicsburg Topographic Quadrangle Maps as shown on Figure 1, the site is situated at an approximate elevation of 430 feet AMSL. As shown on Figure 2, the eastern entry/exit point is located north-northwest of a regional fault. Surface topography at the site slopes west and east along the HDD bore path toward the unnamed tributary to LeTort Spring Run. The major surface water features include an unnamed tributary (S-I47) that flows northwest to LeTort Spring Run which ultimately discharges to Conodoguinet Creek.

The site geology for the redesigned 16-inch HDD profile is mapped as the Ordovician-age St. Paul Group (Osp) as shown on Figure 2 (Socolow, 1980). This geologic unit is described as buff-colored, finely crystalline magnesium limestone containing numerous layers of chert, high calcium limestone in part, with a thickness of approximately 900 feet (Root, 1978). The lower and upper parts of the St. Paul Group are predominantly pure limestone except for minor amounts of dolomite. The middle part consists of darker, impure limestone and abundant interbanded dolomite and some dolomite interbeds. This Group is well bedded, with most beds being fissile to flaggy in nature; however, the Group can contain some thick-bedded sections. Most joints have a blocky pattern, with some having a platy pattern; are moderately well developed, moderately to highly abundant and fairly to regularly spaced. There is a moderate distance between fractures, with most of the fractures being open, but some can be filled with calcite. Fractures are usually steeply dipping to vertical. This Group is moderately resistant to weathering and slightly weathered to shallow depths; resulting in medium-sized blocks. The overlying mantle is moderately thick and in most places the bedrock-mantle interface is characterized by bedrock pinnacles. This Group is considered difficult to excavate, due to the degree and extent of bedrock pinnacle development; however, drilling rates are classified as moderate. Foundation stability is classified as good, provided the excavation extends to sound bedrock and the potential of solution cavities is thoroughly investigated and mitigated. Subsurface drainage is good but surface drainage is poor and characterized by the development of sinkholes at the surface and caves at depth. Secondary porosity provided by hydraulic interconnections between joints and solution cavities is moderate to high in magnitude; while the overall permeability of the Group is generally high (Geyer and Wilshusen, 1982).

According to the United States Department of Agriculture (USDA) Soil Survey of Cumberland County, Pennsylvania, soils in the vicinity of the I-81 HDD consist of six separate soil units. A USDA soils map that depicts the mapped area, along with the soil profile descriptions, is included as **Attachment 2**.

3.0 HYDROGEOLOGY

Groundwater at the site occurs in a fractured, solution-prone, carbonate bedrock aquifer system within the St. Paul Group. In carbonate rocks, water-bearing zones generally occur in solution-enhanced secondary openings that form along bedding planes, joints, faults and fractures. Most of the water-bearing zones penetrated by supply wells occur in individual fractures or groups of interconnected fractures that are sufficiently enlarged by dissolution of bedrock to provide pathways for the transport of groundwater.

The median depth of water supply wells in the St. Paul Group is reported to be 178 feet bgs with a median depth to water of 38 feet bgs (Becher and Root, 1981). Rocks of the St. Paul Group have a reported median sustained yield of 82 gallons per minute (gpm) attributed to well-developed fractures and solution openings. Sustained yields of large capacity production wells are reportedly between 105 and 260 gpm. Although the maximum density of water-bearing zones is developed at shallow depths, these zones are nearly as abundant to depths of 250 feet bgs. Between 251 and 550 feet, water yielding zones are rare. However, in the 551- to 600-foot depth bgs range, the number of zones per 100 feet of hole evaluated is almost as great as in the shallower zone (Becher and Root, 1981).

Well records for 29 individual water supply wells within a 0.5-mile radius of the I-81 HDD were obtained from the Pennsylvania Groundwater Information System (PaGWIS, 2019). The 29 wells identified within a 0.5-mile radius of the HDD consist of 8 commercial/industrial water supply wells, 16 domestic water supply wells, 3 irrigation wells, and 2 with other/unknown use. The well locations are shown on **Figures 2** and **3**. Well construction details were not reported for all of the wells; however, the majority of the identified wells were completed as 6-inch-diameter open-rock wells with total depths ranging from 80 to 875 feet bgs. Reported well yields range from 1 to 100 gpm, while the reported depth to water ranges from 15.9 to 100 feet bgs with an average of 51 feet bgs. The information obtained from these well records is summarized in the following table:

Well No.	Well Use	Casing Depth (feet)	Total Depth (feet)	Water Level (feet)	Yield (gallons per minute)
97032	Domestic	80	705	NOT AVAILABLE	2
320736	Domestic	60	550	NOT AVAILABLE	3
665810	Domestic	21	225	NOT AVAILABLE	5
97112	Domestic	80	365	NOT AVAILABLE	6
97009	Domestic	83.5	550	NOT AVAILABLE	7.5
669948	Domestic	63	142	NOT AVAILABLE	12
17208	Commercial	36	300	NOT AVAILABLE	12
17215	Commercial	119	400	NOT AVAILABLE	20
97029	Industrial	42	435	NOT AVAILABLE	20
96999	Domestic	102	125	NOT AVAILABLE	30
669895	Domestic	20	198	NOT AVAILABLE	30
97002	Industrial	147	875	NOT AVAILABLE	35
97026	Industrial	42	635	NOT AVAILABLE	35
97008	Domestic	63	150	NOT AVAILABLE	60
641271	Irrigation	40	204	NOT AVAILABLE	NOT AVAILABLE
669926	Domestic	31	150	NOT AVAILABLE	NOT AVAILABLE
669924	Domestic	20	300	NOT AVAILABLE	NOT AVAILABLE
669927	Domestic	40	400	100	1

Well No.	Well Use	Casing Depth (feet)	Total Depth (feet)	Water Level (feet)	Yield (gallons per minute)
669925	Domestic	40	100	100	40
66998	Domestic	41	258	85	15
475787	Irrigation	60	300	75	20
17213	Commercial	153	530	53.1	NOT AVAILABLE
97188	Unknown	20	142	42	10
97191	Domestic	119	328	38	10
641270	Irrigation	38	381	30	20
97003	Industrial	NOT AVAILABLE	875	27	40
512820	Other	9	80	25	100
257137	Domestic	59	100	21	25
17187	Commercial	NOT AVAILABLE	NOT AVAILABLE	15.9	NOT AVAILABLE

In February 2018, other Sunoco subcontractors researched private water supplies located within a 450-foot radius of the I-81 HDD. One water supply well was identified within the 450-foot radius and one additional water well was identified outside the search radius as shown on **Attachment 3**. The total depth of the well inside the 450-foot search radius is reported to be greater than 100 feet bgs. Information was not available pertaining to the depth to water or pump setting. The water well identified outside the 450-foot search radius is located approximately 650 feet northwest of the western HDD entry/exit point. This well was reported to have a total depth of 180 feet bgs and pump setting depth of approximately 100 feet bgs.

4.0 FRACTURE TRACE ANALYSIS

Fracture traces underlying, or in close proximity to, the I-81 HDD were evaluated using historical aerial photographs from the years 1994 through 2016 (Google Earth, 2017), the Carlisle and Mechanicsburg, PA USGS 7.5 Minute Quadrangle Topographic Map and the Geologic Map of the Carlisle and Mechanicsburg Quadrangles (Root, 1978). The aerial photographs and maps were used 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 through the fractured bedrock aquifer underlying the I-81 HDD.

Figures 2 and **3** show the results of the fracture trace analysis overlain on the geologic map and aerial base map, respectively. Fourteen fracture traces were identified in close proximity to the proposed I-81 HDD. Five of the fracture traces trend approximately northeast-southwest (NE-SW), parallel to geologic strike. Nine of the fracture traces trend approximately northwest-southeast (NW-SE) and may represent joint sets perpendicular to geologic strike. Nine of the fracture traces correspond with straight stream segments of LeTort Spring Run and unnamed tributary S-I47 and are likely associated with local geologic structure. It is important to note that one of the NW-SE trending fracture traces crosses the HDD near the location of the reported IRs.

5.0 GEOTECHNICAL EVALUATION

Two geotechnical drilling investigations were performed at the site. The initial investigation was performed in January 2015 during the preliminary investigation for the I-81 HDD and prior to initiating the 20-inch HDD operations. A second phase of geotechnical drilling was performed in September of 2017. The 2015 test borings were advanced by hollow-stem auger drilling methods to auger refusal; a maximum depth of 12.3 feet bgs was observed. NQ-sized wireline rock coring methods were utilized in the borings advanced past auger refusal. These borings are designated as SB-01 and SB-02. The second phase test borings completed in 2017 were advanced using hollow-stem auger drilling and NQ-sized wireline rock coring methods. The 2017 borings were designated as B-1 and 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**.

Boring SB-01 was located approximately 190 feet south-southwest of the proposed 16-inch HDD western entry/exit point. Boring SB-02 was located approximately 70 feet southwest of the proposed 16-inch HDD eastern entry/exit point. Boring B-1 was located approximately 80 feet to the west of the proposed 16-inch HDD western entry/exit point, and Boring B-2 was located approximately 50 feet to the east of the proposed 16-inch 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:

- Residual soil depths vary boring from boring; 7.8 feet at SB-01, 7.3 feet at SB-02, 11.5 feet at B-1, and 7.6 feet at B-2. The residual soils are described as follows:
    - **Boring SB-01**: Topsoil, SILT (ML) and fine sand, limestone gravel. Initial auger refusal occurred at 7.5 feet bgs, the boring was offset and the augers were advanced to refusal at 12.3 feet bgs. Groundwater was not encountered.
    - **Boring SB-02**: Topsoil, SILT (ML) with trace limestone fragments, limestone fragments mixed with SILT. Auger refusal occurred at 7.3 feet bgs. Groundwater was not encountered.
    - **Boring B-01**: Stiff, lean CLAY (CL) with trace sand, moist, stiff fat CLAY (CH) with trace sand, moist/wet, and hard lean CLAY (CL) with gravel and trace sand, moist/wet. Groundwater was encountered at 4 feet bgs.
    - **Boring B-02**: Fill consisting of gravelly SILT (ML) with sand, moist, possible fill consisting of lean CLAY (CL) with sand, moist and hard, lean CLAY (CL) with trace sand, moist/wet. Groundwater was encountered at 4 feet bgs.
- 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 completed from 12.3 to 17.3 feet bgs. Gray LIMESTONE with calcite deposits was observed. Only 8 inches of rock core was recovered from the 5-foot run. The log states that a large amount of water was used and that the majority of the material from 12.3 to 17.3 feet bgs was washed away. After retrieving the core barrel, the borehole had collapsed at the bottom of the augers and further coring of the bedrock was not attempted. Groundwater was not observed at the completion of coring operations.

- **Boring SB-02**: Rock coring was not completed at this location.
- **Boring B-1**: B-1 was completed to a total depth of 114 feet bgs. From 11.5 to the completion depth of 114 feet bgs, light gray to black, very fine-grained, weathered to slightly weathered, very broken to massive, hard to very hard, alternating layers of LIMESTONE and DOLOMITE with calcite stringers was encountered. Weathered/highly weathered seams were observed at 12.8, 16.1, 103.3 and 113.5 feet bgs. Soil-filled, nearly vertical fractures were observed between 35.1 and 35.7 feet, while a partially soil-filled diagonal fracture was observed at 36.1 feet bgs. An approximately 1-inch soil seam was observed at 44 feet bgs. Multiple well-developed fractures were observed from 46.1 to 47.7 feet bgs. An approximately 1/8-inch highly to completely weathered parting was observed at 69.1 feet bgs. A diagonal quartz seam, approximately 0.25-inches thick, was observed at 78.3 feet bgs. Rock recoveries ranged from 64 to 100%, while rock quality designations (RQDs) values ranged from poor (38) to excellent (100). Groundwater was observed at 9 feet bgs at the completion of coring operations.
- **Boring B-2**: B-2 was completed to a total depth of 106 feet bgs. From 7.7 to 106 feet bgs light gray-white to dark gray, very fine-grained, slightly weathered to highly weathered, very broken to massive, moderately hard to very hard, alternating layers of LIMESTONE and DOLOMITE with trace calcite stringers and trace pits and vugs was encountered. An approximately 4-inch thick weathered layer was observed at 18.7 feet bgs, and an approximately 0.5-inch thick highly weathered seam was observed at 50.5 feet bgs. A soil layer, approximately 13.5-inches thick, was observed at 20.1 feet bgs, while soil partings were observed at 26 and 98.8 feet bgs. Note: no descriptions of the rock core from 66 to 91 feet bgs (core run 13 to 17) were included on the boring log. A soil layer was encountered between 44.5 and 46.5 feet bgs. Vertical fractures were observed between 49.5 to 49.7 and 99.5 to 100.1 feet bgs, while nearly vertical fractures were observed between 49.7 and 50.2 feet bgs. A layer of trace quartz was observed between 98.8 and 101 feet bgs. Rock recoveries ranged from 50 to 100%, while RQDs ranged from very poor (21) to excellent (97). Groundwater was observed at 25 feet bgs at the completion of coring operations.

Unconfined compressive strength testing was performed on the core samples, and the results are summarized in the table below.

Boring	Sample Depth (feet bgs)	Compressive Strength (tons per square foot)
B-01	18.5	517.15
B-01	32	351.17
B-01	42.2	394.00
B-01	51.5	1256.08
B-01	60.5	567.16
B-01	74.8	534.98
B-01	86.5	462.98

Boring	Sample Depth (feet bgs)	Compressive Strength (tons per square foot)
B-01	98.2	626.88
B-01	111.7	742.86
B-02	8.2	708.29
B-02	22	1084.53
B-02	32.3	605.17
B-02	44.1	668.30
B-02	53.8	560.67
B-02	63.1	517.85
B-02	77	481.04
B-02	88.9	585.63

Please note that RETTEW Associates, Inc. (RETTEW) and Skelly and Loy did not oversee or direct the geotechnical drilling program associated with the I-81 HDD 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 included in this report.

6.0 GEOPHYSICAL SURVEY

RETTEW completed a multi-technique geophysical survey at the I-81 HDD between October 24 and November 17, 2018. The purpose of the survey was to provide supplemental information for the geotechnical drilling programs and to detect and delineate subsurface voids or low-density zones that could contribute to IRs and/or loss of returns (LORs) and to determine the rock profile and rock rippability for ease of excavation along the HDD path.

Three different geophysical methods were utilized to detect and delineate subsurface features and to provide a bedrock profile. These methods and their general results are as follows:

- Microgravity delineated at least three low-density zones within the survey area. These zones could represent relatively minor karst-related air-, water-, or mud-filled voids, or locally deeper rock with thicker soils.
- Seismic refraction and multichannel analysis of surface waves results confirmed the presence of an irregular bedrock surface and zone of “epikarst”.
- Electrical resistivity imaging identified a conductive surface layer overlying a discontinuous resistive layer, with the discontinuities possibly suggesting the presence of deep epikarst “cutters” or clay seams possibly associated with fracture zones.

Results from the geophysical surveys are consistent with each other, and with the geology as mapped by the PA Geological Survey; all suggesting that the local bedrock is only mildly karstified, with a few potential anomalous zones of concern. In the limestone zone, the top-of-rock is expected to be slightly pinnacled (highly irregular) with interfingered competent rock and residual clay soils.

7.0 FIELD OBSERVATIONS DURING 20-INCH HDD ACTIVITIES

RETTEW staff were on-site during 20-inch HDD operations which began on April 27, 2017. The first IR occurred on May 6, 2018, and subsequent IRs resulted in the Corrected Stipulated Order and Agreement referenced in this report. The events which occurred during the 20-inch HDD pipeline installation (drilling from the east to the west) completed on November 2, 2017 are summarized below.

- **April 27-May 2, 2017:** Pretec advanced the pilot hole to a trajectory of approximately 520 feet. On May 2, 2017 a partial LOR was observed that amounted to approximately 19,000 gallons for the day.
- **May 3, 2017:** A void was encountered at a trajectory length of 675 feet and 51 feet bgs. A full LOR/loss of circulation (LOC) was observed at this point. Pretec tripped the drill string out of the borehole in an attempt to clear the annulus and regain circulation.
- **May 6, 2017:** Pretec began to advance the pilot hole beyond the void/LOC interval. At a trajectory length of 692 feet an IR was observed in Wetland I-30. Pretec installed an IR containment structure and pumping equipment at the IR location.
- **May 8-10, 2017:** Pretec utilized the IR containment and pumping equipment to recirculate the drilling fluid from the IR back to the reclaimer. When the pilot hole was advanced to a trajectory of 975 feet and 71 feet bgs, a second IR location was observed adjacent to the May 2 IR location. Drilling activities were suspended while the IR containment was expanded to encompass the new location. After drilling resumed, and when the pilot bit was at a trajectory length of 995 feet and 69.4 feet bgs, drilling fluid stopped surfacing at the second (May 10) IR location; however, full returns back to the drill rig were maintained by pumping the drilling fluid from the first (May 6) IR location.
- **May 11-15, 2017:** Pretec attempted to adjust the path of the HDD. The IR locations reactivated periodically as the pilot bit was at various positions in the borehole. Pretec continued to recirculate the IRs to the mud reclaimer.
- **May 17-24, 2017:** Pretec advanced the pilot hole from west to east using compressed air to a trajectory of 485 feet. At a trajectory length of 300 feet, Pretec reported lost air returns. No new IRs were observed and surfacing of drilling fluids into the May 6th IR containment structure stopped.
- **May 26-30, 2017:** Pretec attempted to adjust the pilot hole from east to west with a reaming bit. The IR containment structure was active during this process. Pretec continued to recirculate the contents of the containment structure to the reclaimer.
- **May 31-June 6, 2017:** Pretec initiated a new pilot hole at a location approximately 4 feet south of the original pilot hole. The pilot hole was advanced to a trajectory length of 841 feet. The previous IR locations reactivated when the pilot hole was advanced to a trajectory length of 682 feet and 56.5 feet bgs.
- **June 7, 2017:** Drilling operations were suspended by the Pennsylvania Department of Environmental Protection (PA DEP).

