

**HORIZONTAL DIRECTIONAL DRILL ANALYSIS
BIDDLE DRIVE CROSSING
PADEP SECTION 105 PERMIT NO.: E15-862
PA-CH-0199.000-RD
(SPLP HDD No. S3-0360)**

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This re-evaluation of the horizontal directional drill (HDD) installation is for a 20-inch diameter pipeline that traverses under Biddle Drive, Devon Drive, Valleyview Drive and Shoen Road in Uwchlan and West Whiteland Townships, Chester County, Pennsylvania, is in accordance with terms and conditions item 2 referencing Exhibit "2" of the Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L (Order), August 10, 2017. Exhibit "2" provides the rationale of HDD re-evaluations which includes a variety of factors for identifying HDDs for reevaluation, not one which was dispositive. These factors include proximity to public and private water supplies, proximity to natural features (e.g. streams and wetlands) and the value of those natural features, proximity to man-made features (e.g. underground utilities and pipelines, railroad crossings), known impacts to rock from historic blasting, geologic conditions, depth of cover, and occurrence of inadvertent returns (IRs).

The installation of the 20-inch diameter pipeline using HDD was initiated June 6, 2017 and was suspended July 13, 2017 due to a groundwater discharge that affected water levels in private water wells in the surrounding community. In the fall of 2017, SPLP chose to install the 16-inch pipe using the permitted 20-inch line profiles. The 16-inch HDD at S3-0360, using the originally permitted 20-inch profile was completed on September 28, 2020. Thus, the requirement under the Order to prepare this re-evaluation on the second pipe installed at S3-0360 is for installation of the 20-inch line using the originally permitted 16-inch profile.

The 20-inch pipeline HDD is referred to herein as HDD S3-0360.

PIPE INFORMATION

20-Inch: 0.456 wall thickness; X-65

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

Ductility of the steel used for pipelines is determined by the percentage of carbon within the steel. Generally, steel pipe is categorized as either "low carbon" having less than 0.3% carbon content within the steel, or "high carbon" having greater than 3% carbon within the steel. As the carbon content within the steel used to make the pipe increases, the flexibility (ductility) of the pipe is decreased. The X65 20-inch pipe utilized on the Mariner project is a low carbon (high ductility) steel pipe.

The design of an HDD profile accounts for the free stress radius of the pipeline segment to be pulled into the drilled entry, through the entry radius of curvature, at maximum horizontal depth, and out the exit radius leaving maximum depth, to exit. As such, 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 the pilot tool will drift in orientation because the cutting tool will proceed with less force into softer material due to natural variances in hardness of the materials, whether soils or bedrock. Steering of the pilot tool is used to correct drifting as it occurs. As a result of this natural drifting within the pilot hole, the entire length of the drilled pilot hole is assessed for stress allowances at three (3) joint intervals before reaming of the annulus is permitted. If errors during pilot drilling or reaming occur and a point is identified that would breach the pipe stress allowance, then the use of an over-reamed annulus is assessed to rectify the breach in stress allowance. In cases where an over-reamed annulus will not correct the stress problem, the HDD has to be re-drilled.

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Specifics for the original permitted 20-inch HDD plan and profile are discussed in the original permitted HDD design summary below. Specifics for the revised 20-Inch HDD plan and profile are discussed in the Redesigned Horizontal Directional Drill Design Summary at the end of this report.

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: (16-INCH, REV. 10-07-16)

- Horizontal length: 2,880 foot (ft)
- Entry/Exit angle: 10 degrees
- Maximum Depth of cover: 184 ft
- Pipe design radius: 1,600 ft

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

ROOT CAUSE FOR AFFECTING LOCAL GROUNDWATER LEVELS DURING INITIAL HDD CONSTRUCTION ACTIVITY

The pilot hole for the 20-inch line at HDD S3-0360 began on June 6, 2017. The pilot, extending northwest into the Chickies Quartzite of North Valley Hills, began producing water at a horizontal distance of 747 feet from the southeast entry/exit on June 22, 2017. By June 28th, the flow rate increased to 70 gallons per minute (gpm) after the pilot hole was at a horizontal distance of 1,287 feet. The groundwater discharge was not occurring during times of active drilling but occurred in the evening during periods when drilling was not being conducted. The discharge diminished to 40 gpm the evening of June 29th. On July 3rd, residents at 118 and 120 Township Line Road complained of cloudy well water. The pilot bore was plugged with bore grout July 6th in an attempt to seal fractures, and was then re-drilled. Groundwater continued to flow each evening when drilling activity was suspended. On July 12, 2017, the pilot bore reached a drill distance of 1,575 feet, and was producing 50 gpm of groundwater in the evening when drilling was suspended. The borehole was sealed with 30 cubic yards of bentonite/cement grout on July 13, 2017 and the rig was demobilized. Groundwater flow from the pilot hole ceased or had been greatly reduced until October 2019 when pilot drilling was reinitiated.

Owners of residential wells surrounding the HDD alignment reported loss of pressure and increased turbidity. The loss in pressure resulted from a lowering of the water table in the local aquifer in association with the groundwater discharge. Advancement of the pilot hole created a preferred pathway for southeasterly groundwater to flow from the fractured bedrock aquifer to Chester Valley, where it was allowed to infiltrate. Modelling of the hydrogeologic system suggests that water table lowering was greatest near the pilot bore and would have been limited to within approximately 1,000 feet of the pilot hole. The turbidity in well water that was reported was most likely caused by mobilization of sediment that commonly collects at the bottom of bedrock wells over time in response to the local lowering the water table and pumping levels in the wells.

In response to this effect on local groundwater levels, SPLP offered all property owners, with private water wells on parcels, or parts of parcels, occurring inside the 450-foot limit of the HDD with public water service. This resulted in the identification of 35 properties with private water supply wells, all of which accepted SPLP's offer of public water connection.

Drilling for the 16-inch line at HDD S3-0360 was initiated on October 9, 2019. The pilot hole was advanced from the southeast entry/exit point at Shoen Road toward the northwest entry/exit point at Devon Drive. Beginning on October 17, 2019, once the pilot hole had advanced over 1,200 feet, groundwater was observed flowing back into the southeast entry/exit pit at varying flow rates ranging from 1 to 60 gpm. Lower flow rates were observed during advancement of the drilling tools, and increased groundwater flowback was observed as drill tooling was removed (tripping out) and during drilling down times. On October 18,

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2019, all tooling was removed to add a new steering assembly. The new assembly and tooling were tripped back in to the bottom of the borehole (rock face) to inject a heavy mud plug, (i.e. a plug of drilling mud thickened with a higher bentonite-to-water ratio). Following injection of the heavy mud plug, the discharge of groundwater ceased. Before drilling operations were shut down, the pilot had been advanced to 1,533 feet of measured borehole distance (or 1,514 feet horizontal distance) from the southeast entry/exit point. As per the Terms and Conditions of Paragraph 3.h. of the Consent Order Agreement between Sunoco Pipeline LP (SPLP) and the Department dated July 24, 2017, drilling operations at HDD S3-0360-16 ceased until a Restart Report could be developed and approved. The final Restart Report was submitted to the Department in January 2020 and was approved by the Department on July 2, 2020. One aspect of the Restart Report was a Seep Monitoring Work Plan designed to monitor the nature of a potential discharge at the seep north of Shoen Road and plan for proper management of discharge fluids.

Pilot drilling for HDD S3-0360-16 was resumed on July 14, 2020, from the northwest entry/exit. Normal drilling conditions prevailed as the pilot hole was advanced to approximately 1,560 feet through August 6, 2020. At that point, drilling from the northwest was suspended, waiting for the pilot intercept boring to connect from the southeast. From July 14, 2020 to August 6, 2020, the seep north of Shoen Road flowed clear at a constant rate of between approximately 1.0 to 2.5 gallons per minute (gpm).

Advancement of the intercept pilot from the southeast consisted of drilling out the former pilot hole, which was partially filled with grout cement. From August 1, 2020, to August 8, 2020, the intercept pilot was advanced with little resistance and consisted of tripping in tooling to a horizontal distance of approximately 1,916 feet. At this position, the northwest section of pilot hole and the southeast section of pilot hole overlapped by approximately 648 feet without connecting. Planned further advance of the southeast section of pilot hole would consist of drilling through fresh bedrock and steering the southeast section of pilot hole to intercept with the northwest section of the pilot hole.

The cutting of a new pilot hole from the southeast was initiated on August 6, 2020 and continued through August 7, 2020 without incident. During that time, the HDD was advanced to 1,822 feet northwest from the southeast entry/exit, and the seep on the north side of Shoen Road maintained a low flow and was clear. Approximately 94 feet of hole was advanced to a horizontal distance of 1,916 feet on August 8, 2020 during which time a change in the flow and quality of the seep was observed. In response, SPLP decided to voluntarily suspend operations to assess conditions. The groundwater discharge from the pilot borehole at the southeast entry/exit began again on August 10, 2020.

As per the Seep Monitoring Work Plan, water from the seep was field tested for pH, specific conductance and color. These measurements did not indicate an impact from drilling fluids. If they had, a sample would have been sent for laboratory analysis of bentonite clay minerals, to verify presence of drilling fluid. Further HDD construction was temporarily suspended by the Department. In response, SPLP issued a Restart Report on August 17, 2020 and drilling was allowed to resume on August 25, 2020.

The groundwater discharge at the southeast entry/exit varied between 25 and 50 gpm during times of suspended drilling activity. An approach to grouting groundwater production zones was provided in the Restart Report that included grouting the water-bearing horizon(s) encountered from the southeast (Shoen Road) drill entry location, targeting water-bearing horizons encountered where groundwater flowback was first observed during drilling, and targeting other locations within the HDD S3-0360 pathway which have been determined to produce "significant" rates of groundwater flow for both pilot-hole and reaming activities, prior to final pipe-pull operations.

The reason for minimizing the groundwater discharge as construction proceeded was based on one remaining active residential well located at 158 Valleyview Drive. Just prior to restart of the HDD in July 2020; however, the landowner agreed to, and SPLP arranged for, hook up to public water. As such, the procedure of grouting water-bearing zones as the pilot hole was advanced was no longer necessary.