- **June 8-9, 2017:** Pretec advanced the pilot hole to a trajectory length of 1,041 feet. The containment structure remained active and Pretec recirculated the returns to the reclaimer. Pretec was directed to cease drilling operations by SPLP's environmental management team.
- **July 10, 2017:** SPLP received restart authorization from PA DEP to resume drilling operations utilizing the IR containment area as an "unconventional relief hole (URH)."
- **July 11-12, 2017:** Pretec completed the pilot hole.
- **July 13-19, 2017:** Pretec initiated the first ream pass. Pretec completed 62 feet of the 18-inch ream pass and 414 feet of the 12-inch ream pass. The containment structure was active at the URH.
- **July 21, 2017:** Pretec resumed reaming at a trajectory length of 67 feet with the 18-inch reamer in an attempt to maintain full returns to the entry pit. The 18-inch reamer was advanced to a trajectory length of 140 feet. Pretec was directed to cease drilling operations by SPLP.
- **September 12, 2018:** Pretec was authorized to resume drilling operations. The 18-inch reamer was tripped out of the borehole.
- **September 13-16, 2017:** Pretec advanced the 30-inch reamer to a trajectory length of 170 feet. Full returns were maintained at the entry pit. Pretec tripped out the 30-inch reamer.
- **September 17-23, 2017:** Pretec advanced the 22-inch reamer to a trajectory length of 460 feet and the 12-inch reamer to a trajectory length of 640 feet. The containment structure reactivated at the URH. Pretec ceased reaming operations and tripped the reamer out of the borehole.
- **September 26-29, 2017:** Pretec initiated reaming from the exit side with a 12-inch reamer. The reamer was advanced from the exit side until it intersected the reamed portion of the borehole from the east side. The containment structure reactivated at the URH as the reamer was advanced to intersect the reamed interval from the entry side. The 12-inch ream was completed on September 29, 2017.
- **October 2-10, 2017:** Pretec reamed from the exit side with a 22-inch reamer. Full returns were maintained at the entry pit and the containment structure did not reactivate during this time period.
- **October 11-23, 2017:** Pretec conducted reaming activities with 22 and 30-inch reamers. The 22-inch ream was completed on October 23, 2017. Full returns were maintained at the entry pit and the containment structure did not reactivate during this time period.
- **October 25-31, 2017:** Pretec advanced the 30-inch reamer. On October 31, 2017, the 30-inch ream pass was completed. Pretec completed the swab pass on October 31, 2017. Full returns were maintained at the entry pit and the containment structure did not reactivate during this time period.
- **November 1-2, 2017:** Pretec completed the 20-inch pipe pull from west to east. The containment structure reactivated at the URH during the pipe pulling operations.

The locations of the above-referenced IRs are identified on the redesigned 16-inch HDD profile contained in **Attachment 1.**

8.0 CONCEPTUAL HYDROGEOLOGIC MODEL AND CONCLUSION

Based on published geologic and hydrogeologic information, results of the two geotechnical investigations, geophysical surveys, and field observations during the completion of the 20-inch HDD, the

I-81 HDD is underlain by carbonate rocks of the St. Paul Group. The hydrogeologic setting is dominated by groundwater flow that occurs in secondary openings along geologic features that include bedding planes, joints, faults and fractures. These well-developed secondary openings are enlarged or enhanced by dissolution of bedrock to provide moderate to high permeability. Water-bearing zones, including those that supply water wells, generally occur at relatively shallow depths below the ground surface. Water-bearing zones in the St. Paul Group are abundant at shallow depths and typically extend to depths of approximately 250 feet bgs.

The originally proposed 16-inch HDD profile was relatively shallow at the entry and exit points and passed through both unconsolidated overburden and fractured bedrock for an extended length. Based on the hydro-structural characteristics of the underlying geology described in this report and the previous occurrence of IRs during installation of the 20-inch pipe, the I-81 HDD site is susceptible to IRs of drilling fluids during HDD operations. As a result, the proposed 16-inch HDD profile has been redesigned to allow for deeper crossings beneath the referenced interstate highway (I-81), Middlesex Road, buried utilities, Wetland W-I30 and Stream S-I47. The revised 16-inch HDD bore path is approximately 83 feet below Stream S-I47 (36 feet deeper than the as-built 20-inch pipe). Importantly, the redesigned 16-inch HDD bore path is 83 feet below Wetland W-I47 (28 feet deeper than the as-built 20-inch pipe) at the location of the IR that occurred during the 20-inch HDD operations. The inclination of the entry and exit angles has been increased to allow the pipe to be installed through protective soils, residual soils, and bedrock, in closer proximity to the entry and exit points than the original, shallower profile. From a geologic perspective, the 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 loss of drilling fluids. Drilling BMPs are described in the Horizontal Directional Drill Analysis component of the overall re-evaluation package.

9.0 REFERENCES

A.E. Becher and S.I. Root, 1981, *Groundwater and Geology of the Cumberland Valley, Cumberland County, Pennsylvania*, Pennsylvania Geological Survey, Water Resource Report 50.

A.R. Geyer and J.P. Wilshusen, 1982, *Engineering Characteristics of the Rocks of Pennsylvania*, Pennsylvania Department of Environmental Resources, Office of Resource Management, Bureau of Topographic and Geologic Survey.

Arthur Socolow, 1980, *Geologic Map of Pennsylvania*, Pennsylvania Department of Environmental Resources, Bureau of Topographic and Geologic Survey.

Google Earth Pro, 2017, Version 7.3.2, accessed January 24, 2019.

Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Groundwater Information System (PaGWIS) database, website address: http://www.dcnr.pa.gov/Conservation/Water/Groundwater/PAGroundwaterInformationSystem/Pages/default.aspx, accessed January 24, 2019.

S. I. Root, 1978, *Geology and Mineral Resources of the Carlisle and Mechanicsburg Quadrangles, Cumberland County, Pennsylvania*.

United States Department of Agriculture, 2017, Natural Resources Conservation Service, Published Soil Surveys for Pennsylvania, Blair County, Pennsylvania: website address: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx, accessed February 11, 2019

United States Geological Survey, 20130620, USGS US Topo 7.5-minute map for Carlisle, PA 2013: USGS - National Geospatial Technical Operations Center (NGTOC).

W.D. Sevon, 2000, *Physiographic Provinces of Pennsylvania*, Pennsylvania Bureau of Topographic and Geologic Survey, Harrisburg, Pennsylvania, Map 13.

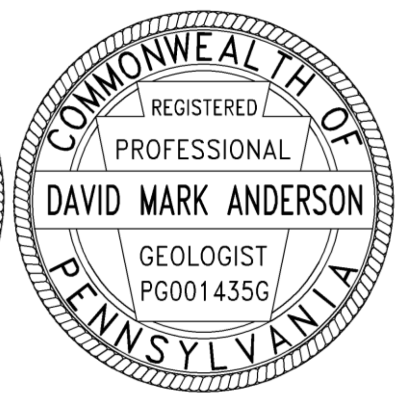
10.0 CERTIFICATION

The studies and evaluations presented in this report (other than Section 5) 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

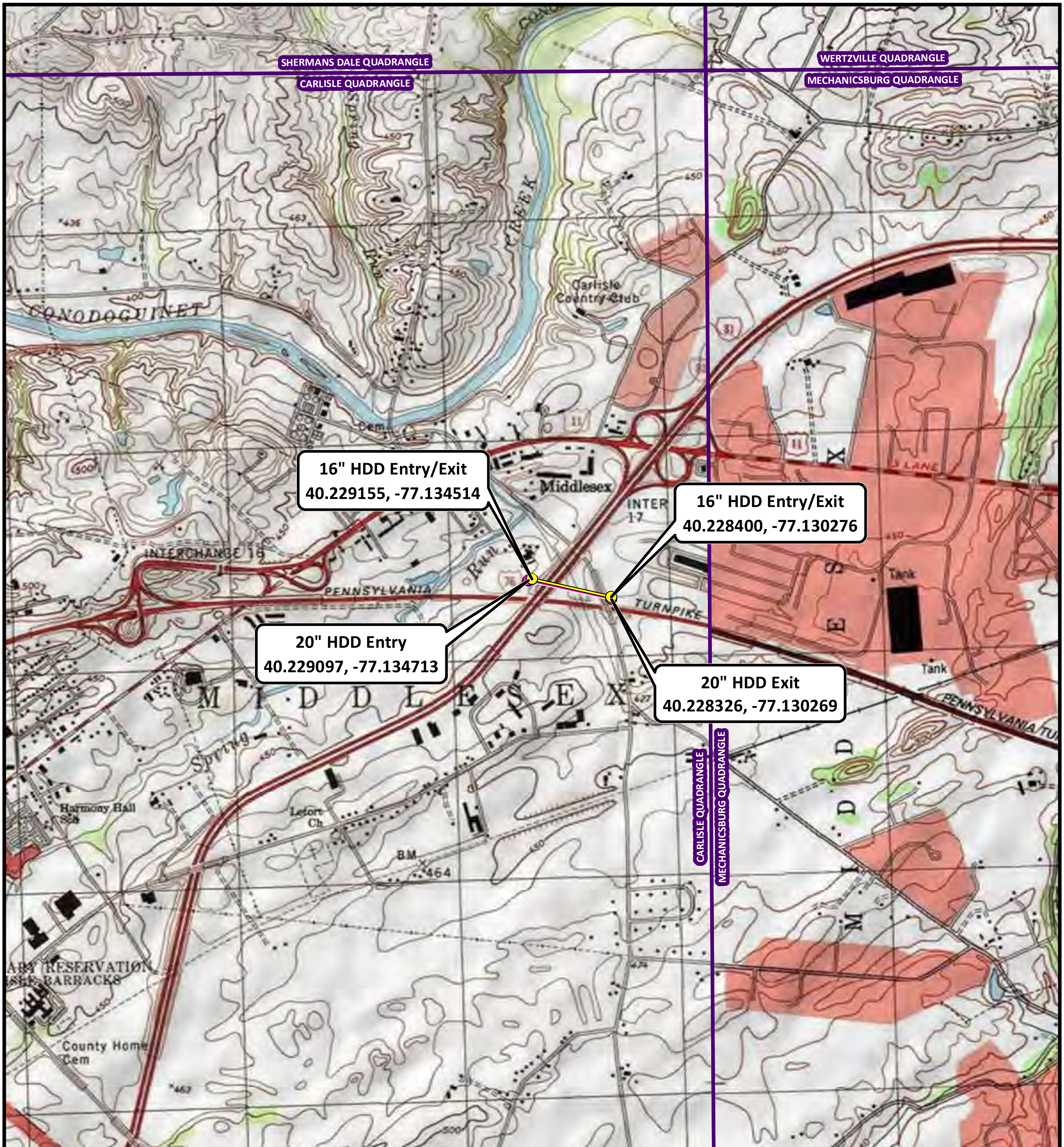


Enclosures

Z:\Shared\Projects\09630\096302011\GS\Hydrogeology Review\I81\I-81 S2-0220 Hydro Re-Eval_Final 2019-02-21.docx

RETTEW

FIGURES



16" HDD Entry/Exit

20" HDD Entry/Exit

16" HDD Profile

20" HDD Profile

Carlisle, PA USGS 7.5' Topographic Quadrangle

2/21/2019

Sunoco Pipeline, L.P.

I-81 HDD Location

Figure 1 - Topographic Basemap

Middlesex Township, Cumberland County, PA

Project No. 096302011

0 2,000 Feet

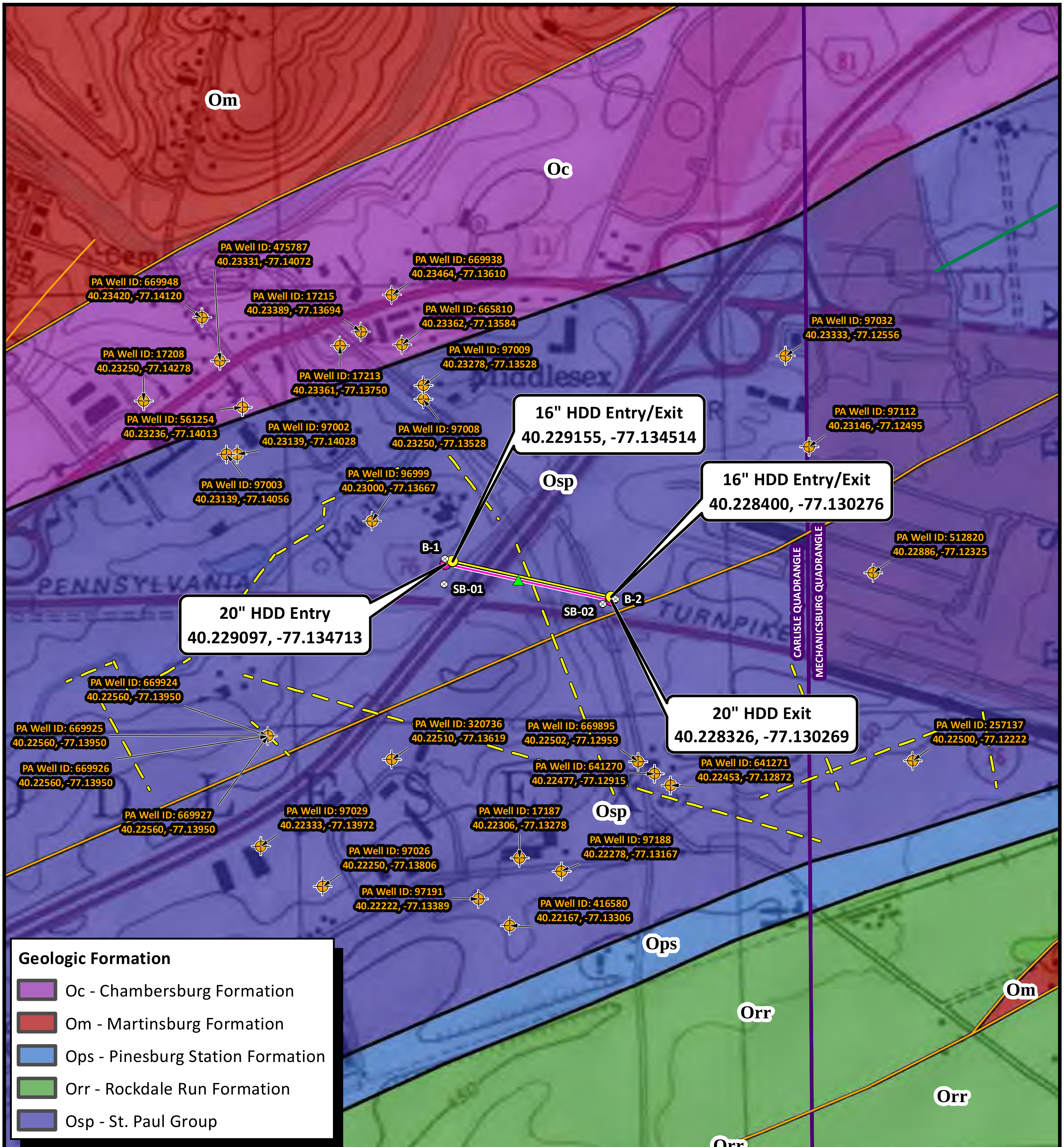
1 inch = 2,000 feet

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed

Sunoco Logistics Partners L.P.

RETTEW

N:\Shared\Projects\09630\096302011\GIS\MapDocs\Reevaluation Reports\I-81\096302011_I-81_Fig1_TopoBasemap_8x11.mxd



- ▲ Inadvertent Return
- Soil Boring
- Residential Well
- 16" HDD Entry/Exit
- 20" HDD Entry/Exit
- 16" HDD Profile
- 20" HDD Profile
- Inferred Fracture Trace
- Geologic Fault

Carlise, PA USGS 7.5' Topographic Quadrangle

2/21/2019

Sunoco Pipeline, L.P.

I-81 HDD Location

Figure 2 - Geologic Map

Middlesex Township, Cumberland County, PA
Project No. 096302011

N S E W

0 1,000 Feet

1 inch = 1,000 feet

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed

Sunoco Logistics Partners L.P.

RETTEW

N:\Shared\Projects\09630\096302011\GIS\MapDocs\Reevaluation Reports\I-81\096302011_I-81_Fig2_GeologicMap_8x11.mxd

Symbol	Legend	Symbol	Legend
▲	Inadvertent Return	—	16" HDD Profile
⊗	Boring Location	—	20" HDD Profile
⊕	Residential Well	- -	Inferred Fracture Trace
●	16" HDD Entry/Exit	—	NHD Stream
●	20" HDD Entry/Exit	—	Road

2/21/2019

Sunoco Pipeline, L.P.

I-81 HDD Location

Figure 3 - Aerial Basemap

Middlesex Township, Cumberland County, PA

Project No. 096302011

N S E W

0 800 Feet

1 inch = 800 feet

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

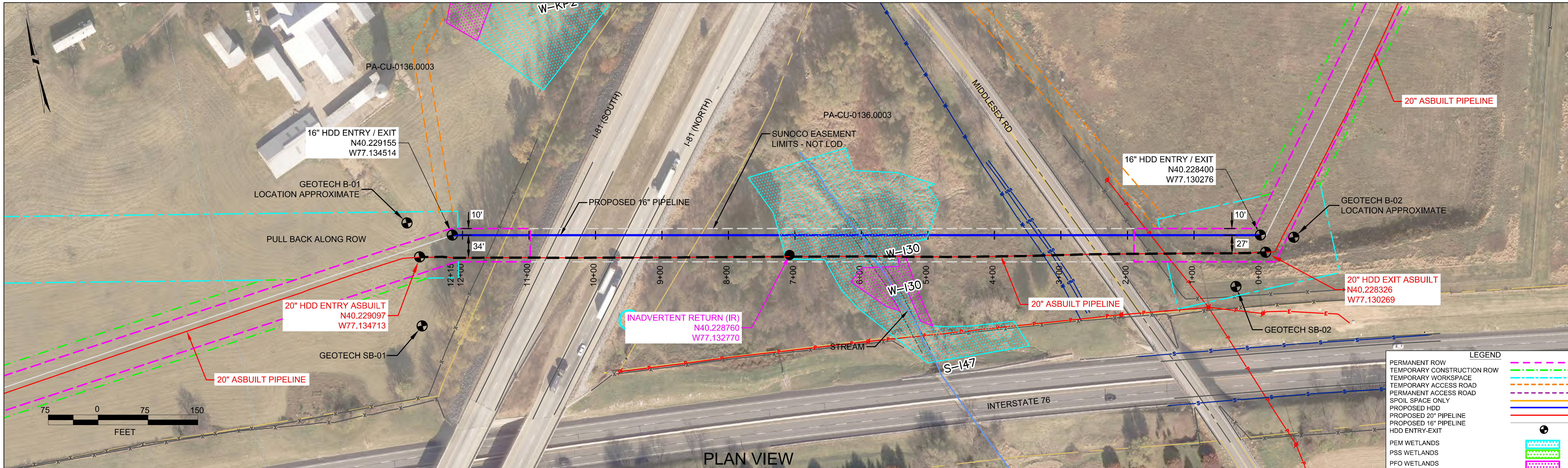
Sunoco Logistics Partners L.P.