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On August 29, 2020, all seepage from the seep area stopped and no discharge was observed for the remainder of 16-inch HDD construction. HDD construction of the 16-line proceeded, without incident, until pulling of the pipe and grouting the annulus, both of which were completed by October 3, 2020.

Grouting of the southeast section of HDD annulus occurred on September 28, 2020. Grouting of the northwest section of HDD annulus occurred on October 2 and 3, 2020. On October 3rd, approximately 50 gallons of grout mixed with groundwater emerged five feet west of the original seep location. The discharge flowed through the existing seep sand bag containment, approximately 100 feet within the existing road ditch and was contained by a second existing sand bag containment. At the request of the Department, an additional sandbag containment was installed down gradient within the road ditch. The grout/groundwater mixture was recovered using sump pumps, hand tools, water pressure sprayers and vac trucks. After cleanup, a slightly turbid groundwater discharge continued to flow from the seep at approximately 1 to 2 gpm. This discharge is being addressed as per the protocol established in the Seep Monitoring Work Plan. To date the seep water has shown an elevated pH representative of the grout. As such, the discharge waters are being contained and managed while the pH drops to level suitable for the protection of aquatic life. An incident report describing the grout / groundwater mixture discharge was issued to the Department on October 5, 2020.

Monitoring wells were installed at five of the residential properties where public water hook-ups were provided to examine local groundwater levels during HDD construction (see Attachment 1). It is important to note that water levels in the monitoring wells responded to drilling activity. During periods of active drilling, the water levels declined in response to a groundwater discharge at the southeast entry/exit. The southeast entry/exit on the profiles for both the 16-inch pipe and 20-inch pipe is located at a lower elevation than the background water table, over approximately 2,450 feet of the 2,857-foot drill path (horizontal distance). As such, completion of the pilot borings for the 16-inch line created a groundwater discharge and SPLP expects similar conditions during construction of the 20-inch line. In October 2019, drilling of the pilot bore for the 16-inch line was suspended and a grout plug was installed at the southeast end of the pilot hole, causing a water level recovery. Drilling for the 16-inch HDD restarted in July 2020. The recovered water levels were maintained until approximately August 21, 2020, when the groundwater discharge began again causing water levels to decline, in response to pilot hole drilling. Construction of the 16-inch HDD, including pulling of the pipe and grouting of annulus at both end sections of the HDD, was completed in early October 2020. In response to the grouting, the groundwater discharge was reduced to approximately one gpm and the water levels in the five local monitoring wells began to rebound (see Section 2.3.4, Attachment 1). The water levels are continuing to rebound as of the submittal of this report. A similar decline in water levels, followed by recovery is expected from drilling and grouting of the completed 20-inch line.

GEOLOGIC ANALYSIS

Based on published mapping, moving southeast to northwest, the HDD profile transects the Harpers Formation and extends partially into the Chickies Formation. The Harpers Formation is a relatively thin (300 to 1,000 feet thick) unit composed of phyllite and micaceous to argillaceous quartzite. The Chickies Formation is composed predominantly of quartzite, with a basal conglomerate and interbeds of slate and phyllite. The valley floor, southeast of the southeast entry/exit point is composed of carbonates, including the Ledger Dolomite. The structure in this area is complex and the formation contacts, as shown in publications, may lack accuracy.

Published geologic maps show a major left-lateral fault within the Chickies Formation, the Ketch (Gap) Fault, passes through the HDD S3-360 path along Township Line Road at approximately Station 17+10 on the proposed profile. In addition, the alignment transects four mapped fracture traces along the northwest half of the profile. All four fracture traces trend north-northeast and the one furthest to the southeast intersects the Ketch Fault along the alignment. The other three fracture traces cross the alignment at

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approximately Stations 22+00, 24+20, and 26+10. These locations are potential zones of fracture concentration, weakness in bedrock, and preferential pathways for fluid migration (drilling fluid or groundwater). The southern end of a fifth north-northeast trending fracture trace is mapped within the alignment right-of-way (ROW) near Station 7+80 and a north-northeast trending lineament is mapped due east and south of the southeast entry/exit (see Attachment 1).

There is no known or mapped karst geology, or sinkholes along the HDD. Karst features associated with the Ledger Dolomite occur due south of the southeast entry/exit.

Deep mining has not been identified beneath or in the area of the HDD alignment.

Rettew performed a geophysical survey in February 2020, covering approximately 400 feet of the southeast end of the proposed alignment for HDD S3-0360. Three different geophysical techniques were utilized to detect and delineate subsurface voids or low-density zones and provide a top of competent bedrock profile; including microgravity, seismic refraction and multi-spectral analysis (MASW), and electrical resistivity (ERI). The seismic refraction and MASW data indicate there is a soil mantle approximately 25 to 35 feet thick over the survey lines and a potential zone of bedrock fracturing at approximately Stations 3+40 on the proposed profile. The ERI profiles show deeper, electrically more conductive anomalies, below an inferred top-of-rock at approximately Stations 0+80, 3+05 and 4+10 on the proposed profile that may represent water- or clay-bearing fractures or weathered seams within bedrock. A zone of lower resistivities was reported occurring from approximately Station 0+50 to 1+00 extending from approximately where the proposed profile may emerge from rock near Shoen Road – where groundwater seepage has been observed.

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

The source of groundwater that occurs within the local bedrock aquifer at HDD S3-0360-20 is direct recharge from precipitation and regional groundwater flow from the northwest. Most of the local groundwater occurs and moves within secondary porosity created by fractures, bedding plane partings, and faults. At some locations, groundwater may fully saturate overlying unconsolidated materials or occur as a perched zone above the water table. Geotechnical boring B6-4W indicates unconsolidated weathered bedrock can be over 130 feet thick in the area of the southeast entry/exit.

Information collected during project related background sampling of 35 domestic wells showed the total depths for 16 of the wells range from 65 to 480 ft below ground surface (bgs) and the water level in five wells ranged from 22 to 260 ft bgs.

A continuous water level monitoring system with remote access has been established at five former residential wells in the area to assess pre-drill conditions and monitor for potential water level impacts during drilling of both the 16-inch and 20-inch HDD at S3-0360. Monitoring of the groundwater levels began in December 2017 and the data have been downloaded weekly. A real-time data logger was installed in the 160 Valleyview Drive monitoring well on October 18, 2019. The water level monitoring data show normal water levels generally fluctuate between 405 and 430 ft amsl.

The surface elevation of the southeastern entry/exit on the proposed profile for the 20-inch line is 353 ft above mean sea level (amsl) and the elevation of the northwestern exit/entry is 576 ft amsl. The proposed profile has a bottom elevation of approximately 279 ft amsl. Water table elevations in the area fluctuate between approximately 405 and 430 ft amsl. Given these relationships, the profile creates a preferential pathway for groundwater discharge that requires mitigation. This type of discharge occurred during initial attempts to install the 16-inch line, affected local water levels and created turbidity in a few of the domestic supply wells. As such, SPLP offered a connection to the local public water supply provided by Aqua

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Pennsylvania to the 35 residents with private water supplies within 450 ft of the HDD alignment, and each resident has accepted the offer.

A naturally occurring zone of groundwater seepage occurs along the HDD alignment, north of Shoen Road. This seepage was investigated by Skelly and Loy (2018 with respect to HDD construction activities). The study concluded that the seep is a persistent hydrologic condition that predates the HDD activities. The primary, toe-of-slope seep was described as a low-flow, intermittent source of hydrology to the area, which intercepts upgradient less-regular seasonal/ephemeral seeps and surface water flows. A seep monitoring program established for the 16-inch line HDD construction will be maintained through construction of the 20-inch line.

ADJACENT FEATURES ANALYSIS

This HDD location is due west of PA Rout 100, approximately one mile northwest of the Exton Mall, and has sections within Uwchlan and West Whiteland Townships, in Chester County, Pennsylvania. This HDD location is set within suburban residential development and, moving northwest to southeast crosses Devon Drive, Biddle Drive (or Township Line Road), Valleyview Drive and Shoen Road.

The HDD alignment crosses no Regulated Waters of the Commonwealth.

SPLP has identified all landowners with property located within 450 ft of the HDD alignment. There are one hundred (100) individual landowners with properties 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 DEP's Central Office.

SPLP has received one hundred responses from the individual landowners. Of these, thirty-five (35) confirmed the use of a private water well, and the remaining landowners verified the use of public water supply. All thirty-five (35) of the private water wells were located and tested. All landowners have accepted SPLP's offer of public water service in response to the groundwater discharge.

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

ALTERNATIVES ANALYSIS

As required by the Order, the reanalysis of HDD S3-0360 includes an evaluation of open cut alternatives, other trenchless technologies, and a re-route analysis. As part of the PADEP Chapter 105 permit process for the Mariner II East Project, SPLP developed and submitted for review a project-wide Alternatives Analysis. During the development and siting of the Project, SPLP considered several different routings, locations, and designs to determine whether there was a practicable alternative to the proposed impact. SPLP performed this determination through a sequential review of routes and design techniques, which concluded with an alternative that has the least environmental impacts, taking into consideration cost, existing technology, and logistics. The baseline route provided for the pipeline construction was to cross every wetland and stream on the project by open cut construction procedures. The Alternatives Analysis submitted to PADEP conceptually analyzed the potential feasibility of any alternative to baseline route

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trenched resource crossings (e.g., reroute, conventional bore, HDD). The decision-making processes for selection of the HDD instead of an open cut crossing methodology is discussed thoroughly in the submitted alternatives analysis and was an important part of the overall PADEP approval of HDD plans as currently permitted. As described below, the open cut trenchless technology and re-route analyses have confirmed the conclusions reached in the previously submitted Alternatives Analysis.

Open-cut Analysis

SPLP specifications require a minimum of 48-inches of cover over the installed pipelines. The Pennsylvania Department of Transportation (PennDOT) cover requirements under public roadways is 60-inches of cover.

The entire HDD profile passes under twenty-two (22) residential properties, five (5) roadways, and ten (10) buried utilities owned by other entities.

Although technically feasible, this alternative is not practicable. The direct effects to the roadways, disturbance to residences, and disruption of traffic that would occur during open cut construction are significantly more onerous than the potential occurrence of a groundwater discharge (which has already been mitigated by providing public water service to potentially affected residences) or IRs that can be easily managed and did not occur during installation of the 16-inch line. Therefore, it is SPLP's conclusion that an HDD crossing of this area is still the preferred methodology.