RETTEW

N:\Shared\Projects\09630\096302011\GIS\MapDocs\Reevaluation Reports\I-81\096302011_I-81_Fig3_AerialBasemap_8x11.mxd

RETTEW

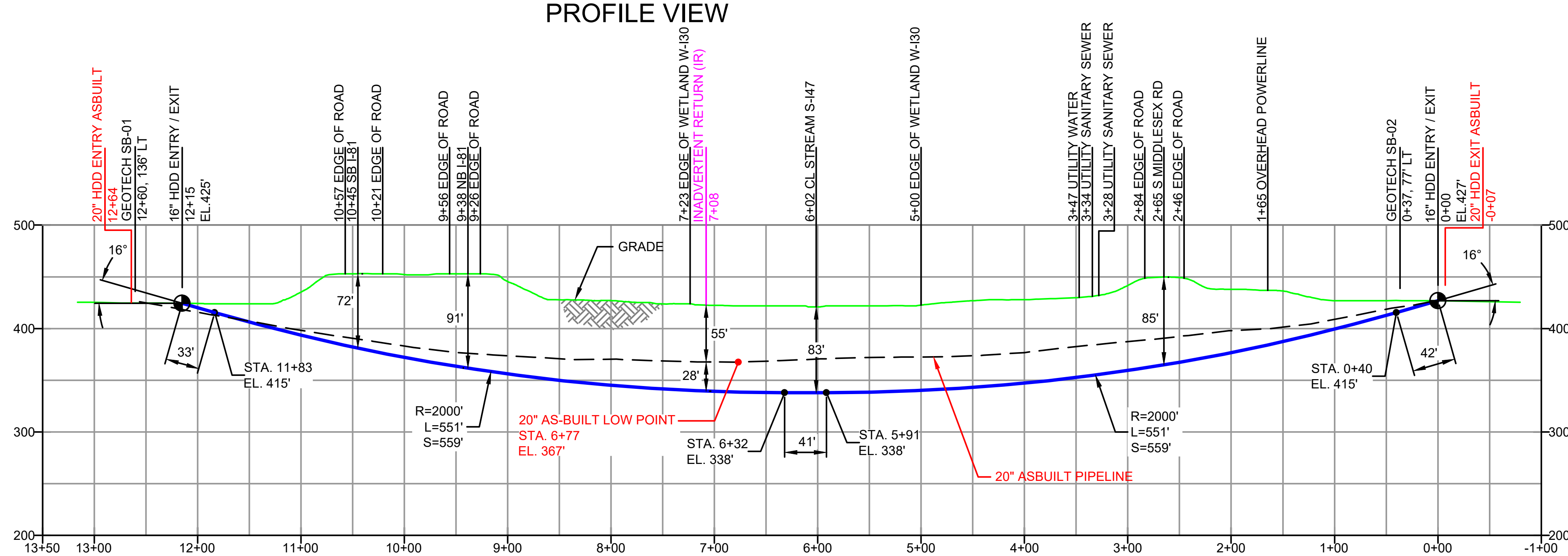
ATTACHMENT 1
HDD PROFILES AND GEOTECHNICAL BORING LOGS



PLAN VIEW

CUMBERLAND COUNTY, PENNSYLVANIA - MIDDLESEX TOWNSHIP
S2-0220-16

PROFILE VIEW



GEOTECH SB-01

- NG EL. 427'
- TOPSOIL (0' - 0.2')
- ML (0.2' - 7.0')
- LIMESTONE (7.0' - 7.8')
- AUGER REFUSAL (7.5')
- COMPLETION DEPTH EL. 419'

GEOTECH SB-02

- NG EL. 439'
- TOPSOIL (0' - 0.2')
- ML (0.2' - 7.0')
- LIMESTONE (7.0' - 7.3')
- AUGER REFUSAL (7.5')
- COMPLETION DEPTH EL. 432'

NOTE: REFER TO TEST BORING LOG S2-0220 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-1

- NG EL. 426'
- RESIDUUM LEAN CLAY CL (0.0' - 3.0')
- RESIDUUM FAT CLAY CH (3.0' - 7.0')
- GROUNDWATER (9.0')
- RESIDUUM LEAN CLAY CL (7.0' - 11.75')
- LIMESTONE/DOLOMITE (11.75' - 114.0')
- BORING TERMINATED EL.312'

NOTE: REFER TO TEST BORING LOG B-1 INTERTEK PROJECT #04911464 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-2

- NG EL. 427'
- FILL ML (0.0' - 2.0')
- POSSIBLE FILL, LEAN CLAY CL (2.0' - 4.0')
- RESIDUUM LEAN CLAY CL (4.0' - 7.5')
- GROUNDWATER (25.0')
- LIMESTONE/DOLOMITE (7.5' - 106.0')
- BORING TERMINATED EL.321'

NOTE: REFER TO TEST BORING LOG B-2 INTERTEK PROJECT #04911464 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=): 1215'
   HDD PIPE LENGTH (S=): 1234'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-4.64	TO	ES-4.65	EROSION & SEDIMENT PLAN
SHEET 37	TO	SHEET 37	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	DESIGN CHANGE - INCREASED ENTRY/EXIT ANGLES AND DEPTH, ADDED GEOTECH DATA	MRS	02/04/19	RMB	02/04/19	AMC	02/04/19
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	MRS	05/10/16	RMB	05/10/16	AAW	05/10/16
EP		JTW	02/26/16	RMB	02/26/16	AAW	02/26/16
B	ADDED GEOTECH INFO	MRS	09/15/15	RMB	09/15/15	AAW	09/15/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	08/31/15

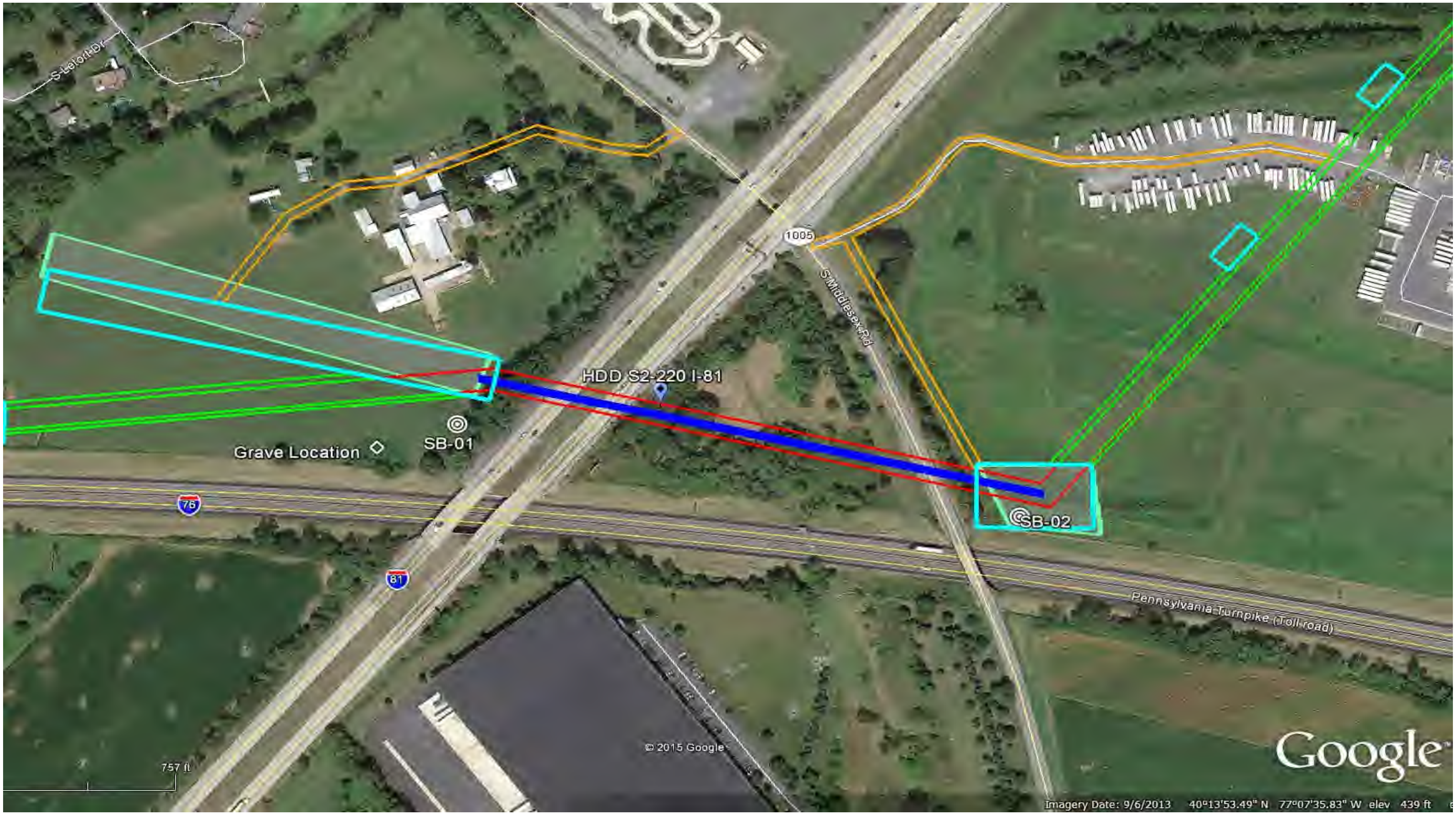
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
I-81
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150' DWG. NO: PA-CU-0136.0003-RD-16



LEGEND:

◎ Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS

HDD S2-0220

CUMBERLAND COUNTY, MIDDLESEX TOWNSHIP, PA

SUNOCO PENNSYLVANIA PIPELINE PROJECT

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406	
Project Location:	S. MIDDLESEX ROAD, NEAR I-81 OVERPASS, CARLISLE, PA		Page 1 of 1	
HDD No.:	S2-0220	Dates(s) Drilled: 01-26-15	Inspector:	E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586	Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft):	17.3

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.2			TOPSOIL (2")					
1**	3.0	5.0	0.2		2	ML	MOIST BROWN SILT AND FINE SAND.	2	5	5	3	**10**
				7.0								
2**	7.5	7.8	7.5	7.8	3		LIMESTONE GRAVEL.	50/4"				
							ROCK CORING					
RUN 1	12.3	17.3	12.3	17.3	8		8" RECOVERY, GRAY LIMESTONE WITH CALCITE DEPOSTS. USED					
							APPROX. 600 GALLONS OF WATER FOR 5' RUN, MOSTLY SOIL					
							WASHOUT. AFTER RETRIEVING CORE BARRELL, UNABLE TO					
							ADVANCE MEASURING TAPE BEYOND BOTTOM OF AUGERS. ALSO					
							UNABLE TO LOWER CORE BARREL AND CORING RODS BEYOND					
							BOTTOM OF AUGERS. ABANDONED FURTHER CORING EFFORT.					
							REFUSAL MATERIAL IS LIKELY A RESULT OF BOULDERY					
							SUBSURFACE CONDITIONS.					
							**BORING ATTEMPTS: INITIALLY ENCOUNTERED CONCRETE AT 2'					
							IN TWO BORING ATTEMPTS. OFF-SET TWICE MORE AND WAS ABLE					
							TO ADVANCE PAST 2', DEEPEST PENETRATION TO AUGER REFUSAL					
							WAS 7.5'. OFF-SET ONCE AGAIN AND AUGERED TO REFUSAL AT 12.3'.					
							THEN ATTEMPTED ROCK CORE.					

Notes/Comments:

Pocket Pentrometer Testing
S1: 1.0 TSF
S2: 2.75 TSF

GRAVE SITE OBSERVED ON PROPERTY.

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

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

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406	
Project Location:	ROADWAY DRIVE, CARLISLE, PA			Page 1 of 1	
HDD No.:	S2-0220	Dates(s) Drilled: 01-26-15		Inspector:	E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED		Total Depth (ft):	7.5

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.2			TOPSOIL (2")					
1	3.0	5.0	0.2		15	ML	ORANGE BROWN SILT, TRACE LIMESTONE FRAGMENTS.	1	3	7	9	**10**
				7.0			(USCS: ML).					
2	7.0	7.3	7.0	7.3	3		LIMESTONE FRAGMENTS MIXED WITH ORANGE BROWN SILT.	50/3"				
							AUGER REFUSAL AT 7.0'. OFF-SET 25' EAST AND CONTINUOUSLY					
							AUGERED TO REFUSAL AT 7.5'. OFF-SET ONE MORE TIME WITH					
							AUGER REFUSAL AT 6'.					
							REFUSAL MATERIAL IS LIKELY A RESULT OF BOULDERY					
							SUBSURFACE CONDITIONS.					
							WET ON SPOON (PERCHED?) AT 7'.					
							DRY AND CAVED AT 7'.					

Notes/Comments:

<u>Pocket Pentrometer Testing</u>

S1: 0.75 TSF

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

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

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0220

HDD No.	Test Boring No.	Sample No.	Depth of Sample (ft.)		Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318)			USCS Classif. (ASTM D2487)
			From	To			Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	
S2-0220	SB-02	1	3.0	5.0	39.9	98.2	48	34	14	ML

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

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0220

HDD No.	NAME	BORING NO.	REGIONAL GEOLOGY DESCRIPTION	GENERAL TOPOGRAPHIC SETTING	BEDROCK FORMATION	GENERAL ROCK TYPE	APPROX MAX FM THICKNESS (FT)	DEPTH TO ROCK (Ft bgs) based on nearby well drilling logs	NOTES / COMMENTS
S2-0220	I-81	SB-01 SB-02	**St. Paul Group** - consists of buff-colored magnesium limestone and very finely crystalline birdseye limestone at its top and base.	Level terrain	St. Paul Group	Crystalline limestone, chert, and dolomite (St. Paul)	1,500	Highly variable! 2-95 ft bgs, average DTB ~ 40 ft bgs	Fractured limestone with voids noted on boring logs Very finely crystalline, "birdseye" limestone at top and base, granular fossiliferous limestone, black chert, and dolomite in middle

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

FIELD DESCRIPTION AND LOGGING SYSTEM FOR SOIL EXPLORATION

GRANULAR SOILS

(Sand, Gravel & Combinations)

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

Relative Proportions

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

Particle Size Identification

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

COHESIVE SOILS

(Silt, Clay & Combinations)

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

Plasticity

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

ROCK

(Rock Cores)

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

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

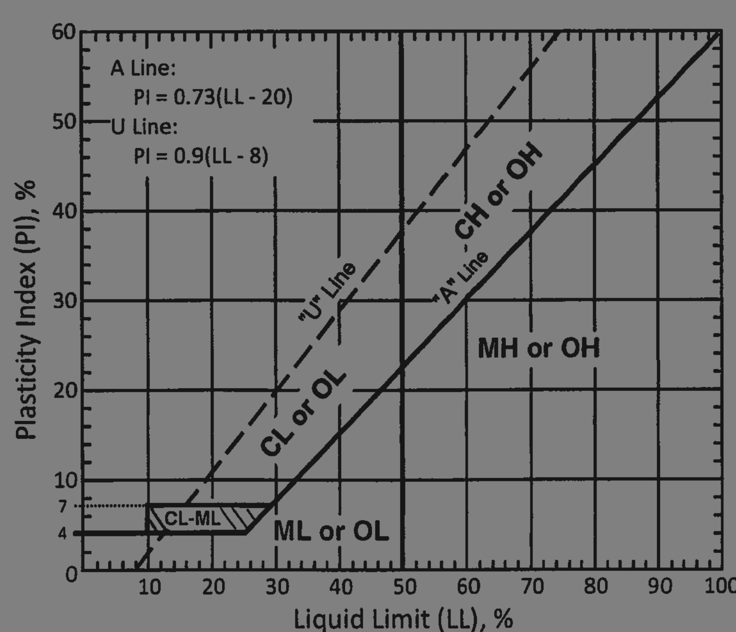
Groundwater observations were made at the times indicated. Groundwater elevations fluctuate throughout a given year, depending on actual field porosity and variations in seasonal and annual precipitation.

UNIFIED SOIL CLASSIFICATION SYSTEM [Casagrande (1948)]

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

Figure 1: Site Vicinity Plan

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

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

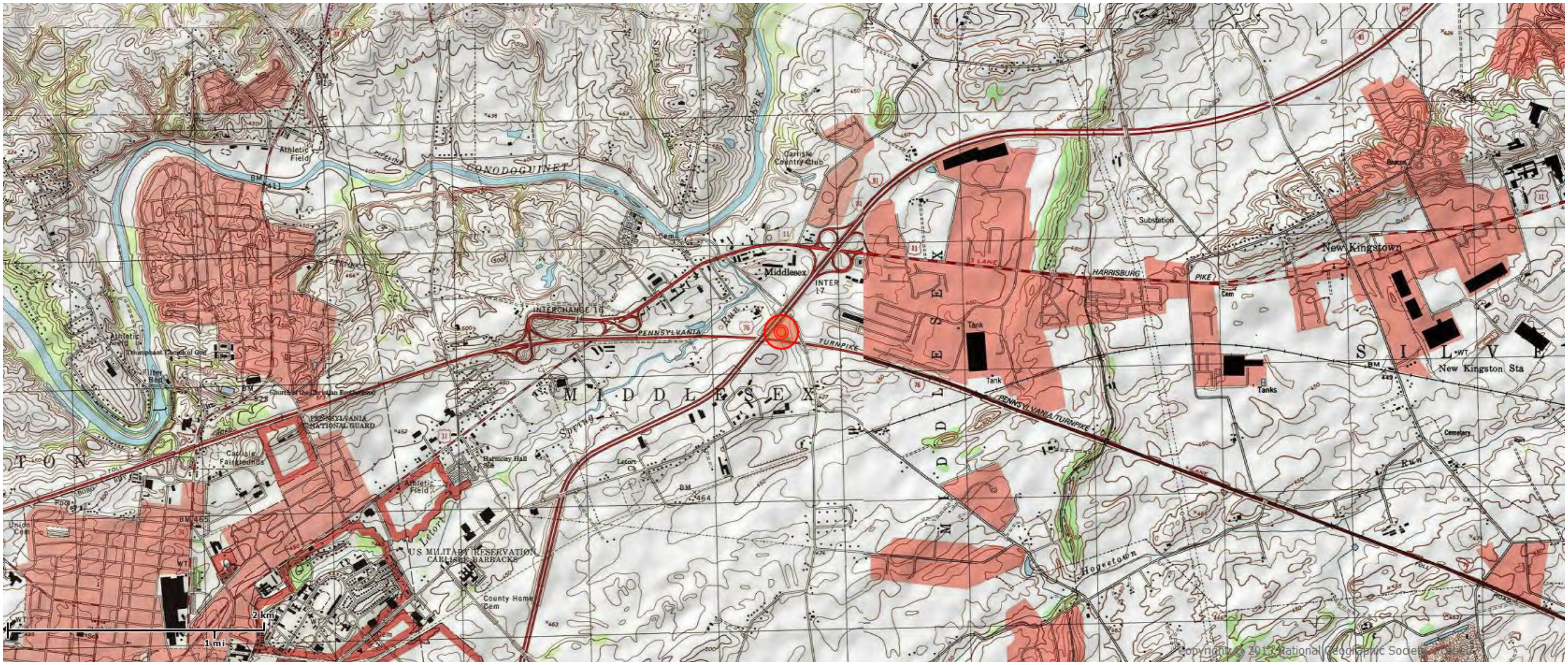


Figure 2: Boring Location Plan

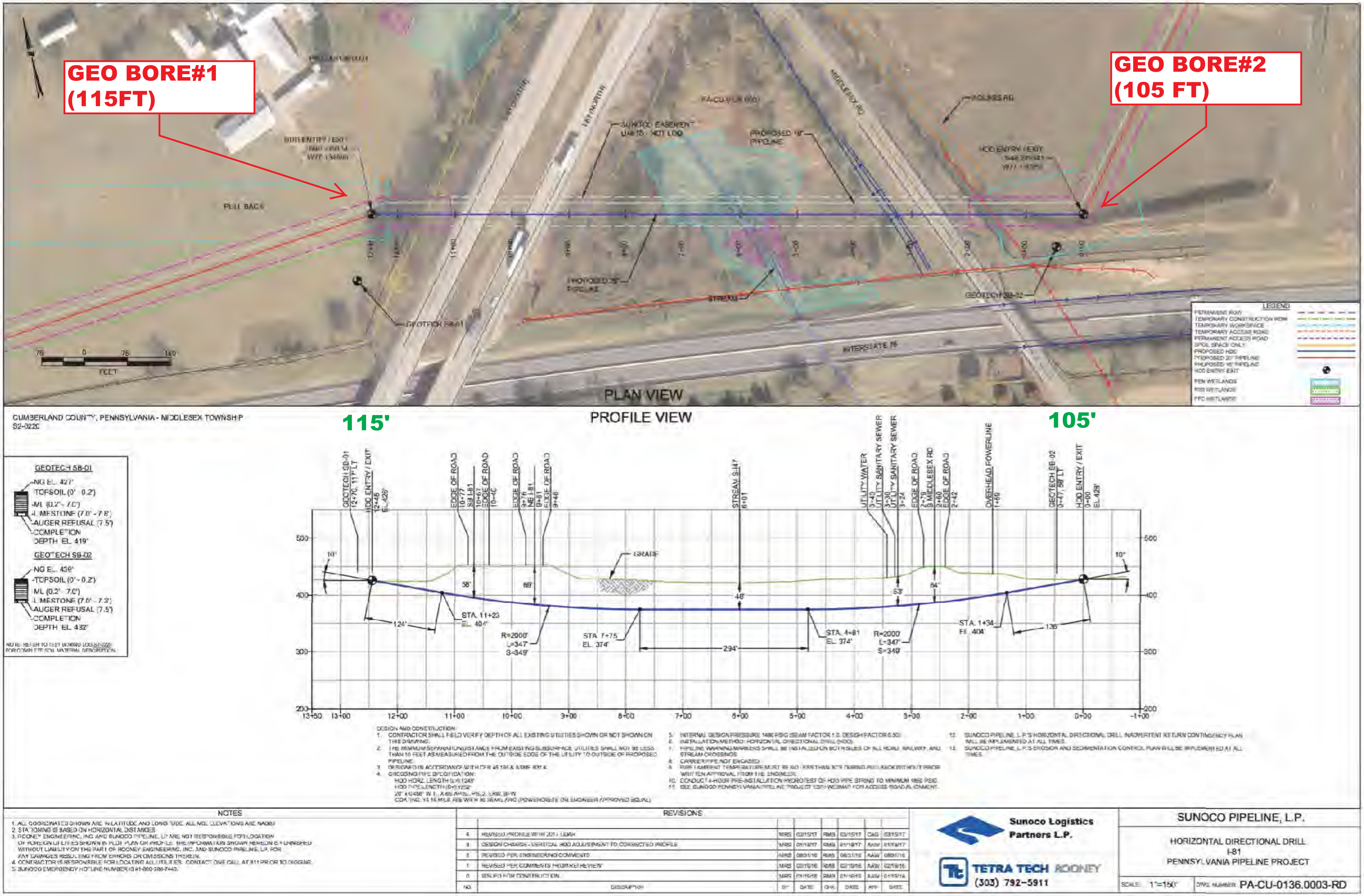
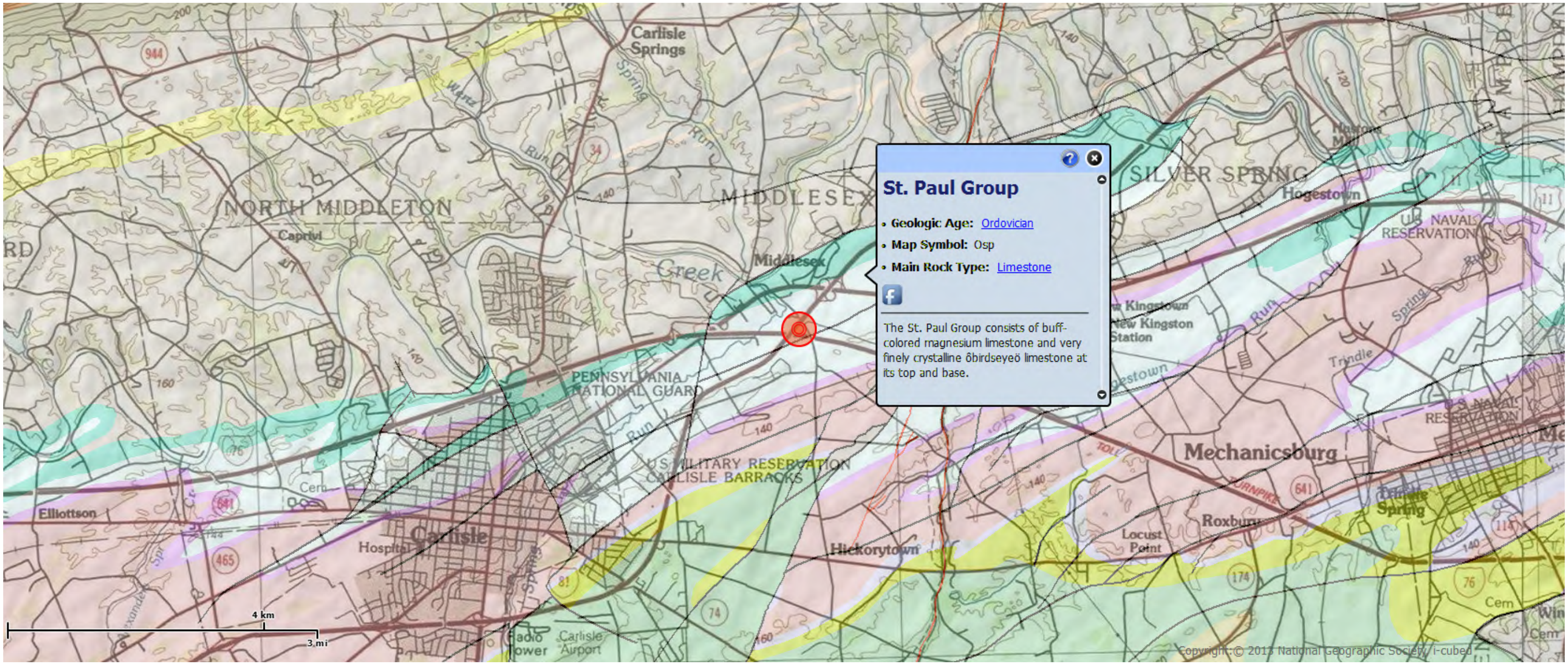


Figure 3: Site Geology Plan

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

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



Created using PA DCNR Map Viewer

Map created on Thu Sep 21 2017

BORING B-1

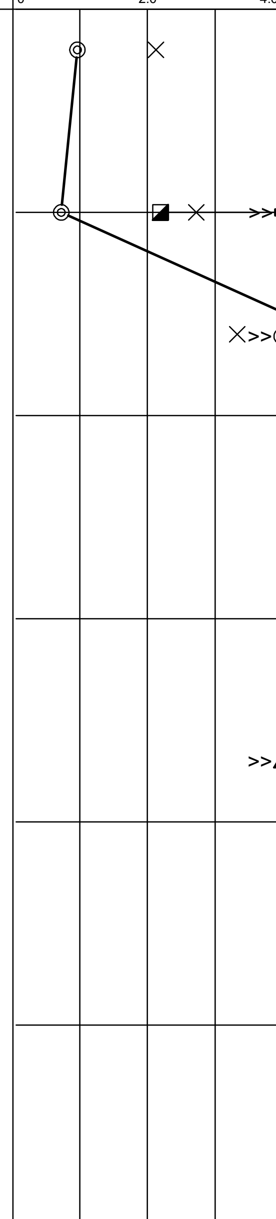
DATE STARTED:	9/5/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/6/17	**DRILLER:** Shane	**LOGGED BY:** L. Proczko
COMPLETION DEPTH	114.0 ft	**DRILL RIG:**	Diedrich D-50 Turbo
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-in Core
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: 4 feet
- Post-Core: 9 feet

BORING LOCATION:
See Boring Location Plan

Elevation (feet)	Depth, (feet)	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	Additional Remarks
	0	S-1	24	**RESIDUUM**-Stiff, Brown, Lean CLAY, trace Sand, moist	CL	5-6-6-7 N=12	27	
	5	S-2	22	**RESIDUUM**-Stiff, Brown, Fat CLAY, trace Sand, moist/wet	CH	4-5-4-5 N=9	34	LL = 53 PL = 27
		S-3	24	**RESIDUUM**-Hard, Brown, Lean CLAY with Gravel, trace Sand, moist/wet	CL	50/2"	42	
	10	R-1	31	**LIMESTONE**-Light gray to dark gray, Very fine grained, Weathered to Slightly Weathered, broken to massive, very hard, trace calcite stringers Weathered/Highly Weathered seam @ 12.8 feet (~ 1-1/2 inches thick)		RQD=46 Rec=64%		2 min. 3 min. 2 min. 2 min.
	15	R-2	22	**DOLOMITE**-Light gray to dark gray, Very fine grained, Weathered to Slightly Weathered, broken to massive, hard, trace calcite stringers		RQD=63 Rec=92%		2 min. 6 min.
		R-3	36	**LIMESTONE**-Light gray to dark gray, Very fine grained, Slightly Weathered, broken to massive, very hard, trace calcite stringers Highly Weathered seam @ 16.1 feet (~ 2 inches thick)		RQD=85 Rec=100%		1 min. 2 min. Q_u = 517.2 tsf 167.1 pcf 2 min.
	20	R-4	56			RQD=80 Rec=93%		2 min. 1 min. 2 min. 1 min. 1 min.
	25	R-5	60	**LIMESTONE**-Light gray to dark gray, Very fine grained, Weathered to Slightly Weathered, very broken to massive, very hard, trace calcite		RQD=38 Rec=100%		4 min. 2 min. 2 min. 2 min. 2 min.
	30							

STANDARD PENETRATION TEST DATA: N in blows/ft ◎; × Moisture; PL; LL (0 – 25 – 50). STRENGTH, tsf: ▲ Qu; ✳ Qp (0 – 2.0 – 4.0)



Continued Next Page

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

PROJECT NO.: 04911464
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Interstate 81 (PPP4)
Cumberland Co., PA
PA-CU-0136.0003-RD/PO#20170824-2

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

BORING B-1

DATE STARTED:	9/5/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/6/17	**DRILLER:** Shane	**LOGGED BY:** L. Proczko
COMPLETION DEPTH	114.0 ft	**DRILL RIG:**	Diedrich D-50 Turbo
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-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	4 feet
▼	Post-Core	9 feet
▽		

BORING LOCATION:
See Boring Location Plan

STANDARD PENETRATION TEST DATA: N in blows/ft ◎; × Moisture; PL; LL (0 – 25 – 50). STRENGTH, tsf: ▲ Qu; ✳ Qp (0 – 2.0 – 4.0)

Elevation (feet)	Depth, (feet)	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	Additional Remarks
	30	R-6	55	**LIMESTONE**-Light gray to dark gray, Very fine grained, Slightly Weathered, broken to massive, very hard, trace calcite stringers		RQD=73 Rec=92%		4 min. 3 min. 3 min. >>▲ Q_u = 351.2 tsf 167.6 pcf 2 min. 3 min.
	35	R-7	60	Soil-filled, nearly vertical fracture from 35.1 to 35.7 feet. Partially soil-filled, diagonal fracture @ 36.1 feet. **DOLOMITE**-Light gray to dark gray-brown, Very fine grained, Slightly Weathered, slightly broken to massive, very hard, trace calcite stringers		RQD=85 Rec=100%		2 min. 2 min. 2 min. 5 min. 2 min.
	40	R-8	60	**LIMESTONE**-Light gray to dark gray, Very fine grained, Slightly Weathered, massive, hard to very hard, trace calcite stringers **DOLOMITE**-Light gray to dark gray, Very fine grained, Slightly Weathered, broken to massive, hard to very hard, trace calcite stringers Soil seam @ 44 feet (~ 1 inch thick)		RQD=93 Rec=100%		2 min. 3 min. 3 min. >>▲ Q_u = 394.0 tsf 167.7 pcf 2 min. 2 min.
	45	R-9	60	**LIMESTONE**-Light gray to dark gray, Very fine grained, Slightly Weathered, broken to massive, hard to very hard, trace calcite stringers Multiple developing fractures from 46.1 to 47.7 feet.		RQD=83 Rec=100%		3 min. 1 min. 1 min. 2 min. 2 min.
	50	R-10	58	**DOLOMITE**-Light gray to black, Very fine grained, Slightly Weathered, slightly broken to massive, hard to very hard, trace calcite stringers		RQD=72 Rec=96%		3 min. 2 min. 2 min. >>▲ Q_u = 1256.1 tsf 174.5 pcf 2 min. 2 min.
	55	R-11	60	**LIMESTONE**-Light gray to dark gray, Very fine grained, Slightly Weathered, very broken to massive, very hard, trace calcite stringers		RQD=100 Rec=100%		2 min. 2 min. 2 min. 2 min. 3 min.
	60							

Continued Next Page

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

PROJECT NO.: 04911464
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Interstate 81 (PPP4)
Cumberland Co., PA
PA-CU-0136.0003-RD/PO#20170824-2

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

DATE STARTED: 9/5/17	**DRILL COMPANY:** Eichelberger's, Inc.					
DATE COMPLETED: 9/6/17	**DRILLER:** Shane	**LOGGED BY:** L. Proczko				
COMPLETION DEPTH 114.0 ft	**DRILL RIG:** Diedrich D-50 Turbo					
BENCHMARK: N/A	**DRILLING METHOD:** Casing/Rock Coring					
ELEVATION: N/A	**SAMPLING METHOD:** 2-in SS1.874-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:						

BORING B-1

Water
- ▽ While Drilling 4 feet
- ▼ Post-Core 9 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
	60			R-12	60	**LIMESTONE**-Light gray to dark gray, Very fine grained, Slightly Weathered, very broken to massive, very hard, trace calcite stringers		RQD=79 Rec=100%		>>▲	
						DOLOMITE-Gray to dark gray, Very fine grained, Slightly Weathered, broken to massive, very hard, trace calcite stringers					
	65			R-13	60			RQD=100 Rec=100%			
	70			R-14	60	**LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, very broken to massive, hard to very hard, trace calcite stringers Highly Weathered/Completely Weathered parting @ 69.1 feet (~ 1/8 inch thick)		RQD=89 Rec=100%			
	75			R-15	60	Diagonal quartz seam @ 78.3 feet (~ 1/4 inch thick)		RQD=93 Rec=100%		>>▲	
	80			R-16	60			RQD=100 Rec=100%			
	85			R-17	60			RQD=98 Rec=100%		>>▲	
	90										

Additional Remarks (by depth):
- 60: 3 min.; Q_u = 567.2 tsf, 170.0 pcf
- 61: 3 min.
- 62: 3 min.
- 63: 3 min.
- 64: 2 min.
- 65: 3 min.
- 66: 2 min.
- 67: 2 min.
- 68: 2 min.
- 69: 2 min.
- 70: 2 min.
- 71: 2 min.
- 72: 4 min.
- 73: 3 min.
- 74: 3 min.
- 75: 2 min.; Q_u = 535.0 tsf, 168.4 pcf
- 76: 3 min.
- 77: 2 min.
- 78: 2 min.
- 79: 2 min.
- 80: 1 min.
- 81: 2 min.
- 82: 2 min.
- 83: 3 min.
- 84: 2 min.
- 85: 3 min.
- 86: 3 min.
- 87: 3 min.; Q_u = 463.0 tsf, 167.2 pcf
- 88: 2 min.
- 89: 2 min.

Continued Next Page

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

PROJECT NO.: 04911464
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Interstate 81 (PPP4)
Cumberland Co., PA
PA-CU-0136.0003-RD/PO#20170824-2

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

DATE STARTED: 9/5/17	**DRILL COMPANY:** Eichelberger's, Inc.		
DATE COMPLETED: 9/6/17	**DRILLER:** Shane	**LOGGED BY:** L. Proczko	
COMPLETION DEPTH 114.0 ft	**DRILL RIG:** Diedrich D-50 Turbo		
BENCHMARK: N/A	**DRILLING METHOD:** Casing/Rock Coring		
ELEVATION: N/A	**SAMPLING METHOD:** 2-in SS1.874-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:			

BORING B-1

Water

∇	While Drilling	4 feet
▼	Post-Core	9 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
	90			R-18	58	Diagonal weathered seam @ 89.9 feet (~ 1/2 inch thick) **LIMESTONE**-Light gray to black, Very fine grained, Slightly Weathered, very broken to massive, hard to very hard, trace calcite stringers		RQD=94 Rec=97%			2 min. 3 min. 4 min. 4 min. 3 min.
	95			R-19	60			RQD=94 Rec=100%		>>	3 min. 4 min. 4 min. 4 min. Q_u = 626.9 tsf 170.7 pcf 3 min.
	100			R-20	54	Weathered layer @ 103.3 feet (~ 3-1/2 inches thick)		RQD=69 Rec=89%			3 min. 2 min. 2 min. 3 min. 4 min.
	105			R-21	53	**DOLOMITE**-Gray to dark gray, Very fine grained, Slightly Weathered, massive, very hard, trace calcite stringers		RQD=75 Rec=88%			5 min. 3 min. 3 min. 3 min. 3 min.
	110			R-22	60	**LIMESTONE**-Light gray to dark gray, Very fine grained, Slightly Weathered, slightly broken to massive, hard to very hard, trace calcite stringers Weathered/Highly Weathered layer @ 113.5 feet (~ 6-1/2 inches thick) Test boring terminated @ 114 feet		RQD=88 Rec=100%		>>	3 min. 2 min. 2 min. Q_u = 742.9 tsf 172.8 pcf 3 min. 2 min.