Use of Conventional Auger Bore

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

Based on experience gained during construction of the Mariner II Pipeline project, conventional auger bores should be limited to approximately 200 linear ft at a time, or less, varying by the underlying substrate. Conventional auger bores attempted at longer distances have, at times, had alignment drift and elevation deflections, which have complicated installation.

The horizontal length of this crossing (2,827 ft) is beyond the technically practicable limits of a conventional auger bore to complete regardless of substrate or topographic conditions. This length of crossing is beyond the technically practicable limits of a conventional auger bore.

A combined open-cut and conventional auger bore approach would involve multiple sections of each installation method. The open-cut sections would be the largest percentage of the installation along the HDD S3-0360 alignment and the open-cut method is not a favorable alternative as described in the previous section. Multiple setup-entry pits for bores under Biddle Drive, Devon Drive, Valleyview Drive and Shoen Road would occur on residential properties creating unwanted community disturbance and attractive nuisances, especially to younger residents. As a result, SPLP concludes that an HDD crossing of this area remains the preferred methodology.

FlexBor Analysis

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

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Direct Pipe Bore Analysis

The direct pipe bore method is also known as "microtunneling". This method of pipeline installation is a remote-controlled, continuously supported pipe jacking method. During the direct pipe installation, operations are managed by an operator in an aboveground 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 drill stem. As a result, there is minimal annular space, which minimizes the potential for drilling fluid returns or the production of groundwater returning back to the point of entry. Unlike an HDD, this technology has no steering capability. Changes in direction are made by adjusting the cutting angle of the tool face, which results in a maximum of 4 degrees radius between the point of entry and exit.

SPLP's construction contractors have successfully completed two Direct Pipe Bore installations during the ME II, Pennsylvania Pipeline Project; one at the Frankston Branch of the Juniata River in Blair County and the other at the Route 100 crossing in Chester County. At these locations, Direct Pipe Bore setups were accomplished within relatively flat areas and the drills were relatively short (950 and 853 feet), as compared to standard HDD technology installations.

Because steering need only occur in one dimension at HDD S3-0360, the use of Direct Pipe technology along the HDD S3-0360 alignment is theoretically feasible. However, the length of the crossing would provide an extremely low chance of success using the Direct Pipe method. In addition, the entry pit dimensions to employ this method are larger than what is required for a conventional bore or HDD. The entry pit could not be closed until the bore was completed and the pipe segments welded together. Due to the length of the bore and impact on residential property, SPLP concludes that the Direct Bore technology is not practicable, and an HDD crossing of this area remains the preferred methodology.

Re-Route Analysis

The pipeline route as currently permitted follows an existing SPLP easement under twenty-two (22) residential properties, five (5) roadways, and ten (10) buried utilities owned by other entities. This alignment bypasses or avoids directly impacting Biddle Drive, Devon Drive, Valleyview Drive and Shoen Road; twenty-two (22) residential properties; and ten (10) buried utilities.

The general route of the Mariner II project in this area of the state is from northwest to the southeast.

There are no existing utility corridors to the northeast or southwest that provide a practical alternative route. Any alternate route considered to the northeast or southwest would require the clearing of a new "greenfield" corridor through existing woodlands, increasing the number of stream crossings, and possibly encroaching on additional private residences before it could rejoin the current route.

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

This re-route analysis conducted for the Biddle Drive HDD confirms the conclusions reached in the previously submitted alternatives analysis.

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HORIZONTAL DIRECTIONAL DRILL REDESIGN

SPLP has considered geologic data and the events during installation of the 16-inch pipeline and has redesigned the 20-inch HDD profile. A summary of the redesign factors is provided below. The original and redesigned HDD plan and profile for the 20-inch pipeline are provided in Attachment 2.

Revised Horizontal Directional Drill Design Summary: 20-inch

- Horizontal length: 2,827 feet (ft)
- Entry/Exit angles: 12 degrees
- Maximum depth of cover: 223 ft
- Pipe design radius: 2,400 ft

The redesigned HDD profile have maximized the angle of entry and exit to reduce the potential for IRs. The primary environmental issue that occurred during partial drilling for the 16-inch line was the creation of a groundwater discharge that lowered the local water table and affected local private water supplies. That type of impact has been addressed by connecting thirty-five (35) residences to public water. Regardless, a long-term lowering of the local water table in association with either the 16-inch or 20-inch HDDs or both will be ameliorated by construction elements incorporated into the drilling plan as described in the Conclusion below. The remaining design factors are below the pipeline stress allowances for all points of analysis.

CONCLUSION

Based on the original and revised profile for the 20-inch HDD, the revised HDD profile increases the depth in bedrock for a majority of the HDD profile; therefore, adjustments to the plan of construction for the 20-inch pipeline represent a reduced risk of IRs. The revised HDD design for the 20-inch line presents some risk of environmental impact from construction in the form of a groundwater discharge that temporarily lowers the groundwater level in the local aquifer. SPLP has mitigated the potential effect of lowering groundwater levels on private water supplies by replacing the private water supplies within 450 feet of the HDD alignment with public water. The Department approved Restart Report for the recently completed 16-inch line contained provisions for protection of the local aquifer including a robust water level monitoring system and provisions for monitoring the volume and quality of natural seepage discharging on the embankment due north of Schoen Road. The seep monitoring program is designed to ensure proper management of impacted seep water. These same monitoring programs will be maintained during construction of the 20-inch line. Upon the start of the 20-inch HDD, SPLP will employ the following HDD best management practices and other site-specific practices:

- SPLP will mandate annular pressure monitoring during the drilling of the pilot hole, which assists in immediate identification of pressure changes indicative of loss of return flows or over pressurization of the annulus, to help manage development pressures that can induce an IR;
- SPLP inspectors will ensure that an appropriate diameter pilot tool, relative to the diameter of the drilling pipeline, is used to ensure adequate “annulus spacing” around the drilling pipeline exits to allow good return flows during the pilot drilling;
- A primary pilot hole drilled from one end of the HDD and intercept pilot hole drilled from the other end of the HDD will be used, as needed, to reduce groundwater flowback and manage annular pressures.

BIDDLE DRIVE CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0199.000-RD
(SPLP HDD No. S3-0360)

- SPLP's contractor will implement short-tripping of the reaming tools, as indicated by monitoring of return flows, to ensure an open annulus is maintained to manage the potential inducement of IRs;
- SPLP's contractor will employ thickened drilling mud during the entire drilling procedure.
- SPLP will continue to monitor the groundwater levels in the area using the groundwater monitoring well network.
- Monitoring of the seep discharge north of Shoen Road will ensure that any turbid water that might discharge will be sampled (if necessary), captured and controlled using Best Management Practices, without interruption of drilling processes.
- Once the pipe-pull has been completed, the annulus will be grouted in the following manner:
 - The intention is to grout as much of the open annular space as practicable.
 - Small diameter pipe will be inserted from the southeast/Shoen Road entry location (which is the low side). The insertion will progress until refusal or until the lowest elevation of the profile is attained at approximately 800 feet (horizontally) from the southeast end. Grout will then be injected into the hole until refusal or until grout appears at the entry or exit side.
 - After the grout has time to set up/cure and creates a "plug" on the low side, the same process will be completed from the northwest/exit (Devon Drive) location. The insertion will progress until refusal, and then grout will then be injected into the hole until refusal or until grout appears at the entry or exit side.

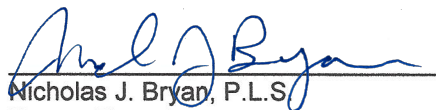
In summary, groundwater conditions will be monitored while implementing a series of controls aimed at managing the groundwater discharge created by the HDD borehole annulus. Upon completion of the drilling of the borehole and pulling of the pipe, the borehole annulus will be grouted to the extent practicable. Based on previous experience, groundwater level recovery is anticipated in response to grouting of the HDD annulus.

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PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0199.000-RD
(SPLP HDD No. S3-0360)

FEASIBILITY DETERMINATION


Based on the information reviewed by the Professional Geologists, Professional Engineers, and HDD specialists, the HDD Reevaluation Team's opinion is that the proposed HDD design and implementation of the management measures contained within this re-evaluation report will minimize the risk of a water resource impact from groundwater discharge or IRs.

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

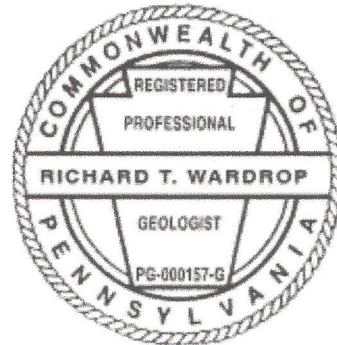

Nicholas J. Bryan, P.L.S.
Energy Transfer
Sr. Director – E&C Environmental
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10/8/2020
Date


Pertaining to the practice of geology


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Lead Hydrogeologist

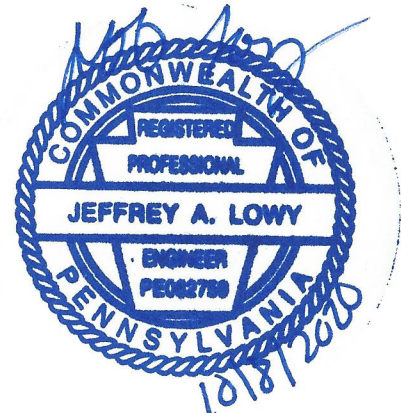
10/8/2020
Date



Pertaining to the pipeline stress and HDD geometry


Jeffrey A. Lowy, P.E.
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Rooney Engineering, Inc.
Civil Engineer

10/18/2020
Date



**BIDDLE DRIVE CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0199.000-RD
(SPLP HDD No. S3-0360)**

**ATTACHMENT 1
GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT**



HDD HYDROGEOLOGIC REEVALUATION REPORT

**Mariner East II
Spread 6
S3-0360
Devon Drive - Biddle Drive – Shoen Road
West Whiteland and Uwchlan Townships, Chester County, Pennsylvania**

Prepared for:

Sunoco Pipeline, L.P.

Prepared by:

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

October 2020



HDD HYDROGEOLOGIC REEVALUTION REPORT

**Mariner East II
Spread 6
S3-0360
Devon Drive - Biddle Drive – Shoen Road
Uwchlan and West Whiteland Townships, Chester County, Pennsylvania**

October 2020

Prepared for:

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

Prepared by:

A handwritten signature in blue ink that reads "Richard T. Wardrop".

Richard T. Wardrop, P.G.
Lead Hydrogeologist

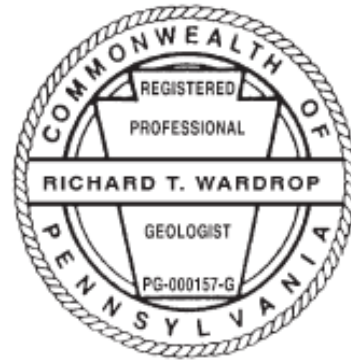
Reviewed by:

A handwritten signature in blue ink that reads "David J. Demko".

David J. Demko, P.G.
Vice President, Program Manager

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

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



October 8, 2020

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

Date

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FIGURES

- Figure 1. Site Location Map
- Figure 2. Site Geologic Map
- Figure 3. Fracture Trace Map
- Figure 4. Direction of Groundwater Flow and Monitoring Well Locations
- Figure 5. Residential Wells Replaced with Public Water Hookups
- Figure 6. Groundwater Levels

ATTACHMENTS

- Attachment A. Permitted and Proposed Plan and Profiles
- Attachment B. Geotechnical Boring Reports
- Attachment C. Skelly & Loy, Inc. Seep Investigation Memorandum
- Attachment D. Rettew Geophysical Survey Report

1.0 INTRODUCTION

Sunoco Pipeline, L.P., (SPLP) retained Groundwater & Environmental Services, Inc. (GES) to prepare HDD Hydrogeologic Reevaluation Reports (HRRs) for horizontal directional drills (HDDs) listed on Exhibit 2 of Stipulated Order EHB Docket No. 2017-009-L between SPLP and the Pennsylvania Department of Environmental Protection (Department) signed August 10, 2017. This report discusses the hydrogeologic reevaluation for the 20-inch line at HDD S3-0360, hereinafter referred to as HDD S3-0360. HDD S3-0360 is listed on Exhibit 2 due to a groundwater discharge that affected the water levels in local private water supply wells during an initial attempt to construct of HDD S3-0360 in July 2017. As a result of this discharge, public water service was provided to 35 residents in the area of the HDD. The alignment for HDD S3-0360 is located between Devon Drive in Uwchlan Township and Shoen Road in West Whiteland Township, Chester County, Pennsylvania. The discussion presented in this report is based on an alignment and profile developed by Tetra Tech/Rooney labeled HDD S3-0360-16, dated October 7, 2016 (permitted profile). This plan and profile (P&P) was originally developed for the 16-inch line but is now being used for the 20-inch line, as SPLP chose, in the fall of 2017, to use the 20-inch alignments in Spread 6 to install the 16-inch line, first, followed by installation of the 20-inch line using the alignments originally intended for the 16-inch line. GES has also been provided a proposed alternative profile labeled HDD S3-0360, revised November 15, 2017 (proposed profile, see **Attachment A**). For the purpose of this assessment, GES utilized both the permitted P&P and proposed P&P to evaluate the hydrogeologic conditions at HDD S3-0360.

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

A map depicting the location of the HDD with topographic information for the surrounding area is presented as **Figure 1**.

This report presents the following information:

- Geologic and hydrogeologic characteristics in the area of HDD S3-0360;
- Summaries of studies performed pertinent to reevaluation, including fracture trace analysis and geotechnical borings;
- A site conceptual model; and
- A reevaluation summary with conclusions.

The contents of this report were developed from interpretation of published information, field observations, and related field studies. Site geotechnical boring programs were conducted by Tetra Tech in June 2015 and January 2016, then by Terracon Consultants, Inc. (Terracon) in August 2017. The Terracon borings were affiliated with HDD S3-0350 and HDD S3-0370, northwest and southeast of HDD S3-0360, respectively. Note that GES did not oversee or direct either geotechnical drilling program, including, but not limited to, the selection of number and location of borings, determination of surface elevations, target depths, observations of rock cores during drilling operations, or preparation of boring logs. The geotechnical reports, boring logs, and core photographs were generated by the two SPLP contractors. GES relied on these reports and incorporated their data into the general geologic and hydrogeologic framework for this hydrogeologic reevaluation report.

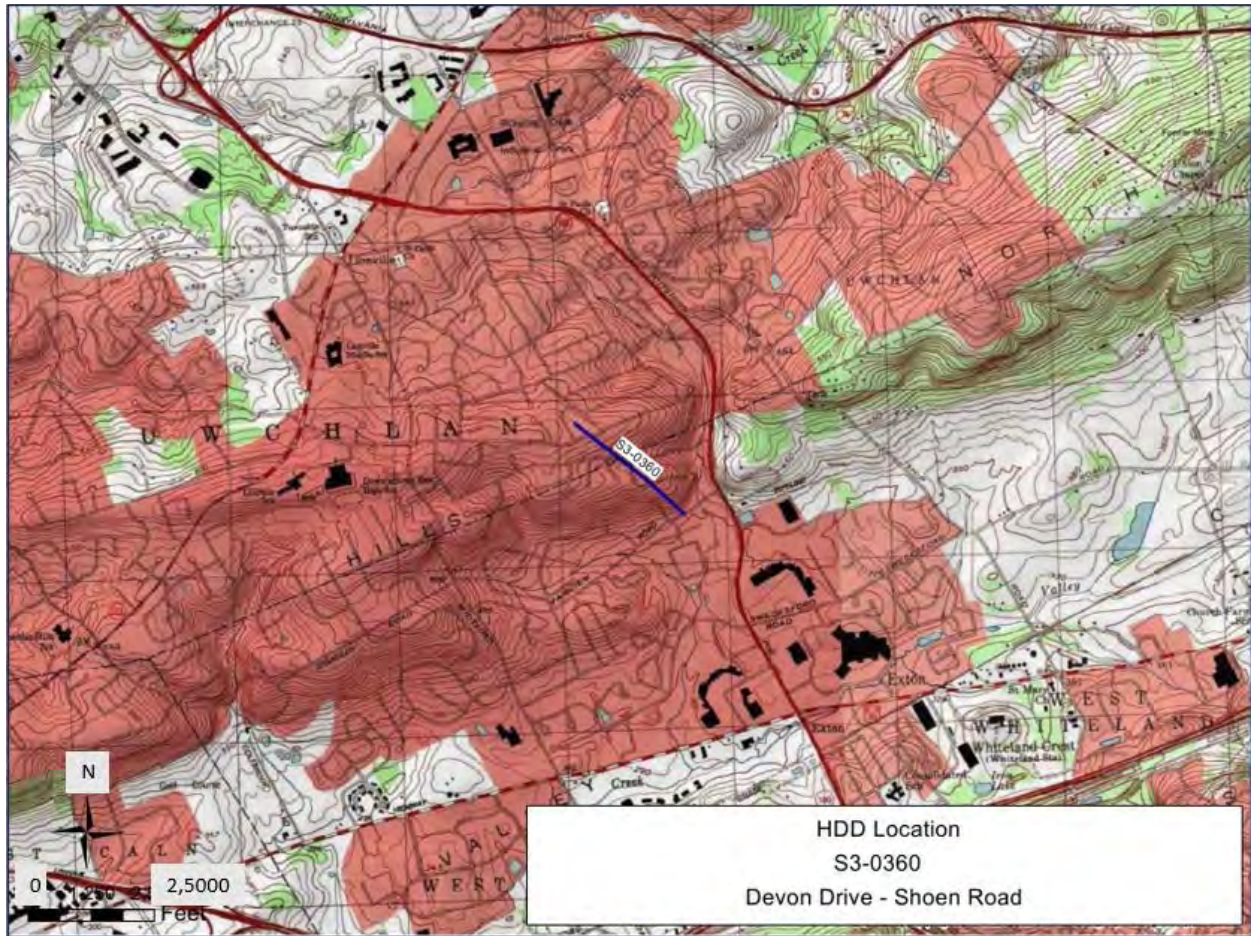


Figure 1. Site Location Map (modified from USGS 2017)

2.0 HDD GEOLOGY / HYDROGEOLOGY

2.1 Physiography

HDD S3-0360 is located within the Piedmont Uplands Section of the Piedmont Physiographic Province in Southeast Pennsylvania. The Piedmont Uplands Section is characterized by broad, rounded to flat-topped hills and shallow valleys with low to moderate topographic relief from 150 to 250 feet.

2.1.1 Topography

The topography along HDD S3-0360 consists of the prominent ridge named North Valley Hills. Chester Valley lies immediately to the south and is two miles wide at this location. The surrounding area is comprised of suburban residential and commercial properties (**Figure 1**).

The permitted profile for HDD S3-0360 dips ten degrees from the northwestern entry/exit, includes a horizontal central portion at an elevation of 318 feet above mean sea level (ft amsl), becomes concave turning upwards towards the southeastern entry/exit, and exits at ten degrees to land surface (see **Attachment A**). The surface elevation at the northwestern entry/exit is at approximately 575 ft amsl and is at approximately 353 ft amsl at the southeast entry/exit. The overall horizontal length of HDD S3-0360 for the permitted profile is 2,880 feet. The proposed profile prepared by Tetra Tech/Rooney (rev. 11/15/17) is slightly shorter and runs deeper than the permitted profile. The entry and exit angles are both at 12 degrees to achieve a lower horizontal central portion at an elevation of 279 ft amsl. The overall horizontal length of the proposed profile is 2,827 feet with northwestern and southeastern entry/exits at 576 and 353 ft amsl, respectively.

2.1.2 Hydrology

The nearest surface water body to HDD S3-0360 is Tributary 00274 of West Valley Creek. This tributary generally runs 1,500 feet east of the bore and passes 350 feet east of the southeastern entry/exit. A second stream, Tributary 00275 of West Valley Creek, lies approximately 1,000 feet southwest of the southeast entry/exit.