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

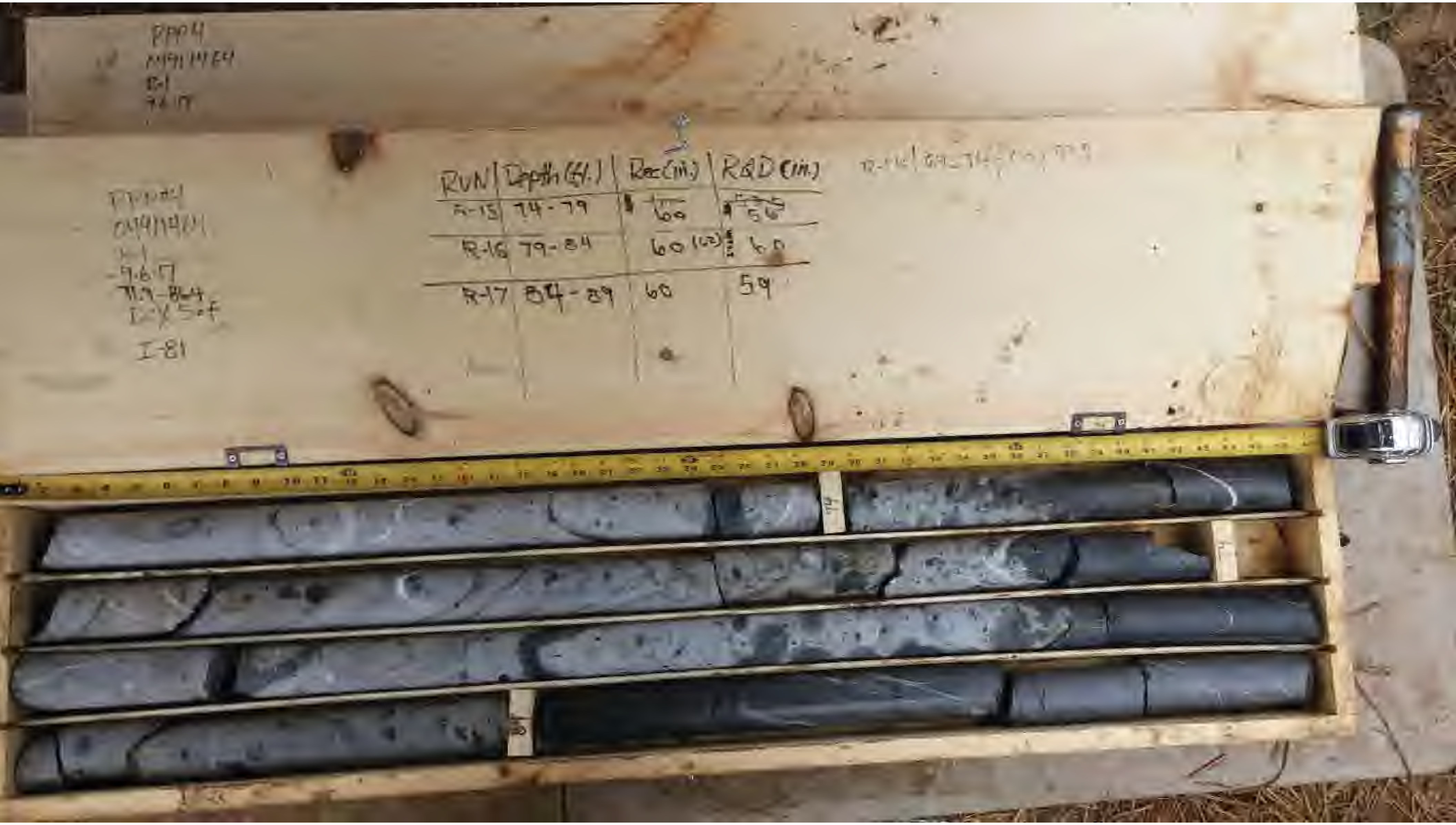
PROJECT NO.: 04911464
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Interstate 81 (PPP4)
Cumberland Co., PA
PA-CU-0136.0003-RD/PO#20170824-2

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

PPP#4
RUN | Depth | Rec (in) | RQD (in)
R-1 | 10-14 | 30.5 | 22
R-2 | 14-16 | 22 | 1.5
R-3 | 16-19 | 36 | 30.5
R-4 | 19-24 | 55.5 | 48
R-5 | 24-29 | 60 | 23


B-1
9.5.17
27-44
Box 2 of
I-81
RUN | Depth (ft.) | Rec (in.) | RQD (in.)
R-6 | 29-34 | 55 | 43.5
R-7 | 34-39 | 60 | 51
R-8 | 39-44 | 60 | 56
29
34
39
44


PPP#4
04911464
B-1
95.17
4IN-5CB
Box 3 of
I-81
RUN | Depth (ft.) | Rec (in) | RQD (in)
R-9 | 44-49 | 60 | 50
R-10 | 49-54 | 57.5 | 43
R-11 | 54-59 | 60 | 60


RUN | Depth (ft.) | Rec (in.) | RQD (in.)
R-15 | 74 - 79 | 60 | 56
R-16 | 79 - 84 | 60 | 60
R-17 | 84 - 89 | 60 | 59
I-81


Box 6 of
I-81
RUN
Depth (ft.)
Rec (in.)
RQD (in.)
56.5
41.5

BORING B-2

DATE STARTED:	9/6/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/7/17	**DRILLER:**	Mike **LOGGED BY:** L. Proczko
COMPLETION DEPTH	106.0 ft	**DRILL RIG:**	Diedrich D-50 Turbo
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-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:			

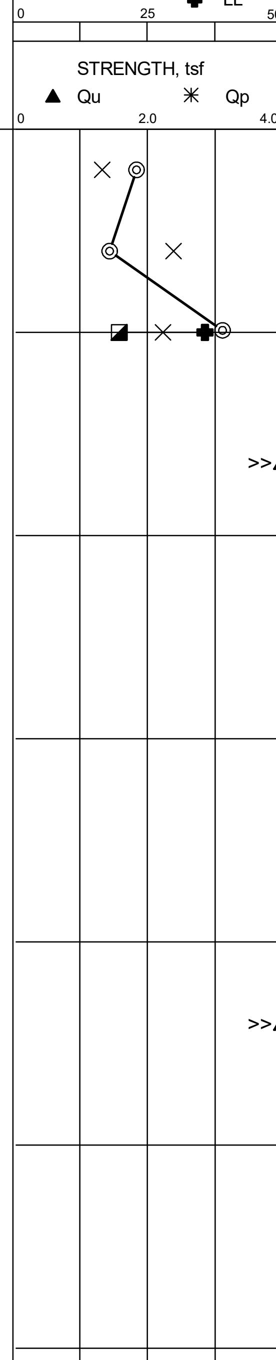
Water

▽	While Drilling	4 feet
▼	Post-Core	25 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, %	Additional Remarks
	0			S-1	15	**FILL**-Dark gray-brown, Gravelly SILT with Sand, moist	ML	20-16-7-9 N=23	17	Fines=50.0%
				S-2	17	**Possible FILL**-Brown, Lean CLAY with Sand, moist	CL	8-9-9-10 N=18	30	
	5			S-3	22	**RESIDUUM**-Hard, Brown, Lean CLAY, trace Sand, moist/wet	CL	12-18-21-50/5" N=39	28	LL = 36 PL = 20
				R-1	43	**DOLOMITE**-Light gray-white to dark gray, Very fine grained, Slightly Weathered, slightly broken to massive, hard to very hard, trace calcite stringers		RQD=61 Rec=72%		>>Q_u = 708.3 tsf 173.3 pcf
	10									
				R-2	55			RQD=75 Rec=92%		
	15					**LIMESTONE**-Light gray-white to dark gray, Very fine grained, Slightly Weathered, very broken to massive, moderately hard to very hard, trace calcite stringers				
				R-3	50	Weathered layer @ 18.7 feet (~ 4 inches thick) Soil layer @ 20.1 feet (~ 13-1/2 inches thick)		RQD=69 Rec=83%		
	20									>>Q_u = 1084.5 tsf 175.9 pcf
				R-4	58			RQD=88 Rec=96%		
	25					Soil parting @ 26 feet (< 1/8 inch thick)				
				R-5	59			RQD=82 Rec=98%		
	30									

STANDARD PENETRATION TEST DATA
N in blows/ft ◎ × Moisture ◪ PL ✚ LL
STRENGTH, tsf ▲ Qu ✳ Qp



Continued Next Page

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

PROJECT NO.: 04911464
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Interstate 81 (PPP4)
Cumberland Co., PA
PA-CU-0136.0003-RD/PO#20170824-2

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

DATE STARTED: 9/6/17	**DRILL COMPANY:** Eichelberger's, Inc.	**BORING B-2**	
DATE COMPLETED: 9/7/17	**DRILLER:** Mike **LOGGED BY:** L. Proczko	Water: While Drilling	4 feet
COMPLETION DEPTH 106.0 ft	**DRILL RIG:** Diedrich D-50 Turbo	Post-Core	25 feet
BENCHMARK: N/A	**DRILLING METHOD:** Casing/Rock Coring		
ELEVATION: N/A	**SAMPLING METHOD:** 2-in SS1.874-in Core		
LATITUDE: n/a°	**HAMMER TYPE:** Automatic	**BORING LOCATION:**	
LONGITUDE: n/a°	**EFFICIENCY** N/A	See Boring Location Plan	
STATION: N/A **OFFSET:** N/A	**REVIEWED BY:** F. Hoffman		
REMARKS:			

Elevation (feet)	Depth, (feet)	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS) RQD & Recovery % (NX)	Moisture, %	Additional Remarks
	30	R-6	59	**LIMESTONE**-Light gray-white to dark gray, Very fine grained, Slightly Weathered, very broken to massive, moderately hard to very hard, trace calcite stringers		RQD=88 Rec=98%		>> Q_u = 605.2 tsf 169.2 pcf
	35			**DOLOMITE**-Buff to light gray, Very fine grained, Slightly Weathered, slightly broken to massive, hard to very hard, trace calcite stringers				
		R-7	60	**LIMESTONE**-Light gray-white to dark gray, Very fine grained, Slightly Weathered, broken to massive, hard to very hard, trace calcite stringers		RQD=94 Rec=100%		
	40	R-8	41			RQD=39 Rec=68%		
				LIMESTONE-Light gray to gray-brown, Very fine grained, Weathered, very broken to slightly broken, moderately hard to hard, trace calcite stringers				>> Q_u = 668.3 tsf 168.6 pcf
	45			**SOIL**				
		R-9	58	**LIMESTONE**-Light gray-white to dark gray-brown, Very fine grained, Slightly Weathered, very broken to massive, hard to very hard, trace calcite stringers Vertical fracture from 49.5 to 49.7 feet. Nearly vertical fracture from 49.7 to 50.2 feet. Highly Weathered seam @ 50.5 feet (~ 1/2 inch thick)		RQD=76 Rec=97%		
	50	R-10	30	**LIMESTONE**-Light gray to dark gray-brown, Very fine grained, Weathered to Slightly Weathered, very broken to massive, moderately hard to hard, multiple soil layers, trace calcite stringers		RQD=33 Rec=50%		>> Q_u = 560.7 tsf 173.5 pcf
	55	R-11	60	**LIMESTONE**-Dark brown to yellow-gray-brown, Very fine grained, Weathered to Highly Weathered, very broken to slightly broken, moderately hard, trace pits and vugs, trace calcite stringers		RQD=21 Rec=100%		
	60							

STANDARD PENETRATION TEST DATA: N in blows/ft ◎; × Moisture; PL; LL; 0 25 50. STRENGTH, tsf: ▲ Qu; ✳ Qp; 0 2.0 4.0

Continued Next Page

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

PROJECT NO.: 04911464
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Interstate 81 (PPP4)
Cumberland Co., PA
PA-CU-0136.0003-RD/PO#20170824-2

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

DATE STARTED: 9/6/17	**DRILL COMPANY:** Eichelberger's, Inc.		**BORING B-2**		
DATE COMPLETED: 9/7/17	**DRILLER:** Mike	**LOGGED BY:** L. Proczko	**Water**	While Drilling	4 feet
COMPLETION DEPTH 106.0 ft	**DRILL RIG:** Diedrich D-50 Turbo			Post-Core	25 feet
BENCHMARK: N/A	**DRILLING METHOD:** Casing/Rock Coring				
ELEVATION: N/A	**SAMPLING METHOD:** 2-in SS1.874-in Core				
LATITUDE: n/a°	**HAMMER TYPE:** Automatic		**BORING LOCATION:**		
LONGITUDE: n/a°	**EFFICIENCY** N/A		See Boring Location Plan		
STATION: N/A **OFFSET:** N/A	**REVIEWED BY:** F. Hoffman				
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					**LIMESTONE**-Gray-brown to dark gray, Very fine grained, Weathered to Slightly Weathered, slightly broken to massive, moderately hard to hard, trace pits and vugs, trace calcite stringers					
						LIMESTONE-Light gray to dark gray, Very fine grained, Slightly Weathered, very broken to massive, moderately hard to very hard, trace calcite stringers				>>▲	Q_u = 517.8 tsf 165.9 pcf
				R-12	60			RQD=82 Rec=99%			
	65										
				R-13	60			RQD=82 Rec=100%			
	70										
				R-14	60			RQD=97 Rec=100%			
	75										
										>>▲	Q_u = 481.0 tsf 170.7 pcf
				R-15	60			RQD=88 Rec=100%			
	80										
				R-16	58			RQD=73 Rec=97%			
	85										
				R-17	60			RQD=75 Rec=100%		>>▲	Q_u = 585.6 tsf 168.8 pcf
	90										

Continued Next Page

intertek Total Quality. Assured. psi

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

PROJECT NO.: 04911464
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Interstate 81 (PPP4)
Cumberland Co., PA
PA-CU-0136.0003-RD/PO#20170824-2

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

BORING B-2

DATE STARTED:	9/6/17	**DRILL COMPANY:**	Eichelberger's, Inc.
DATE COMPLETED:	9/7/17	**DRILLER:** Mike	**LOGGED BY:** L. Proczko
COMPLETION DEPTH	106.0 ft	**DRILL RIG:**	Diedrich D-50 Turbo
BENCHMARK:	N/A	**DRILLING METHOD:**	Casing/Rock Coring
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS1.874-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	4 feet
▼	Post-Core	25 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
	90					**LIMESTONE**-Light gray to dark gray, Very fine grained, Slightly Weathered, very broken to massive, moderately hard to very hard, trace calcite stringers					
				R-18	60	**DOLOMITE**-Light gray to gray, Very fine grained, Slightly Weathered, broken to massive, very hard		RQD=91 Rec=100%			
	95										
				R-19	60	**LIMESTONE**-Buff to dark gray, Very fine grained, Slightly Weathered, very broken to massive, hard, trace calcite stringers Soil parting @ 98.8 feet (< 1/8 inch thick) Vertical fracture from 99.5 to 100.1 feet. Trace quartz from 98.8 to 101 feet.		RQD=84 Rec=100%			
	100										
				R-20	60			RQD=88 Rec=100%			
	105										
						Test boring terminated @ 106 feet					

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

PROJECT NO.: 04911464
PROJECT: Energy Transfer HDD (DPS)
LOCATION: Interstate 81 (PPP4)
Cumberland Co., PA
PA-CU-0136.0003-RD/PO#20170824-2

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


I-81 EASTSIDE
GEO BORE B-2
BOX 1 OF 7
9/5/17
PPP4
04911464
RUN | DEPTH | REC | RQD
R-1 | 6.0 - 11.0 | 3.6 | 2.7
R-2 | 11.0 - 16.0 | 4.8 | 3.6
R-3 | 16.0 - 21.0 | 4.3 | 3.5
R-4 | 21.0 - 26.0 | 4.8 | 4.7
6.0
11.0
16.0

9/6/17
PPP#4
049/1964
RUN.
DEPTH
REC
RQD
R-4
21.0-26.0
4.8
R-5
26.0-31.0
3.10
R-6
31.0-36.0
5.0
3.9
R-7
36.0-41.0


I 81 EASTSIDE
B-2
Box 3 OF
9/6/17
PPP4
04911464
RUN
DEPTH
REC
RQD
R-7
36.0-41.0
R-8
41.0-46.0
34
24
46.0-51.0
4.0
R-10
51.0-56.0
18
R11
56.0-61.0
50
12

Box 4 of 7
9/6/17
M1911464
RUN
DEPTH
REC
RQD
R-11
56.0-61.0
5.0
R-12
61.0-66.0
5.0
R-13
66.0-71.0
5.0
5.0
66.0
71.0

EASTSIDE
9/6/17
PPP#4
Run
Depth
REC
RQD
R-14
71.0-76.0
5.0
4.9
R-15
76.0-81.0
5.0
4.3
R-16
81.0-86.0
5.0
3.8
76.0
81.0


PPP#4
B-2
9-7-17
86-100.2
Box 6 of 7
I-81
RUN
Depth (ft.)
Rec (in.)
RQD (in.)
R-17
86-91
60
45
R-18
91-96
60
54.5
R-19
96-101
60
50.5
91
96
101


PPP4
04911464
B-2
9-7-16
100.2-106
Box 7 of 7
I-81
RUN | Depth (ft.) | Rec (in.) | RQD (in.)
R-20 | 101-106 | 60 | 53
101

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

Description	Criteria
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.

SOIL CLASSIFICATION CHART

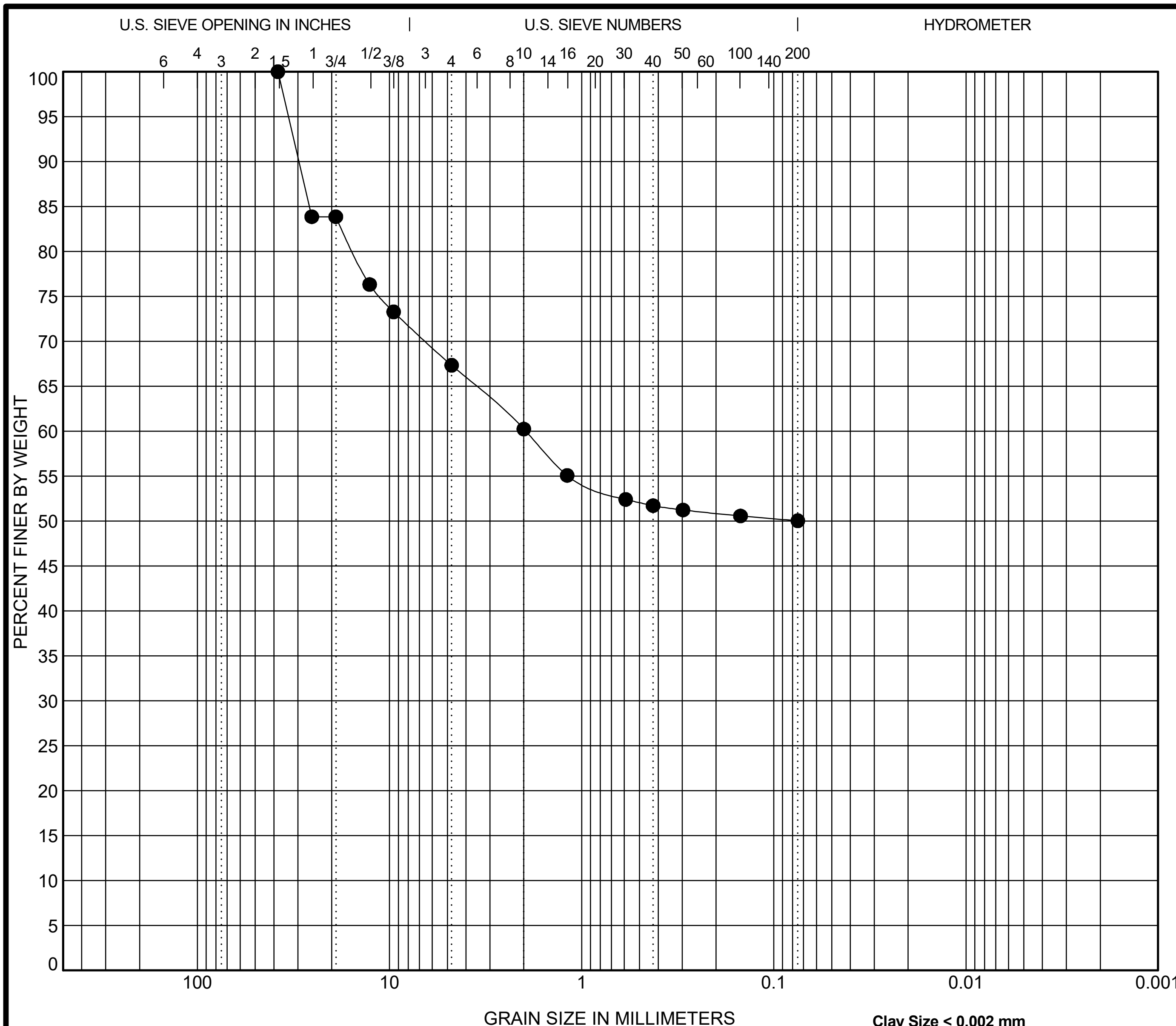
' 0$BĀ(1!) Ā#. <)#Ā!" $Ā1#$(Ā0 Ā&(&Ā0$Ā< " ($") &'$Ā# &)ĀĀ! ##&2&Ā! 0& ' #