2.2 Geology

2.2.1 Soils

Surficial soils along the path of HDD S3-360 predominantly belong to the Edgmont Series, classified as fine-loamy, mixed, active, mesic Typic Hapludults (USDA NRCS WSS). These soils are generally characterized as a channery sandy loam with bedrock at 3.5 to 7 feet below ground surface (ft bgs). Soil borings conducted by Tetra Tech in June 2015 and January 2016 reported soils composed of quartz-rich sand, silty sand, and low-plasticity silts (see **Attachment B**).

2.2.2 Bedrock Lithology

Figure 2 is a map depicting site bedrock geology for the area surrounding HDD S3-0360 based on the work by Kochanov (2016). From southwest to northeast, the completed HDD will transect the Harpers Formation and extend partially into the Chickies Formation. The Harpers Formation is a relatively thin (300 to 1,000 feet thick) unit composed of phyllite and micaceous to argillaceous quartzite (Kochanov, 2016). The Chickies Formation is composed predominantly of quartzite, with a basal conglomerate and interbeds of slate and phyllite (Low et al., 2002). A contact between the Chickies and an undifferentiated granodioritic gneiss occurs approximately 800 feet north of the northwest exit/entry point. The valley floor, southeast of the southeast entry/exit point is composed of carbonates, including the Ledger Dolomite.

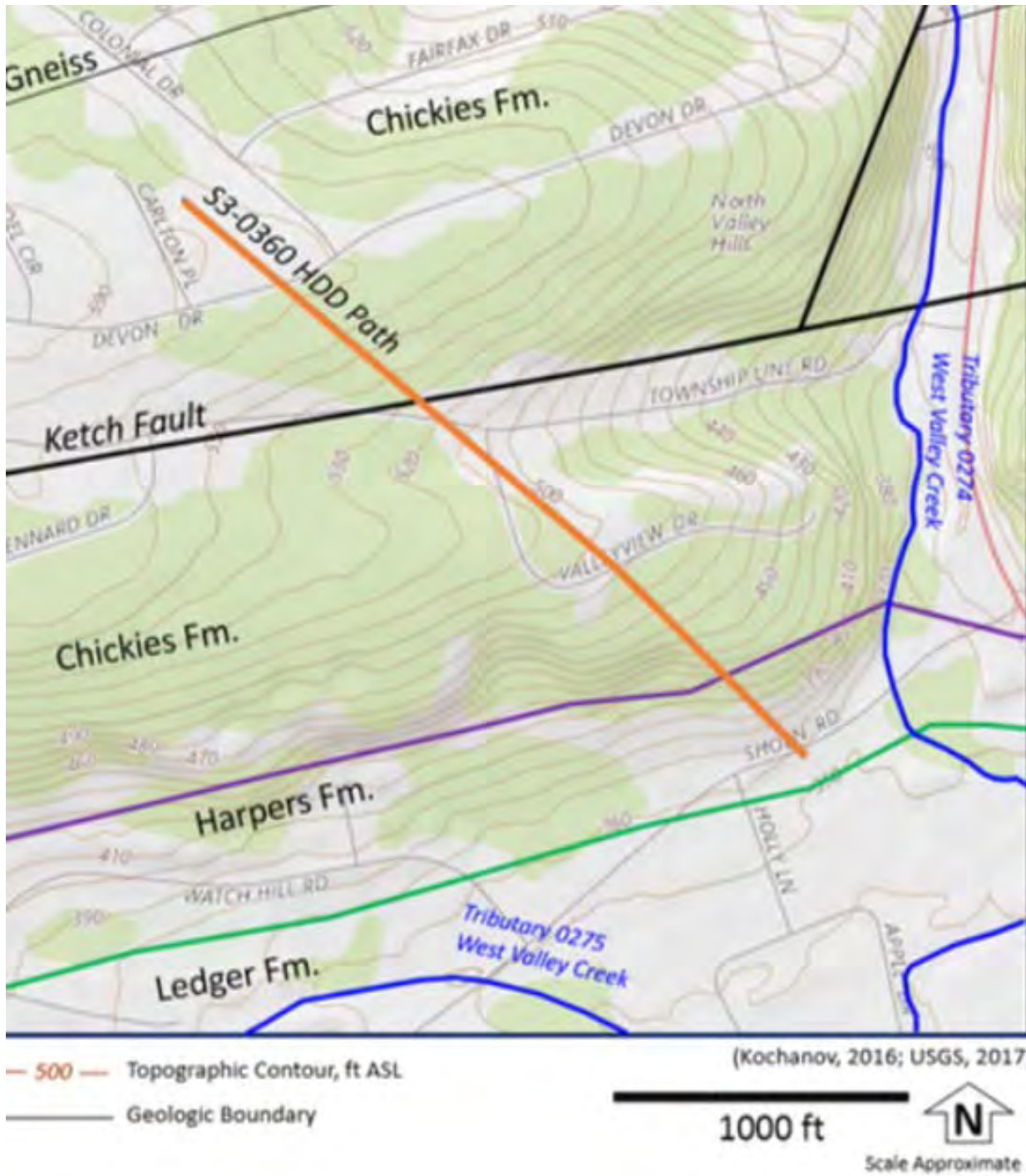


Figure 2. Site Geologic Map (modified from Kochanov, 2016)

2.2.3 Structure

The rocks of North Valley Hills have been folded then subjected to left-lateral shear. A major left-lateral fault, the Ketch (Gap) Fault, bisects the Chickies Formation and passes through the proposed HDD S3-360 alignment near Township Line Road.

2.2.4 Fracture Trace Analysis

Fracture trace analysis using high altitude aerial photography was performed for the area of interest to identify potential zones of bedrock weakness along the drill path. Fracture traces (one mile in length or less) and lineaments (greater than one mile in length) are the surficial expression on natural landscapes of vertical to near vertical zones of bedrock fracture concentration. Fracture trace analysis is partly subjective; therefore, every mapped fracture trace does not necessarily represent a zone of bedrock fracture concentration.

Fracture trace analysis for HDD S3-0360 was performed using aerial stereographic pairs flown in 1937. The proposed path of the proposed profile, mapped fracture traces, and a lineament are shown on **Figure 3** and on the proposed HDD profile in **Attachment A**. The alignment transects four of the mapped fracture traces and the Ketch Fault along the northwest half of the profile. All four fracture traces trend north-northeast and the one furthest to the southeast intersects the Ketch Fault along the HDD alignment at approximately Station 17+10. The other three fracture traces cross the alignment at approximately Stations 22+00, 24+20, and 26+10. These locations are potential zones of fracture concentration, weakness in bedrock, and preferential pathways for fluid migration (drilling fluid or groundwater). The southern end of a fifth, north-northeast trending fracture trace, is mapped within the alignment right-of-way (ROW) near Station 7+80 and a north-northeast trending lineament is mapped due east and south of the southeast entry/exit.

2.2.5 Karst

Karst features are not characteristic of either the Harpers or Chickies Formations. The contact between the Harpers Formation to the north and Ledger Formation to the south occurs at or due south of the southeast entry/exit for the HDD. The Ledger Formation is a massive, pure, coarsely crystalline dolomite that promotes development of karst features.

2.2.6 Mining

A quarry used to mine sand in the 19th Century is located 2,000 feet southwest of HDD S3-0360. Records do not indicate any other mining activity proximal to the alignment.

2.2.7 Rock Engineering Properties

The Chickies Formation rock properties are as follows (Geyer and Wilshusen, 1982):

- Moderately well- to well-bedded quartzite.
- Joints are moderately well developed, widely spaced, fairly regular, and open.
- Slow drilling rates due to many quartz veins that exceed 12 inches in width.

Unconfined compressive strength tests on two samples of Chickies Quartzite collected by Terracon from geotechnical boring B6-9E, near the northwestern entry/exit of HDD S3-0360, revealed that the quartzite is very hard, with values of 24,4438 and 28,480 psi (**Attachment B**).

The Harpers Formation rock properties are as follows (Geyer and Wilshusen, 1982):

- Crudely bedded quartzite.
- Joints are moderately poorly formed, moderate to closely spaced, irregular pattern, steeply dipping and open.
- Slow drilling rate due to many quartz veins that exceed 12 inches in width.

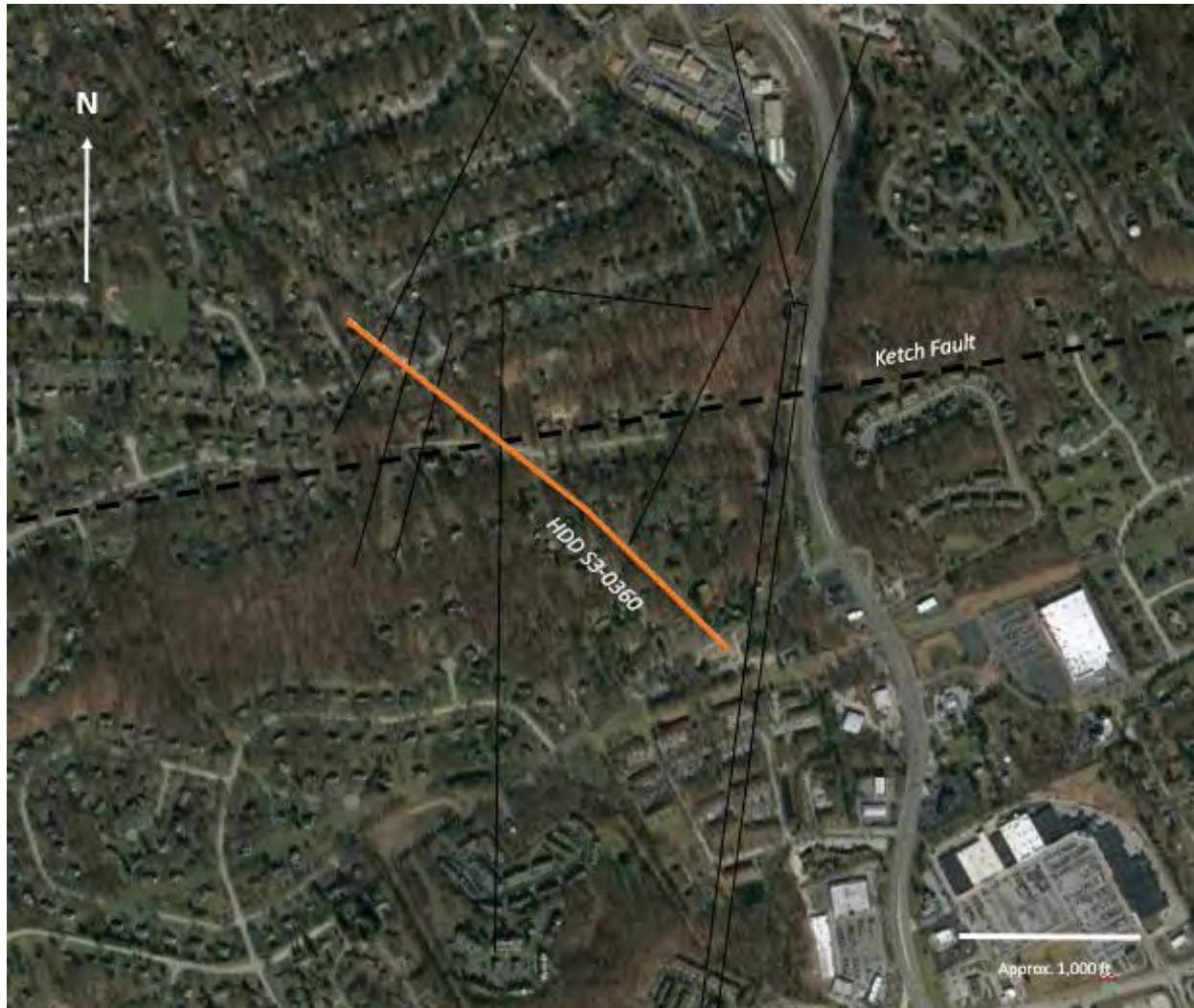


Figure 3. Fracture Trace Map (mod. from GoogleEarth™)

Note: Solid black lines indicate fracture traces and parallel lines east of HDD indicate a lineament.

2.2.8 Results of Geotechnical Borings

Original Borings

Four geotechnical borings (S3-0360 SB-01, SB-02, and SB-03; and S3-0350 SB-04) were drilled by Tetra Tech in June 2015 and January 2016 in support of the permitted HDD design. From southeast to northwest, SB-03, SB-02, SB-01 and SB-04 were located proximal to Stations – 0+15, 7+57, 17+12 and 29+83, respectively. Borings SB-01 and SB-03 were advanced to a depth of 30.0 ft bgs; boring SB-02 was advanced to a depth of 41 ft bgs; and SB-04 was advanced to a depth of 63.8 ft bgs.

The unconsolidated materials in the overburden at SB-03, SB-02 and SB-01 were generally comprised of sand and silt with little gravel to depths of 30, 24.5 and 30 feet, respectively. SB-02 was advanced beyond the unconsolidated materials into quartzite bedrock to a total depth of 41 feet. The core recoveries over this interval were 68 and 83 percent and the rock quality index (RQD) values were 47 and 56 percent. The unconsolidated material in the overburden at SB-04 were comprised of 63.8 feet of sand and silt. No rock cores were collected in SB-04.

Groundwater was not detected in SB-01, SB-02, and SB-03, although iron staining was noted (an indication of the seasonal high water table) in the soils sampled at SB-02 at a depth of 34 to 37 ft bgs. Groundwater was encountered in SB-04 at 30 ft bgs.

Recent Borings

B6-9E

Terracon boring B6-9E was advanced on August 28-31, 2017, adjacent to the northwest entry/exit point. The surface elevation is listed on the log as approximately 574 ft amsl and the boring was installed to a depth of 140 feet or approximate elevation 434 ft amsl. The lowest elevation for the proposed profile is 279 ft amsl. Unconsolidated overburden observed at B6-9E was comprised of silty sand before split-spoon refusal at 34 ft bgs and the start of coring. Bedrock cores were logged as felsic gneiss and quartzite. Recoveries throughout the core were low with all but two ranging from 0 to 45 percent. The five-foot core from 100 to 105 ft bgs had a recovery of 80 percent and the three-foot core from 112 to 115 ft bgs had a recovery of 100 percent. RQD values were low throughout the cores, ranging from 0 to 27 percent. The boring log indicates that groundwater was encountered at a depth of 25 ft bgs.

B6-4W

Boring B6-4W was advanced by Terracon on August 15-16, 2017, adjacent to the southeast entry/exit point. The surface elevation is listed on the log as approximately 353 ft amsl and the boring was installed to a depth of 130 feet or approximate elevation 223 ft amsl. The lowest elevation for the proposed profile is 279 ft amsl. Unconsolidated overburden observed at B6-4W was comprised of sandy clay with gravel and decomposed rock to the total depth of 130 ft bgs. Split spoon refusal was encountered at a depth of 96 ft bgs. Rock coring was performed from 96 to 110 ft bgs (elevation 257 to 243 ft amsl). Over this interval, core recovery was poor, ranging from 12.5 to 23 percent and rock quality RQD was zero percent. Terracon drill logs indicate the rock that was cored may have been a quartzite boulder. Split-spoon sampling was resumed from a depth to 110 ft bgs to the final depth of 130 ft bgs. Geologic mapping of this area indicates a geologic contact between the Harpers and Ledger Formations in the vicinity of the boring B6-4W. The Harpers Formation is a brownish gray phyllite and the Ledger Formation is a gray dolomite. However, these rock types were not observed in boring B6-4W. The log for B6-4W indicated that groundwater was not encountered.

OW-1

Monitoring well OW-1 was installed by Tetra Tech on June 21-23, 2017 to a depth of 120 ft bgs using the air rotary drilling method. This well was located along the western edge of the drill pad for the southeast entry/exit of HDD S3-0360-16. Unconsolidated overburden observed at OW-1 was comprised of silt and sandy silt to a depth of approximately 60 ft bgs where fractured limestone with soft zones was encountered to the bottom of the boring.

2.3 Hydrogeology

2.3.1 Occurrence of Groundwater

The source of groundwater that occurs within the local bedrock aquifer at HDD S3-0360-20 is direct recharge from precipitation and regional groundwater flow from the west. Most of the local groundwater occurs and moves within secondary porosity created by fractures, bedding plane partings, and faults. At some locations, groundwater may fully saturate overlying unconsolidated materials or occur as a perched zone above the water table. Geotechnical boring B6-4W indicates unconsolidated weathered bedrock can be over 130 feet thick in the area of the southeast entry/exit.

In the area of HDD S3-0360, groundwater generally flows south from the recharge zone in North Valley Hills, through the Chickies and Harpers Formations, and into Chester Valley. Groundwater in the vicinity

of the S3-0360 HDD path is expected to be influenced by the anisotropy created by the structural fabric of the rocks and by the Ketch Fault causing an eastward flow vector towards a tributary of West Valley Creek. A depiction of the local water table configuration is provided in **Figure 4**.

2.3.2 Local Water Supply Wells

SPLP performed a preconstruction survey of landowners within 450 feet of the ROW at HDD S3-0360 and 35 landowners responded positively to an offer to have their wells tested. **Figure 5** illustrates the sampling locations. The sampling locations are identified with yellow dots and a 450-foot radius is identified with a purple line. The total depths for 16 of the wells range from 65 to 480 ft bgs. Five wells indicate depths to water ranging from 22 to 260 ft bgs. Eight wells reported pump depths ranging from 71 to 480 ft bgs.

In June of 2017 thirty-four homeowners accepted SPLP's offer for connection to the local public water supply provided by Aqua Pennsylvania. In July 2020, the last remaining property owner of the 35 private wells within 450-feet of the HDD alignment accepted SPLP's offer and the residence was connected to public water supplied by Aqua Pennsylvania (see **Figure 5**).

Published median well yields are variable in the Chickies Quartzite and Harpers Formations. Median yield of 20 gallons per minute (gpm) may be obtained in properly sited and constructed wells (Geyer and Wilshusen 1982). Based on the results of a PaGWIS database search, yields from wells drilled into the Chickies Formations and within a mile of HDD S3-0360 range from 1 to 5 gpm.

2.3.3 Springs and Seeps

A naturally occurring zone of groundwater seepage occurs along the HDD alignment, north of Shoen Road. This seepage was investigated by Skelly and Loy (2018) with respect to HDD construction activities (see **Attachment C**). The study concluded that the seep is a persistent hydrologic condition that predates the HDD activities. The primary toe-of-slope seep was described as a low-flow, intermittent source of hydrology to the area, which intercepts upgradient less-regular seasonal/ephemeral seeps and surface water flows.

2.3.4 Water Levels

Groundwater was detected in geotechnical borings SB-04 and B6-9E, at northwest end of the proposed profile, at depths of 30 and 25 ft bgs, respectively, in unconsolidated materials. Groundwater was encountered at 28.0 ft bgs in boring SB-03, installed at the southeast end of the proposed profile. A depth to groundwater was not recorded for boring B6-4E, also located near the southeast end of the profile. Typical depth to groundwater in the Chickies Quartzite uplands is approximately 40 feet, as indicated by a residential well monitored by the US Geological Survey (USGS) and reported by Low et al. (2002).

Local water level measurements of private wells adjacent to the HDD S3-0360 bore path were recorded during well sampling activities by GES. Water level measurements could be obtained from 5 of the 35 private wells sampled, and had depths to water ranging from 22 to 260 ft bgs.