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
À ! " #$ %" ! & $(# &#	%" ! ,$) !' (%" ! , $))4 # &#	À) $!' %" ! ,$) #		GW	* $)) +%"!($(Ā %" !,$) #-Ā%"!,$) Ā+ #!' (Ā. & 01" $#-Ā) &00) $Ā"Ā ' Ā2&$#
		7)&00) $Ā " Ā' Ā2&'$#8		GP	3 ") 4 +%"!($(Ā %" !,$) #-Ā%"!,$) +#!'(Ā & 01"$#- Ā) &00) $Ā" Ā 2& $#
	. "$Ā06!'Ā : ; = 2 Ā ! "# $ 2" ! À0& ' " $0! &'$(Ā ' Ā' > Ā#&$,$	%" ! ,$) #Ā* &06 2& $#		GM	#&) 04Ā%" !,$) #-Ā%"!,$) Ā#!'(Ā + #&)0Ā. &/01" $#
		7! 33" $Ā&! <) $Ā . 1'0 2Ā2&'$#8		GC	À) !4$4Ā %" !,$) #-Ā%"!,$) Ā#!'(Ā + À) ! 4Ā. &/01" $#
. "$Ā06!'Ā : ; = 2Ā !0$"& !) Ā#) ! "%$ " Ā06! 'Ā' > ?;;Ā #&$, $Ā#&@$	#!' (!' (#! '(4 # &#	À) $! 'Ā#! ' (#		SW	* $)) +%"!($(Ā #! '(#- Ā%" !,$)) 4 #! ' (#-Ā) &00) $Ā " Ā' Ā2&'$#
		7)&00) $Ā " Ā' Ā2&'$#8		SP	3 ") 4 +%"!($(Ā #! '(#- Ā%" !,$)) 4 #!' (- Ā) &00) $Ā"Ā ' Ā2&$#
	. "$Ā06!'Ā : ; = 2 Ā ! "# $ 2" ! À0& ' 3!##& '% Ā 'Ā' >Ā #&$,$	#! '(# Ā* &06 2& $#		SM	#&) 04Ā#! '(#- Ā#!'(Ā#&) 0Ā & 01 "$#
		7! 33" $Ā&! <) $Ā . 1'0 2Ā2&'$#8		SC	À) !4$4Ā #! '(#- Ā#!'(ĀÀ) !4 . & 01"$#
2& $ %" ! & $(# &#	#&) 0# !' (À) ! 4#	) &91 &(Ā)&. &0) $##Ā06 !' Ā;		ML	& " %! ' &Ā#&) 0#Ā' (Ā$ " 4Ā2& $ #!'(#- Ā À5Ā 2) 1"- Ā#&) 04Ā" À) !4$4Ā 2&$Ā #!' (#Ā "ĀÀ) !4$4 #&) 0#Ā* &06 Ā#) &%60Ā3) !#0& À&04
				CL	& " %! '& ÀĀ) !4#Ā 2 Ā * Ā0 . $(&. Ā3) !#0& À&04-Ā%" !,$)) 4 À) !4#- Ā#!'(4Ā À) !4#- Ā#&) 04ĀÀ) ! 4#-) $!'Ā À) !4#
				OL	" %! ' &Ā#&)0 #Ā ' (Ā " %! '& ÀĀ#&)0 4 À) !4#Ā 2 Ā * Ā3) ! #0&À&04
. "$Ā06!'Ā : ; = 2Ā !0$"& !) Ā# #. !)) $"Ā06 !' ' >Ā ; Ā#&$ $ #&@$	#&) 0# !' (À) ! 4#	) &91 &(Ā)&. &0 %" $!0$"Ā 06!'Ā : ;		MH	& " %! '& ÀĀ#&) 0#-Ā &À!À $ 1#Ā " (&0 . !À$ 1#Ā2& $Ā#! '(Ā "Ā#&) 04 # &#
				CH	& " %! '& ÀĀ) !4#Ā 2 Ā6 &%6 3) !#0& À&04
				OH	" %! ' &ĀÀ) ! 4#Ā 2Ā $(&1 Ā0 Ā6&%6 3) ! #0&À&04-Ā " %! ' &Ā#&)0#
6&%6)4 Ā " %! '& ÀĀ# &#				PT	3$!0- Ā61 . 1#-Ā#* !. 3Ā# &#Ā* &06 6 &%6Ā " %! ' &ĀÀ ' 0$' 0#

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.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	**B-2**	**1.0**	**Gravelly SILT with Sand (ML)**					

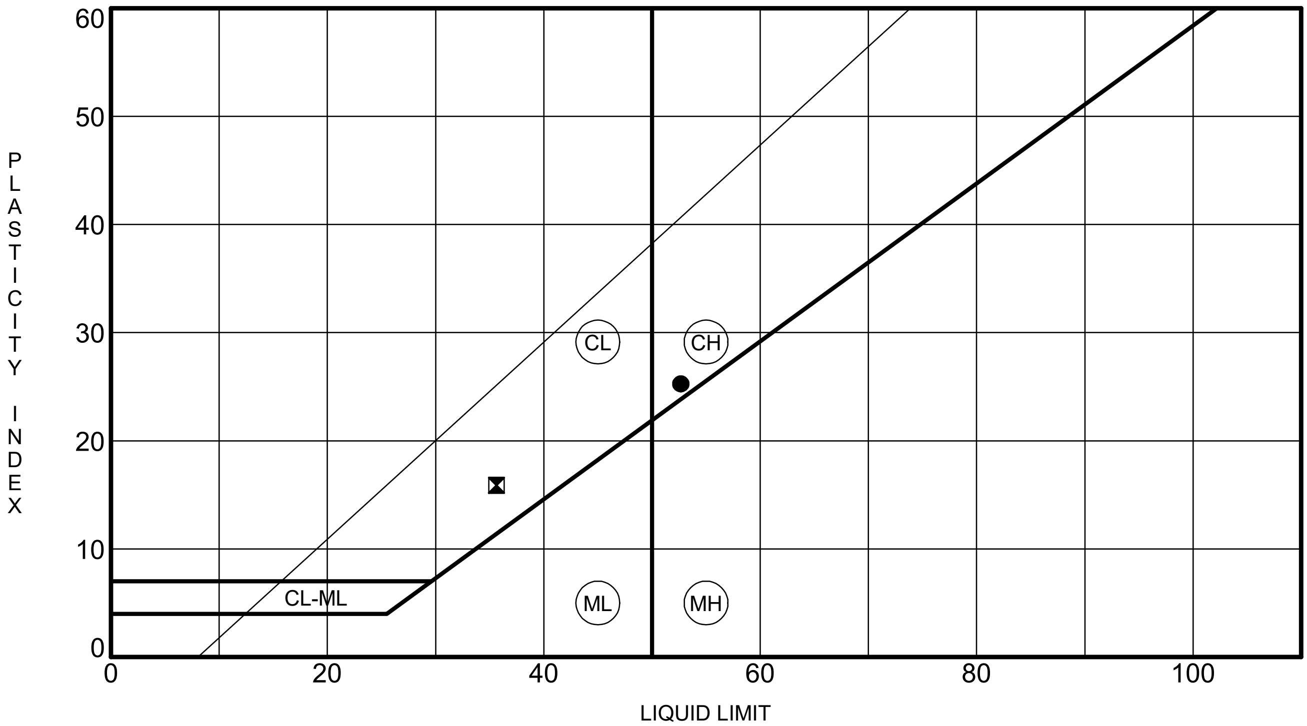
	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**B-2**	**1.0**	**38.1**	**1.954**			**32.7**	**17.3**	**50.0**	

intertek psi

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.: 04911464
Location: Interstate 81 (PPP4)
Cumberland Co., PA



	Boring	Depth (ft)	LL	PL	PI	Fines	Classification (*Visual)
●	**B-1**	**5.0**	**53**	**27**	**26**		**Fat CLAY (CH)**
⧗	**B-2**	**5.0**	**36**	**20**	**16**		**Lean CLAY (CL)**

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

ATTERBERG LIMIT RESULTS

PSI Job No.: 04911464
Project: Energy Transfer HDD (DPS)
Location: Interstate 81 (PPP4)
Cumberland 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-1	1							27			
B-1	5	53	27	26				34			
B-1	8							42			
B-1	18.5				517.15						
B-1	32				351.17						
B-1	42.2				394.00						
B-1	51.5				1256.08						
B-1	60.5				567.16						
B-1	74.8				534.98						
B-1	86.5				462.98						
B-1	98.2				626.88						
B-1	111.7				742.86						
B-2	1					50.0%		17			
B-2	3							30			
B-2	5	36	20	16				28			
B-2	8.2				708.29						
B-2	22				1084.53						
B-2	32.3				605.17						
B-2	44.1				668.30						
B-2	53.8				560.67						
B-2	63.1				517.85						
B-2	77				481.04						
B-2	88.9				585.63						

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

Summary of Laboratory Results

PSI Job No.: 04911464
Project: Energy Transfer HDD (DPS)
Location: Interstate 81 (PPP4)
Cumberland Co., PA
PA-CU-0136.0003-RD/PO#20170824-2

ATTACHMENT 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
Cumberland County, Pennsylvania

February 11, 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.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

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.

Soil Map

Map Scale: 1:4,100 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 50, 100, 200, 300

Feet: 0, 150, 300, 600, 900

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 1:15,800.

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: Cumberland County, Pennsylvania
Survey Area Data: Version 13, 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: Aug 23, 2013—Feb 22, 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
HaB	Hagerstown silt loam, 3 to 8 percent slopes	52.5	63.8%
HaC	Hagerstown silt loam, 8 to 15 percent slopes	6.7	8.1%
HcB	Hagerstown silt loam, rocky, 3 to 8 percent slopes	8.6	10.4%
HcC	Hagerstown silt loam, rocky, 8 to 15 percent slopes	0.4	0.4%
HuA	Huntington silt loam, 0 to 5 percent slopes	5.2	6.4%
Wa	Warners silt loam	8.9	10.9%
Totals for Area of Interest		**82.3**	**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.

Cumberland County, Pennsylvania

HaB—Hagerstown silt loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 2rc98
Elevation: 600 to 1,750 feet
Mean annual precipitation: 37 to 45 inches
Mean annual air temperature: 45 to 55 degrees F
Frost-free period: 155 to 190 days
Farmland classification: All areas are prime farmland

Map Unit Composition

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

Description of Hagerstown

Setting

Landform: Hills
Landform position (two-dimensional): Backslope, footslope, summit
Landform position (three-dimensional): Side slope, base slope, interfluve
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Parent material: Clayey residuum weathered from limestone

Typical profile

Ap - 0 to 10 inches: silt loam
Bt1 - 10 to 21 inches: silty clay loam
Bt2 - 21 to 56 inches: silty clay
C - 56 to 73 inches: silty clay loam
R - 73 to 83 inches: bedrock

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: 43 to 98 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 8.7 inches)

Interpretive groups

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

Minor Components

Opequon

Percent of map unit: 5 percent

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

Carbo

Percent of map unit: 5 percent
Landform: Hills
Landform position (two-dimensional): Summit, backslope, shoulder
Landform position (three-dimensional): Side slope, crest
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Hydric soil rating: No

Funkstown

Percent of map unit: 3 percent
Landform: Valley floors
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Base slope
Down-slope shape: Concave
Across-slope shape: Concave, linear
Hydric soil rating: No

Timberville

Percent of map unit: 2 percent
Landform: Hills
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Head slope, base slope
Down-slope shape: Concave, linear
Across-slope shape: Convex, concave, linear
Hydric soil rating: No

HaC—Hagerstown silt loam, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: 2tb03
Elevation: 600 to 1,750 feet
Mean annual precipitation: 32 to 45 inches
Mean annual air temperature: 41 to 65 degrees F
Frost-free period: 155 to 181 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

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

Description of Hagerstown

Setting

Landform: Hillslopes
Landform position (two-dimensional): Backslope, shoulder
Landform position (three-dimensional): Side slope
Down-slope shape: Linear, convex, concave
Across-slope shape: Linear, convex
Parent material: Clayey residuum weathered from limestone and dolomite

Typical profile

Ap - 0 to 8 inches: silt loam
Bt1 - 8 to 19 inches: silty clay loam
Bt2 - 19 to 54 inches: silty clay
C - 54 to 71 inches: silty clay loam
R - 71 to 81 inches: bedrock

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: 43 to 98 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
Salinity, maximum in profile: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water storage in profile: Moderate (about 7.0 inches)

Interpretive groups

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

Minor Components

Carbo

Percent of map unit: 8 percent
Landform: Hills
Landform position (two-dimensional): Summit, backslope, shoulder
Landform position (three-dimensional): Crest, side slope
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Hydric soil rating: No

Opequon

Percent of map unit: 5 percent
Landform: Ridges
Landform position (two-dimensional): Shoulder, summit
Landform position (three-dimensional): Side slope, crest
Down-slope shape: Linear, convex
Across-slope shape: Convex, linear
Hydric soil rating: No

Clarksburg

Percent of map unit: 2 percent
Landform: Hillslopes
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope, head slope
Down-slope shape: Linear
Across-slope shape: Concave
Hydric soil rating: No

HcB—Hagerstown silt loam, rocky, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: r8wn
Elevation: 460 to 1,500 feet
Mean annual precipitation: 30 to 45 inches
Mean annual air temperature: 45 to 57 degrees F
Frost-free period: 140 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Hagerstown and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hagerstown

Setting

Landform: Ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Clayey residuum weathered from argillaceous limestone

Typical profile

H1 - 0 to 10 inches: silt loam
H2 - 10 to 19 inches: clay
H3 - 19 to 57 inches: clay

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: 40 to 84 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: High (about 10.0 inches)

Interpretive groups

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

HcC—Hagerstown silt loam, rocky, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: r8wp
Elevation: 460 to 1,500 feet
Mean annual precipitation: 30 to 45 inches
Mean annual air temperature: 45 to 57 degrees F
Frost-free period: 140 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Hagerstown and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hagerstown

Setting

Landform: Ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Clayey residuum weathered from argillaceous limestone

Typical profile

H1 - 0 to 10 inches: silt loam
H2 - 10 to 19 inches: clay
H3 - 19 to 57 inches: clay

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: 40 to 84 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: High (about 10.0 inches)

Interpretive groups

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

HuA—Huntington silt loam, 0 to 5 percent slopes

Map Unit Setting

National map unit symbol: r8x6
Mean annual precipitation: 35 to 55 inches
Mean annual air temperature: 46 to 59 degrees F
Frost-free period: 110 to 170 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Huntington and similar soils: 90 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Huntington

Setting

Landform: Drainageways
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Colluvium derived from limestone and shale

Typical profile

H1 - 0 to 11 inches: silt loam
H2 - 11 to 44 inches: silt loam
H3 - 44 to 60 inches: stratified fine sand to silty clay loam

Properties and qualities

Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
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: Occasional
Frequency of ponding: None
Available water storage in profile: High (about 10.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 1
Hydrologic Soil Group: B
Hydric soil rating: No

Minor Components

Atkins

Percent of map unit: 5 percent
Landform: Flood plains

Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Base slope
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: Yes

Wa—Warners silt loam

Map Unit Setting

National map unit symbol: r8yj
Elevation: 250 to 1,000 feet
Mean annual precipitation: 30 to 45 inches
Mean annual air temperature: 46 to 55 degrees F
Frost-free period: 140 to 210 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Warners and similar soils: 90 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Warners

Setting

Landform: Depressions
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Base slope
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Parent material: Carbonatic fine-silty alluvium

Typical profile

H1 - 0 to 12 inches: silt loam
H2 - 12 to 33 inches: silt loam
H3 - 33 to 62 inches: marl

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly 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 0 inches
Frequency of flooding: Frequent
Frequency of ponding: Frequent
Calcium carbonate, maximum in profile: 90 percent
Available water storage in profile: High (about 11.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: B/D
Hydric soil rating: Yes

Minor Components

Somewhat poorly drained soils
Percent of map unit: 5 percent
Hydric soil rating: No

References

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

National Research Council. 1995. Wetlands: Characteristics and boundaries.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_054262

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053577

Soil Survey Staff. 2010. Keys to soil taxonomy. 11th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053580

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053374

United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053624

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052290.pdf

RETTEW

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-10022017-632-01	655	655	180	Unknown	~100
WL-09122017-615-01	437	437	>100	Unknown	Unknown

Legend

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

Testing locations current as of 02/05/2018

- GES Testing Location

Location

N

0 250 500
Feet

Well Location Map
HDD# PA-CU-0136.0003-RD
Cumberland County, PA.

Prepared By: TETRA TECH

Date: 2/5/2019

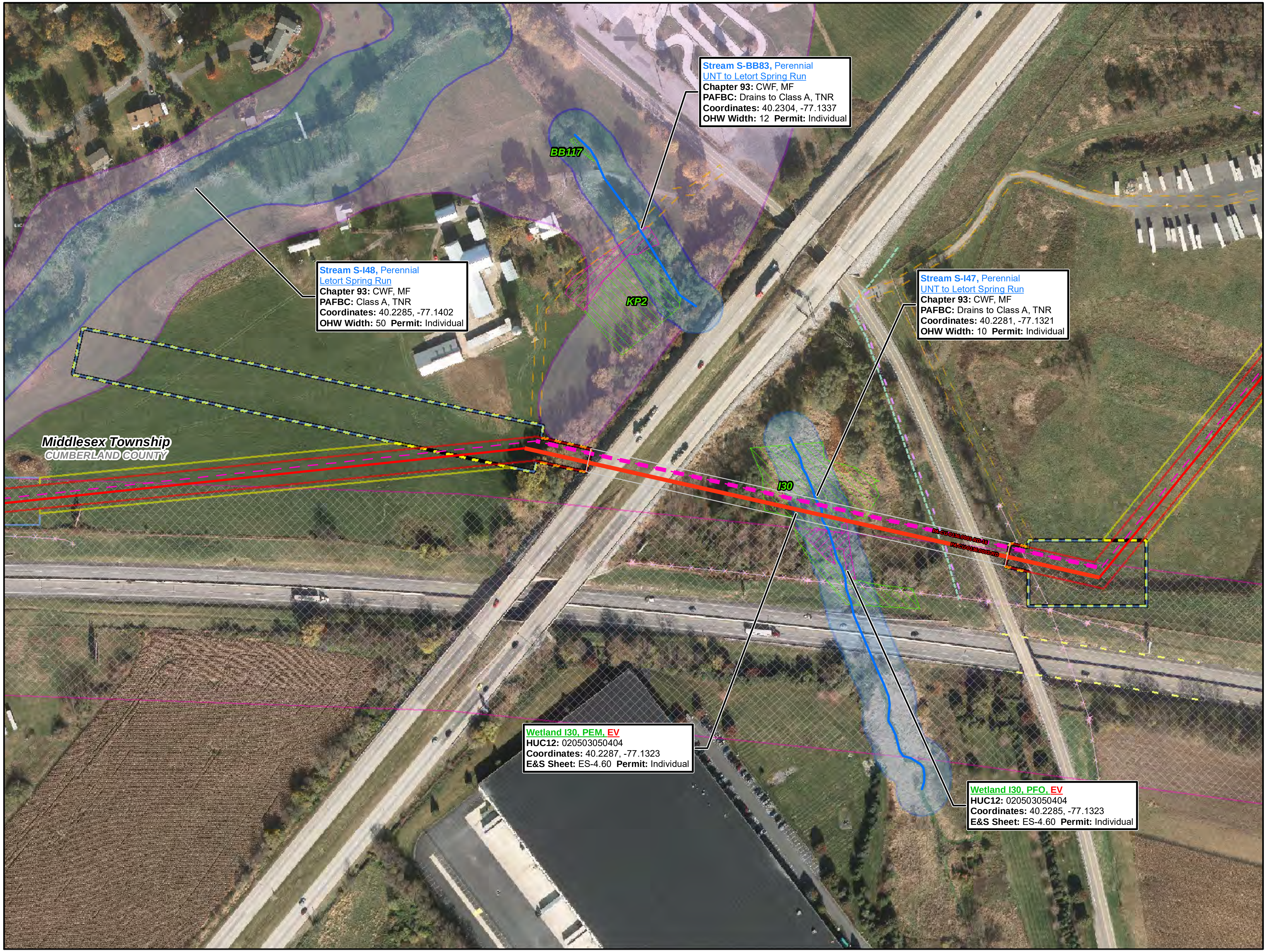
Base Map;
ESRI World Imagery, 09/24/2015

Coordinate System: NAD 83 Stateplane, PA South, Feet

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

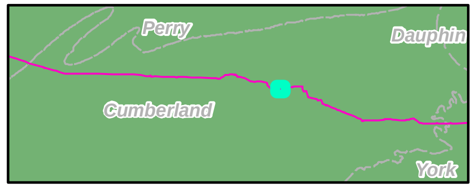
ATTACHMENT 2

ALTERNATIVES ANALYSIS FIGURES



Legend

- PPP 1, HDD
- PPP 1
- PPP 2, HDD
- PPP 2
- Permanent ROW
- Temporary ROW
- ATWS
- Temporary Access Road
- HDD Alternative LOD
- Perennial Stream
- PEM Wetland
- PFO Wetland
- Chapter 105 Floodway
- Ch. 106 Floodplain Fringe
- Cultural Resources
- Existing Electric Line
- Existing Sanitary Sewer
- Existing Storm Sewer
- Existing Water Line



0 100 200

1 inch = 200 feet

N

Figure 1.
PA-CU-0136.0002-WX-16
HDD Alternative LOD
Sunoco Pennsylvania Pipeline Project,
Cumberland County, PA.
Sheet 1 of 1

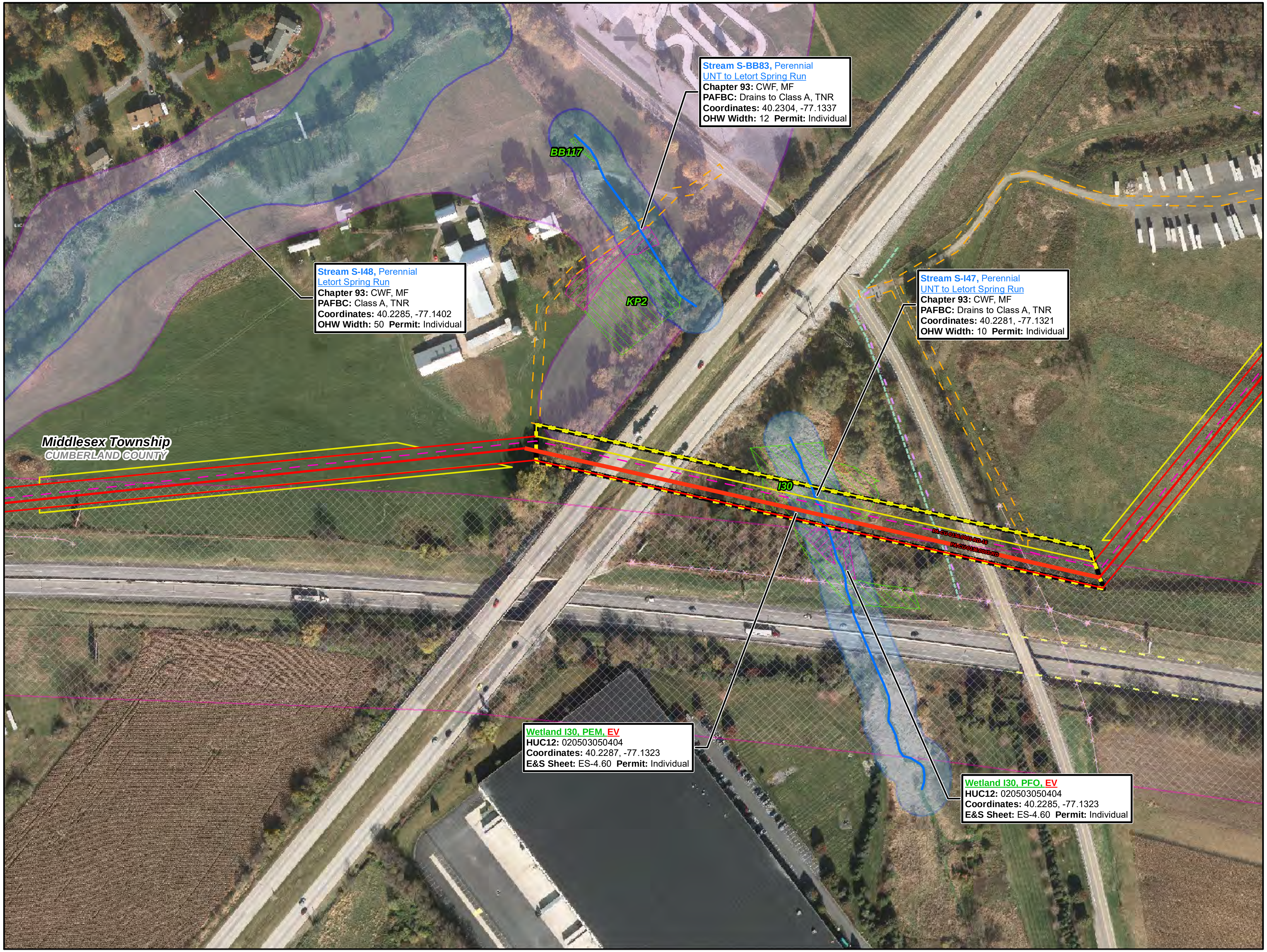
Prepared By: TETRA TECH

Date: 6/5/2019

Base Map; SPLP 2014-2016, Roads from NRCS Geo-spatial Data Giveaway, 100-Year Floodplain from FEMA NFHL, downloaded 9/2016. Aquatics, TT 2013-2016.

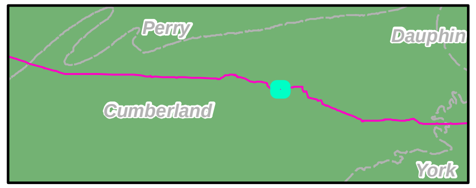
Coordinate System: NAD 83 Stateplane, PA South, Feet

C:\Users\stephanie.aselage\Documents\00_Projects\212IC_BF_00037_PPP\MXD\Figure1_I81_HDD.mxd LN



Legend

- PPP 1, HDD
- PPP 1
- PPP 2
- Permanent ROW
- Temporary ROW
- Temporary Access Road
- Open Cut Alternative LOD
- Perennial Stream
- PEM Wetland
- PFO Wetland
- Chapter 105 Floodway
- Ch. 106 Floodplain Fringe
- Cultural Resources
- Existing Electric Line
- Existing Sanitary Sewer
- Existing Storm Sewer
- Existing Water Line



0 100 200

1 inch = 200 feet

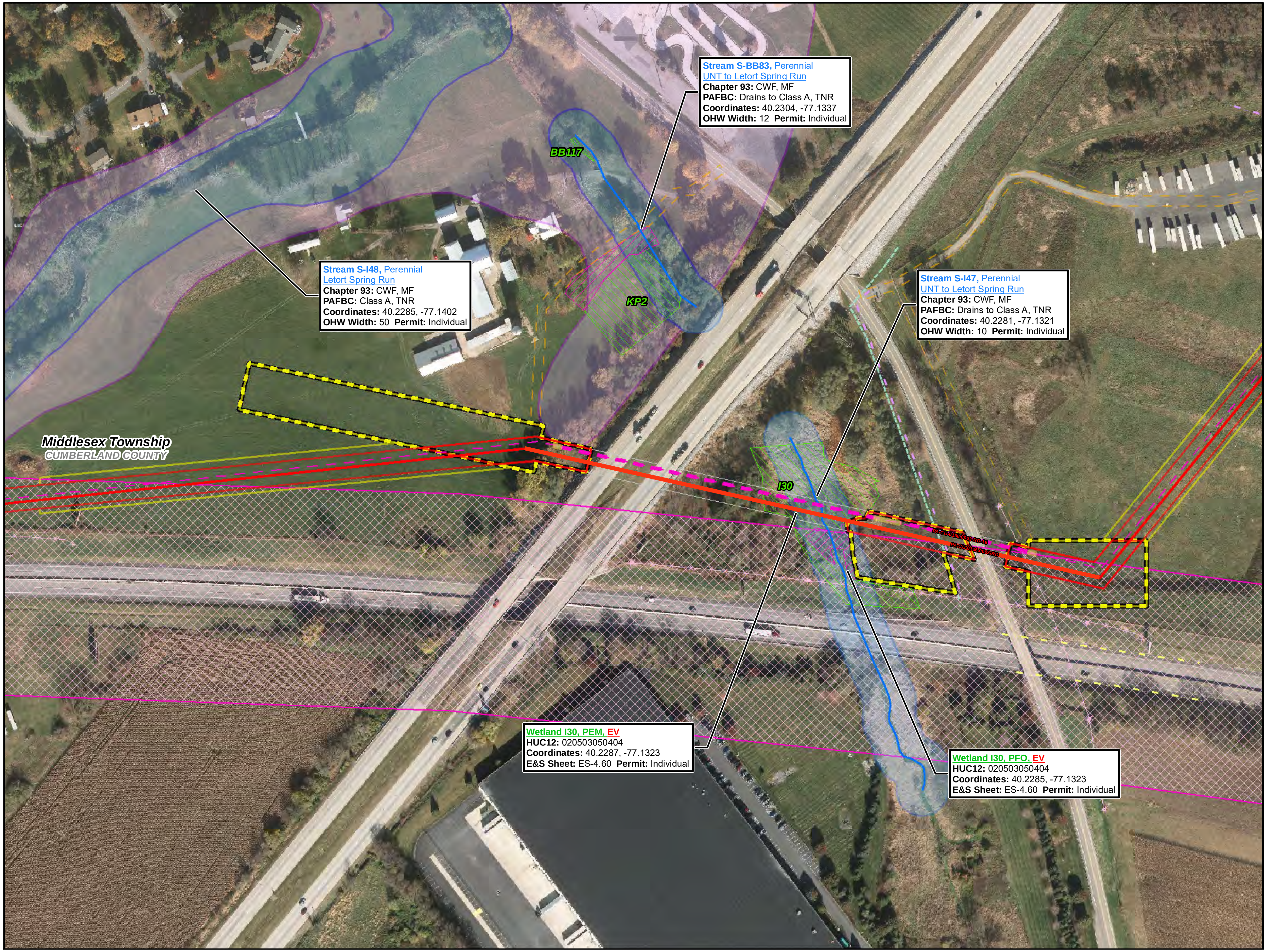
N

Figure 2
PA-CU-0136.0002-WX-16
Open Cut Alternative LOD
Sunoco Pennsylvania Pipeline Project,
Cumberland County, PA.
Sheet 1 of 1

Prepared By: TETRA TECH	Date: 6/5/2019

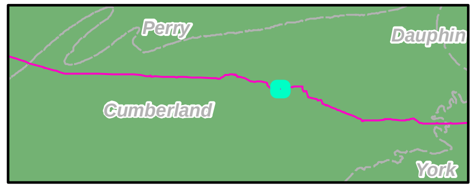
Base Map; SPLP 2014-2016, Roads from NRCS Geo-spatial Data Giveaway, 100-Year Floodplain from FEMA NFHL, downloaded 9/2016. Aquatics, TT 2013-2016.

Coordinate System: NAD 83 Stateplane, PA South, Feet



Legend

- PPP 1, HDD
- PPP 1
- PPP 2, CAB
- PPP 2
- Permanent ROW
- Temporary ROW
- Temporary Access Road
- Bore Pits
- Bore/Open Cut Alternative LOD
- Perennial Stream
- PEM Wetland
- PFO Wetland
- Chapter 105 Floodway
- Ch. 106 Floodplain Fringe
- Cultural Resources
- Existing Electric Line
- Existing Sanitary Sewer
- Existing Storm Sewer
- Existing Water Line



0 100 200

1 inch = 200 feet

N

Figure 3.
PA-CU-0136.0002-WX-16 Combination Open Cut/CAB Alternative 1
Sunoco Pennsylvania Pipeline Project,
Cumberland County, PA.
Sheet 1 of 1

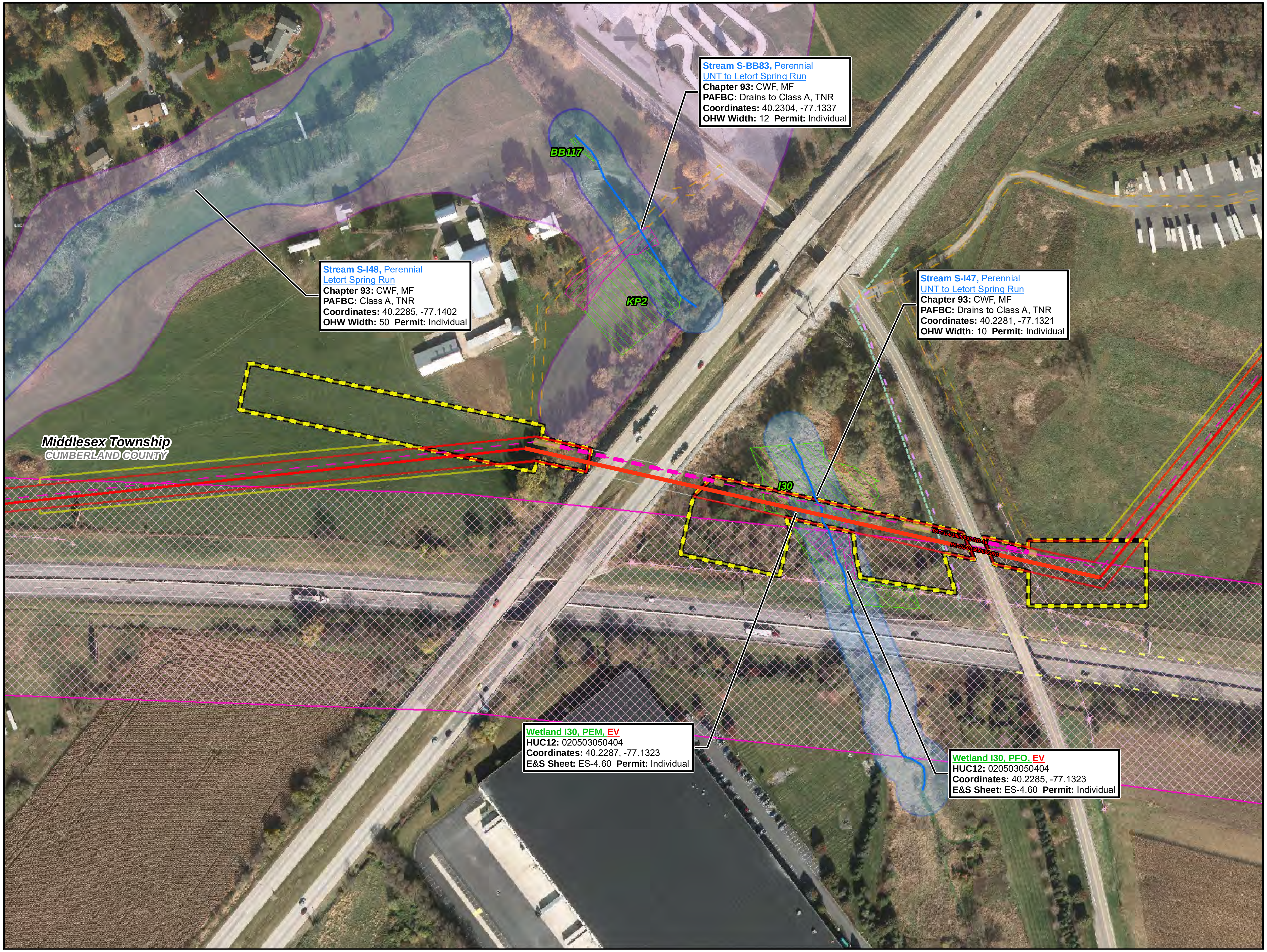
Prepared By: TETRA TECH

Date: 6/7/2019

Base Map; SPLP 2014-2016, Roads from NRCS Geospatial Data Giveaway, 100-Year Floodplain from FEMA NFHL, downloaded 9/2016. Aquatics, TT 2013-2016.