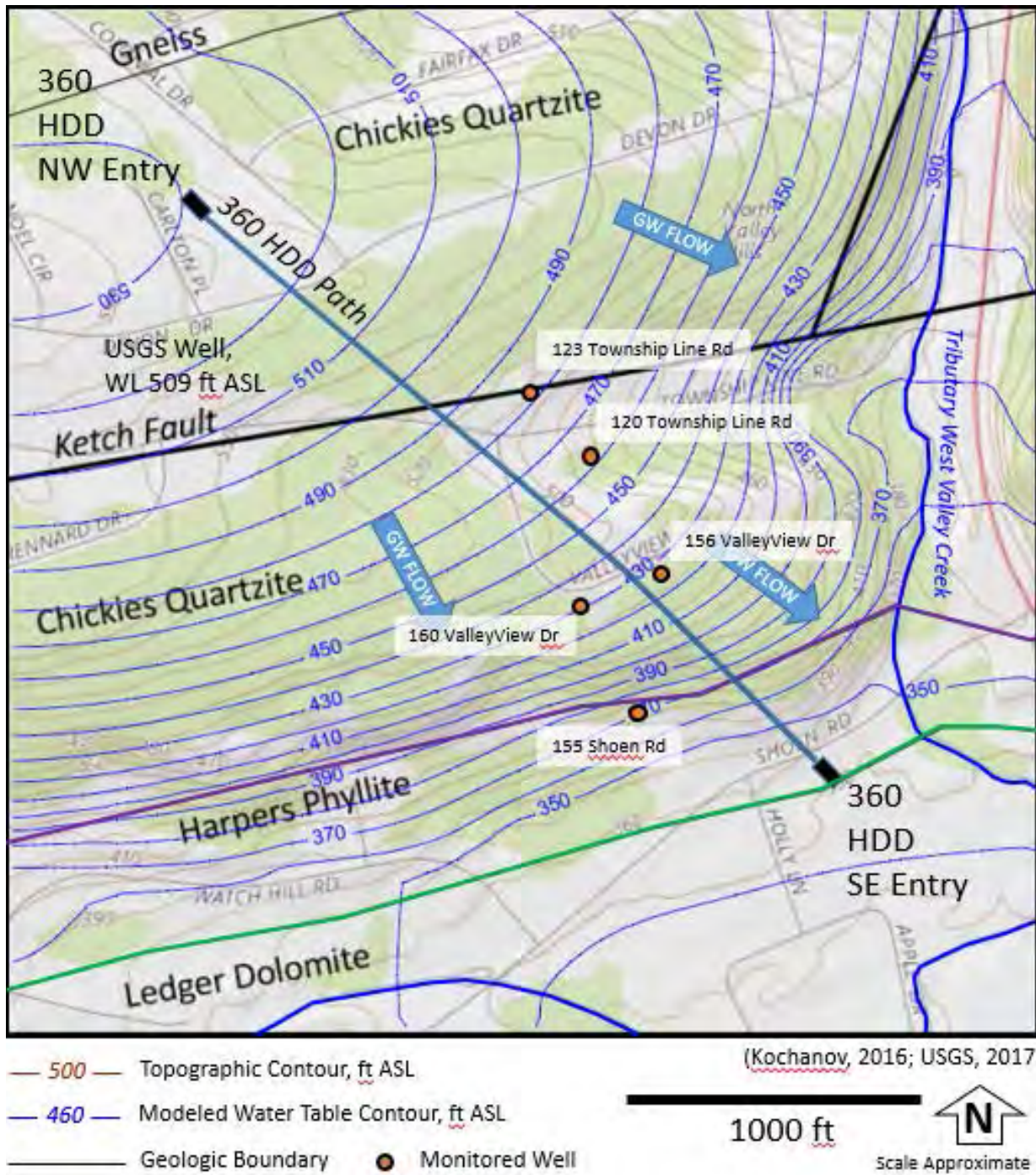


Figure 4. Direction of Groundwater Flow and Monitoring Well Locations

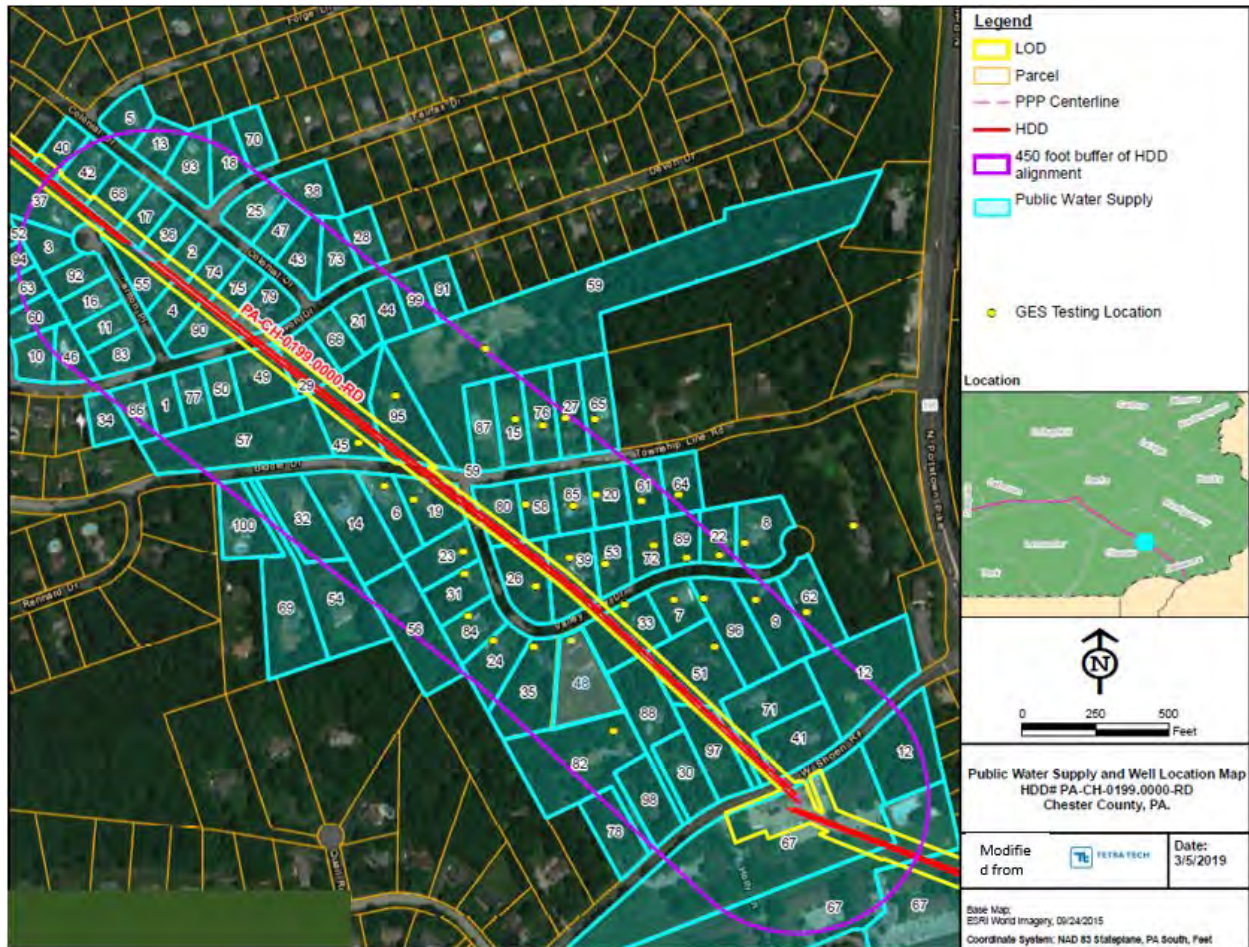


Figure 5. Residential Wells Replaced with Public Water Hookups

A search of the Pennsylvania Groundwater Information System (PAGWIS) identified eight wells drilled in the Chickies quartzite within approximately 0.5 miles feet of the HDD S3-0360 alignment. One of the wells was the monitoring well installed at the western edge of the HDD S3-0360 southern drill pad (OW-1). Two of the wells were commercial wells, one well was designated as “unused” and four were domestic wells. The well depths for the domestic wells ranged from 150 to 300 ft bgs and static water levels for the domestic wells, recorded at the time of installation, ranged from 35 to 50 ft bgs. The records indicate groundwater was encountered a depth of approximately 25 ft bgs when monitoring well OW-1 was installed near the southeast end of the HDD profile.

A continuous water level monitoring system with remote access has been established at five former residential wells in the area to assess pre-drill conditions and monitor for potential water level impacts during drilling of both the 16-inch and 20-inch HDD at S3-0360 (see **Figure 4** for locations). Monitoring of the groundwater levels began in December 2017 and the data have been downloaded weekly. A real-time data logger was installed in the 160 Valleyview Drive monitoring well on October 18, 2019. The natural groundwater level fluctuations recorded until October 4, 2020 are shown on **Figure 6**.

As shown on **Figure 6**, water levels in the monitoring wells responded to HDD construction activity. During periods of active drilling, the water levels declined in response to a groundwater discharge at the southeast entry/exit. The southeast entry/exit for the P&Ps for both pipes is located at a lower elevation than the background water table, over approximately 2,450 feet of the 2,857-foot drill path (horizontal distance). As such, completion of the pilot borings for the 16-inch line created a groundwater discharge

and SPLP expects similar conditions for the 20-inch line. In October 2019, drilling of the pilot bore for the 16-inch line was suspended and a grout plug was installed at the southeast end of the pilot hole, causing a water level recovery. The recovered water levels were maintained until approximately August 21, 2020, when the groundwater discharge caused water levels to decline, once again, in response to pilot hole drilling. Construction of the 16-inch HDD was completed in early October 2020. The pipe pull was completed on September 26th and the annulus for the southeast section of HDD was grouted on September 28th. At that time, a tremie pipe was inserted 360 feet into the annulus and 40 yards of flowable fill grout were injected into the annulus until it appeared at the southeast entry/exit mud pit. In response to the grouting, the groundwater discharge was greatly reduced to approximately one gpm and the water levels in the five local monitoring wells began to rebound (see **Figure 6**). The water levels are continuing to rebound as of the submittal of this report. Grouting of the northwest section of the 16-inch HDD was performed on October 2nd and 3rd. A similar recovery response is expected from grouting of the completed 20-inch line. See **Section 3** for more details associated with construction of the 16-inch line. Proposed approaches to mitigate groundwater discharge are provided in **Section 4.0**.