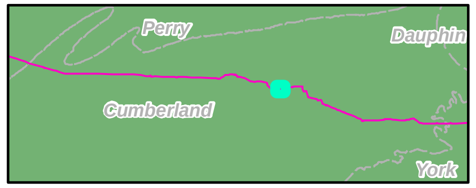
Coordinate System: NAD 83 Stateplane, PA South, Feet

C:\Users\stephanie.aselage\Documents\00_Projects\2121C_BF_00037_PPP\MXD\Figure3_I81_CAB.mxd LN



Legend

- PPP 1, HDD
- PPP 1
- PPP 2, CAB
- PPP 2
- Permanent ROW
- Temporary ROW
- Temporary Access Road
- Bore Pits
- Bore/Open Cut Alternative LOD
- Perennial Stream
- PEM Wetland
- PFO Wetland
- Chapter 105 Floodway
- Ch. 106 Floodplain Fringe
- Cultural Resources
- Existing Electric Line
- Existing Sanitary Sewer
- Existing Storm Sewer
- Existing Water Line



0 100 200

1 inch = 200 feet

N

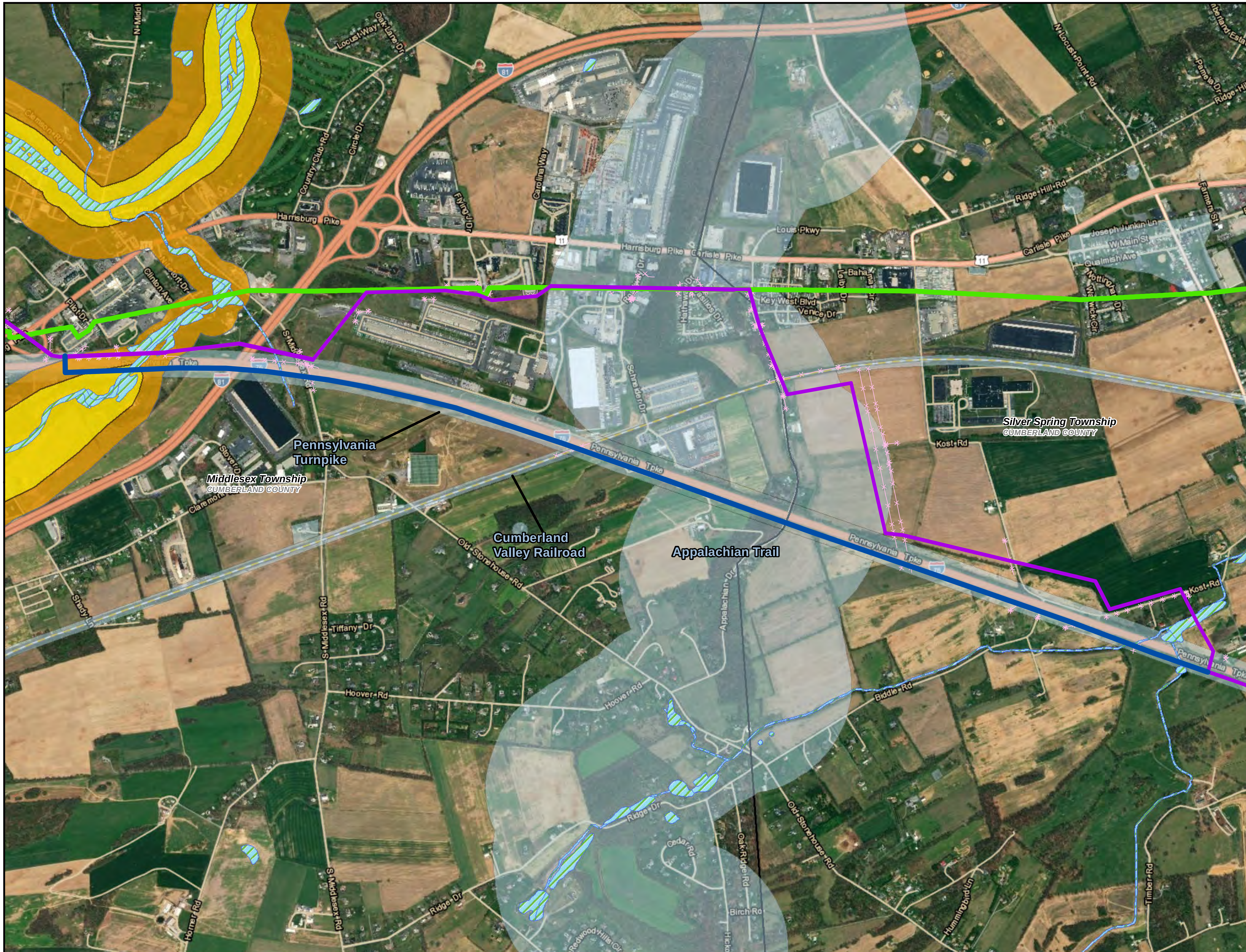
Figure 4.
PA-CU-0136.0002-WX-16 Combination Open Cut/CAB Alternative 2
Sunoco Pennsylvania Pipeline Project, Cumberland County, PA.
Sheet 1 of 1

Prepared By: TETRA TECH

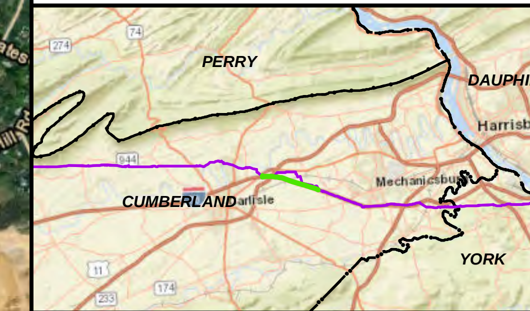
Date: 6/7/2019

Base Map; SPLP 2014-2016, Roads from NRCS Geospatial Data Giveaway, 100-Year Floodplain from FEMA NFHL, downloaded 9/2016. Aquatics, TT 2013-2016.

Coordinate System: NAD 83 Stateplane, PA South, Feet



PROJECT LOCATION



Legend

- Proposed/Permitted Route
- Potential Reroute Alternative
- Original Proposed Route (ME1)
- NWI
- CNHI Core
- CNHI Supporting
- Historic Districts
- Municipal Boundary
- Existing Electric Line

0 750 1,500 Feet

N

Figure 5.
Potential LeTort/I-81 Route Alternative

Prepared By: TETRA TECH

Date: 05/2019

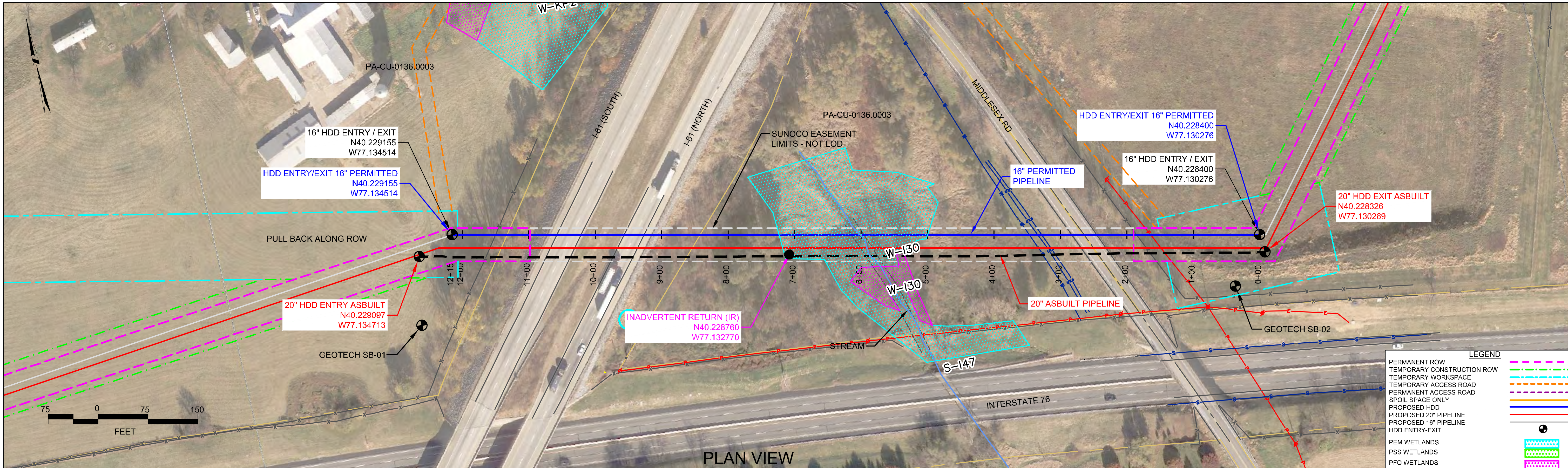
Base Map;
ESRI World Imagery, April 2017

Coordinate System: WGS 84

HORIZONTAL DIRECTIONAL DRILL ANALYSIS
I-81 ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E21-449
PA-CU-0136.0003-RD-16
(SPLP HDD No. S2-0220-16)

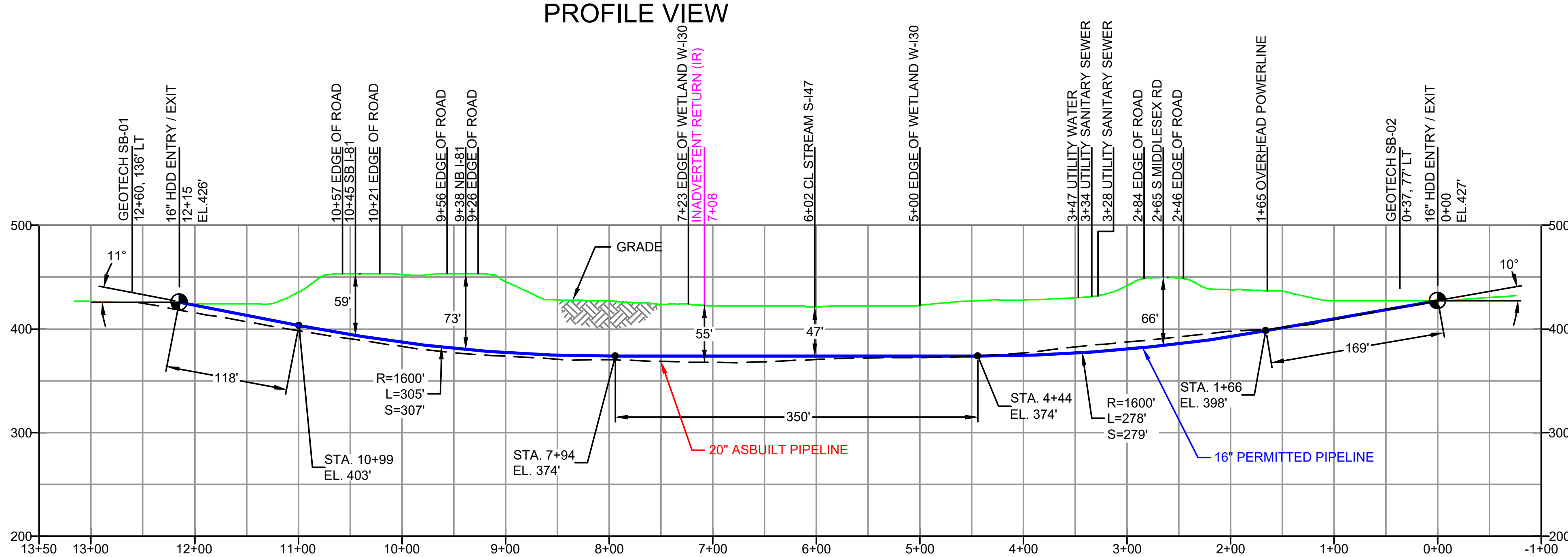
ATTACHMENT 3

HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



CUMBERLAND COUNTY, PENNSYLVANIA - MIDDLESEX TOWNSHIP
S2-0220-16

PROFILE VIEW



GEOTECH SB-01

- NG EL. 427'
- TOPSOIL (0' - 0.2')
- ML (0.2' - 7.0')
- LIMESTONE (7.0' - 7.8')
- AUGER REFUSAL (7.5')
- COMPLETION DEPTH EL. 419'

GEOTECH SB-02

- NG EL. 439'
- TOPSOIL (0' - 0.2')
- ML (0.2' - 7.0')
- LIMESTONE (7.0' - 7.3')
- AUGER REFUSAL (7.5')
- COMPLETION DEPTH EL. 432'

NOTE: REFER TO TEST BORING LOG S2-0220 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=):1215'
   HDD PIPE LENGTH (S=):1223'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 1. 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
3	REVISED PROFILE WITH 2017 LIDAR	MRS	03/15/17	RMB	03/15/17	CAG	03/15/17
2	REVISED PER ENGINEERING COMMENTS	MRS	08/31/16	RMB	08/31/16	AAW	08/31/16
1	REVISED PER COMMENTS FROM REI REVIEW	MRS	02/19/16	RMB	02/19/16	AAW	02/19/16
0	ISSUED FOR CONSTRUCTION	MRS	01/19/16	RMB	01/19/16	AAW	01/19/16

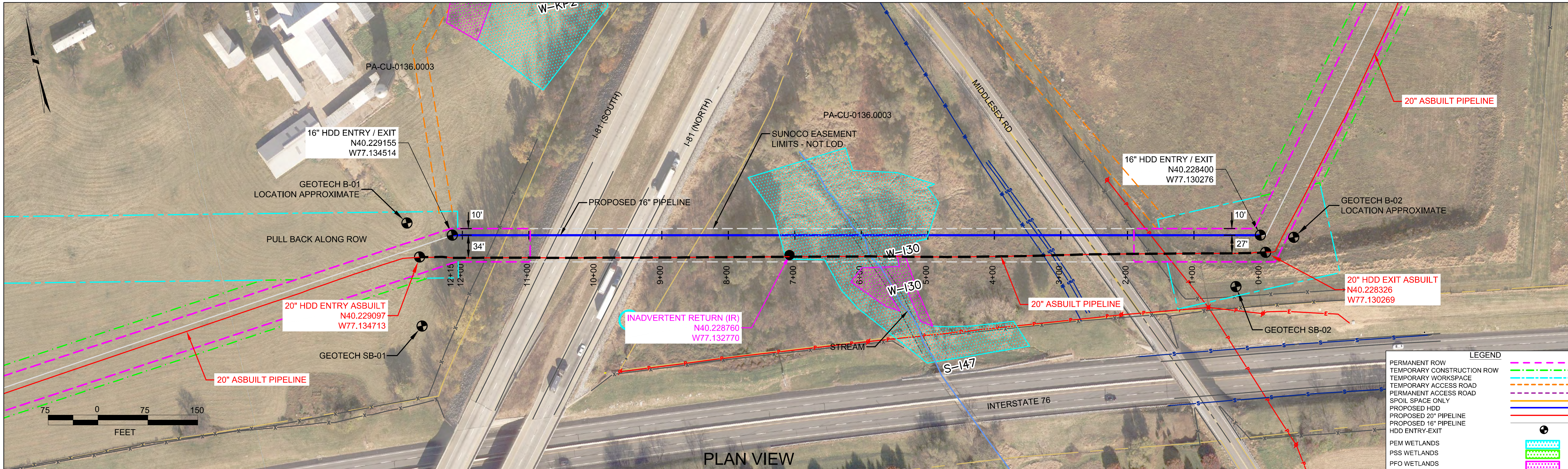
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

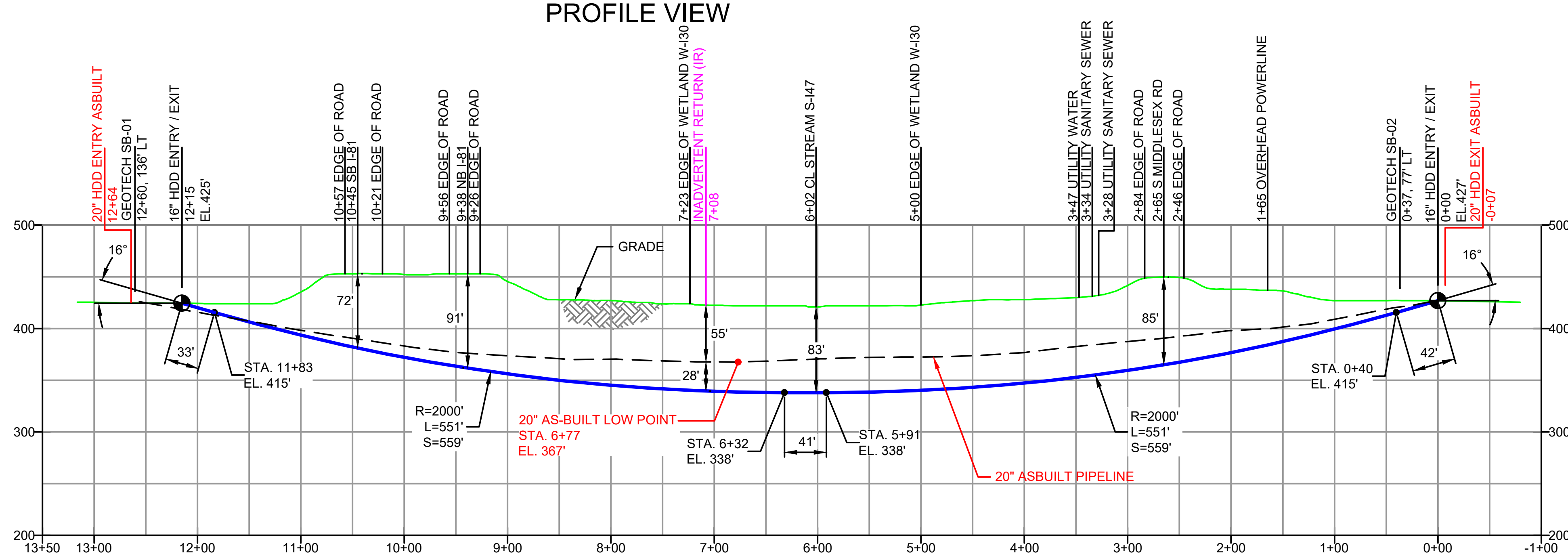
HORIZONTAL DIRECTIONAL DRILL
I-81
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150' DWG. NO. PA-CU-0136.0003-RD-16 IR EXHIB



CUMBERLAND COUNTY, PENNSYLVANIA - MIDDLESEX TOWNSHIP
S2-0220-16

PROFILE VIEW



GEOTECH SB-01

- NG EL. 427'
- TOPSOIL (0' - 0.2')
- ML (0.2' - 7.0')
- LIMESTONE (7.0' - 7.8')
- AUGER REFUSAL (7.5')
- COMPLETION DEPTH EL. 419'

GEOTECH SB-02

- NG EL. 439'
- TOPSOIL (0' - 0.2')
- ML (0.2' - 7.0')
- LIMESTONE (7.0' - 7.3')
- AUGER REFUSAL (7.5')
- COMPLETION DEPTH EL. 432'

NOTE: REFER TO TEST BORING LOG S2-0220 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-1

- NG EL. 426'
- RESIDUUM LEAN CLAY CL (0.0' - 3.0')
- RESIDUUM FAT CLAY CH (3.0' - 7.0')
- GROUNDWATER (9.0')
- RESIDUUM LEAN CLAY CL (7.0' - 11.75')
- LIMESTONE/DOLOMITE (11.75' - 114.0')
- BORING TERMINATED EL.312'

NOTE: REFER TO TEST BORING LOG B-1 INTERTEK PROJECT #04911464 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B-2

- NG EL. 427'
- FILL ML (0.0' - 2.0')
- POSSIBLE FILL, LEAN CLAY CL (2.0' - 4.0')
- RESIDUUM LEAN CLAY CL (4.0' - 7.5')
- GROUNDWATER (25.0')
- LIMESTONE/DOLOMITE (7.5' - 106.0')
- BORING TERMINATED EL.321'

NOTE: REFER TO TEST BORING LOG B-2 INTERTEK PROJECT #04911464 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=):1215'
   HDD PIPE LENGTH (S=):1234'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 2100 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 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. Revised 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

DWG NO		DWG NO	DESCRIPTION
ES-4.64	TO	ES-4.65	EROSION & SEDIMENT PLAN
SHEET 37	TO	SHEET 37	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP3	DESIGN CHANGE - INCREASED ENTRY/EXIT ANGLES AND DEPTH, ADDED GEOTECH DATA	MRS	02/04/19	RMB	02/04/19	AMC	02/04/19
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	MRS	05/10/16	RMB	05/10/16	AAW	05/10/16
EP		JTW	02/26/16	RMB	02/26/16	AAW	02/26/16
B	ADDED GEOTECH INFO	MRS	09/15/15	RMB	09/15/15	AAW	09/15/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	08/31/15

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
I-81
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=150'   DWG. NO: PA-CU-0136.0003-RD-16