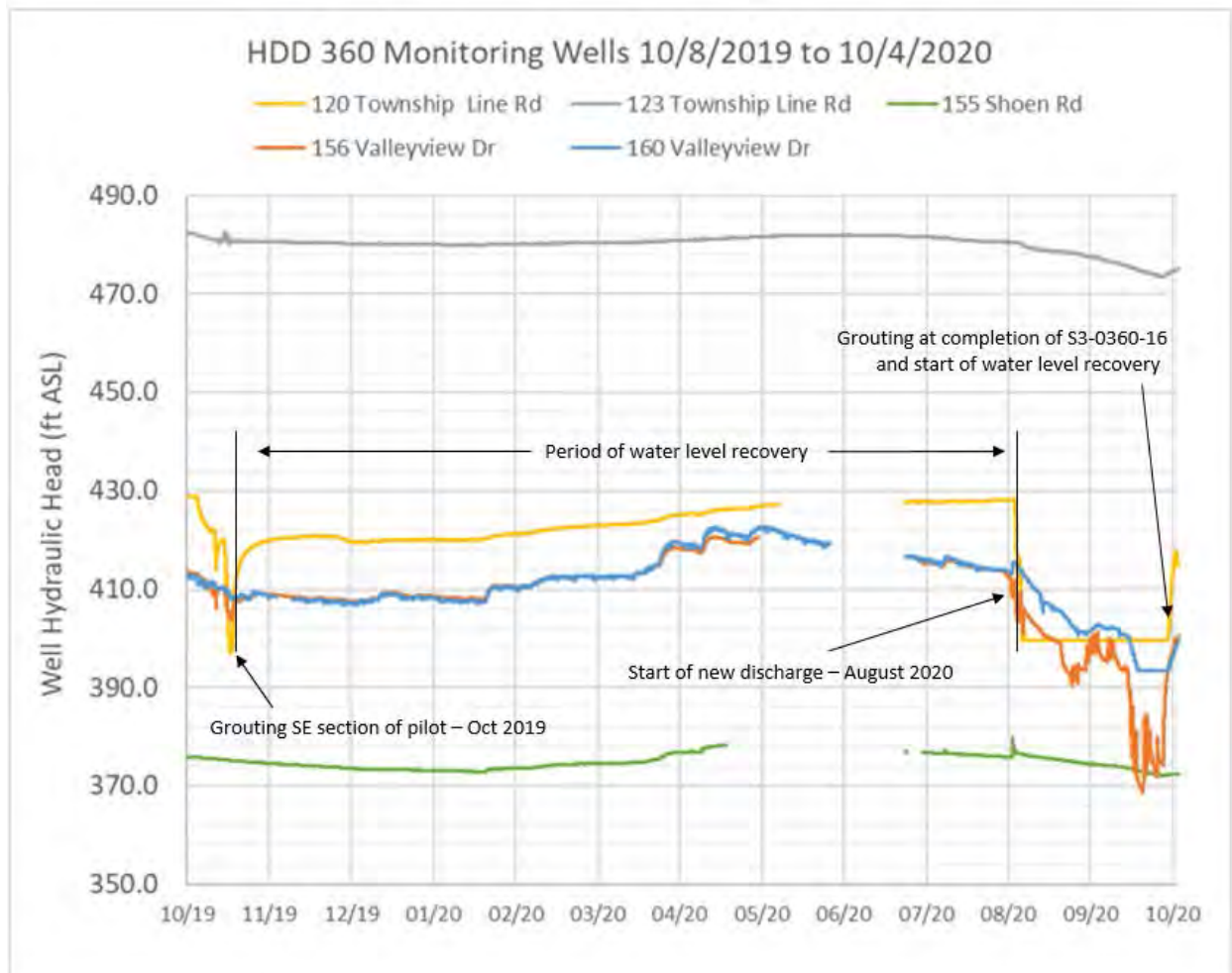


Figure 6. Groundwater Levels

2.3.5 Geophysical Studies

Rettew performed a geophysical survey in February 2020, covering approximately 400 feet of the southeast end of the proposed alignment for HDD S3-0360 (see **Attachment D**). Three different geophysical techniques were utilized to detect and delineate subsurface voids or low-density zones and provide a top of competent bedrock profile; including microgravity, seismic refraction and multi-spectral analysis (MASW), and electrical resistivity (ERI).

None of the mapped fracture traces or the mapped lineament referenced in Section 2.2.5 occur within the geophysical survey grid.

The microgravity survey delineated two zones of gravity lows (less dense subsurface materials) approximately centered around Stations 1+10 and 1+60 on the proposed profile. Rettew's report states, "These may be roughly where the HDD (16-inch profile) emerges from high-velocity material (rock)."

Rettew concluded that the seismic refraction and MASW survey confirmed the presence of an undulating bedrock surface likely due to deeper weathering along suspected fracture zones, but not apparent extremely-low-velocity zones of the type associated with voids that might contribute to subsidence. The seismic refraction data indicate a general three-layer stratigraphy consisting of a residual or sedimentary soil mantle, a weathered rock zone, and competent bedrock zone. The uppermost (soil mantle) is estimated to be approximately 25-35 feet. The deeper, more competent bedrock zone had refraction velocities over 10,000 feet per second. In addition, the seismic refraction results show a low-velocity zone indicative of possible near vertical fracture zone in the competent bedrock. This was mapped at approximately Station 3+40 on the proposed profile. The MASW results were similar to the seismic refraction results.

The ERI survey identified a relatively conductive surface layer over a discontinuous mildly resistive layer, with the discontinuities possibly supporting the presence of fracture zones. The lowest resistivities were recorded in the shallow subsurface adjacent to Shoen Road, and are presumed to represent saturated (and therefore electrically conductive) soils. The shape of the low-resistivity zone mimics the curvature of the as-built section of the HDD profile for the 16-inch pipeline, which was partially drilled at the time of the geophysical survey.

According to Rettew, the ERI profiles show a general three-layer model, similar to the seismic refraction and MASW survey, with a relatively conductive surface layer, over a discontinuous mildly resistive layer, over a more conductive layer. The upper layer was described as relatively discontinuous, with irregularities that could represent near-surface disturbances given the site development history. Deeper, electrically more conductive anomalies below the inferred top-of-rock are mapped at approximately Stations 0+80, 3+05, and 4+10 on the proposed profile, and may represent water- or clay-bearing fractures or weathered seams within bedrock. The zone of lower resistivities occurs from approximately Station 0+50 to 1+00 at the southeast end of the proposed profile and, according to Rettew, extends from roughly where the HDD profiles may emerge from rock to the south end of the survey on Shoen Road where seepage has been observed.

3.0 OBSERVATIONS TO DATE

3.1 On This HDD Alignment

The pilot hole for the 20-inch line at HDD S3-0360 began on June 6, 2017. The pilot, extending northwest into the Chickies Quartzite of North Valley Hills, began producing water at a horizontal distance of 747 feet from the southeast entry/exit on June 22, 2017. On June 28th, the flow rate increased to 70 gpm after the pilot hole was at a horizontal distance of 1,287 feet. The groundwater discharge was not occurring during times of active drilling but occurred in the evening during periods when drilling was not occurring. The discharge diminished to 40 gpm the evening of June 29th. On July 3rd, residents at 118 Township Line Road and 120 Township Line Road complained of cloudy well water. The pilot bore was plugged with bore grout in an attempt to seal bedrock fractures, and was then re-drilled. Groundwater continued to flow each evening when drilling activity was suspended. On July 12, 2017, the pilot bore reached a drill distance of 1,575 feet, and was producing 50 gpm of groundwater in the evening when drilling was suspended. The borehole was sealed with 30 cubic yards of bentonite/cement grout on July 13, 2017 and the rig was demobilized. After this grouting event, groundwater flow from the pilot hole was minimal. No IRs occurred during this initial attempt to advance the pilot hole.

During the period of groundwater discharge while the original pilot bore was advanced, owners of residential wells surrounding the HDD alignment reported loss of pressure and increased turbidity. The loss in pressure resulted from a lowering of the water table in the local aquifer in association with the groundwater discharge. Modelling of the hydrogeologic system suggested that water table lowering was greatest near the pilot bore and was limited to within approximately 1,000 feet of the pilot bore. The turbidity in well water was most likely caused by sediment that commonly collects at the bottom of private wells over time and the lowering of well pumping levels in response to the groundwater discharge.

In response to the above described water resource impact, SPLP offered public water hookups to all of the residential wells within 450 feet of the HDD alignment. This offer resulted in a total of 35 connections to public water. Five of the wells were converted to water level monitoring wells, equipped with automatic water level recorders. The locations of the monitoring wells are shown on **Figure 4**.

A zone of groundwater seepage was observed July 20, 2017 along the north margin of Shoen Road directly over the bore path; however, Skelly & Loy made a determination that the seepage at this location pre-dated the start of drilling (see **Attachment C**). Local water discharges from the seepage zone, from surface water runoff, and minimal seepage from the abandoned HDD pilot hole are managed at a constructed detention basin on the south side of Schoen Road, where ponded water is allowed to seep into the subsurface.

In the fall of 2017, SPLP chose to install the 16-inch HDDs using the 20-inch HDD profiles in Spread 6 of the ME II project.

Drilling for the 16-inch line at HDD S3-0360 was initiated on October 9, 2019. The pilot hole was advanced from the southeast entry/exit point at Shoen Road toward the northwest entry/exit point at Devon Drive. Beginning on October 17, 2019, once the pilot hole had advanced over 1,200 feet, groundwater was observed flowing back into the southeast entry/exit pit at varying flow rates ranging from 1 to 60 gpm. Lower flow rates were observed during advancement of the drilling tools, and increased groundwater flowback was observed as drill tooling was removed (tripping out) and during drilling down times. On October 18, 2019, all tooling was removed to add a new steering assembly. The new assembly and tooling were tripped back in to the bottom of the borehole (rock face) to inject a heavy mud plug. (i.e. a plug of drilling mud thickened with a higher bentonite-to-water ratio.) Following injection of the heavy mud plug, the discharge of groundwater ceased. Before drilling operations were shut down, the pilot had been advanced to 1,533 feet of measured borehole distance (or 1,514 feet horizontal distance) from the southeast



entry/exit point. As per the Terms and Conditions of Paragraph 3.h. of the Consent Order Agreement between SPLP and the Department dated July 24, 2017, concerning drilling operations at HDD S3-0360-16 (Devon Rd/ Shoen Road), construction activity ceased until a Restart Report could be developed and approved. The final Restart Report was submitted to the Department in January 2020 and was approved by the Department on July 2, 2020. Drilling of a new pilot hole for the 16-inch line began on July 15, 2020.

A groundwater level monitoring program has been established in the area of HDD S3-0360 using the five residential wells converted to monitoring wells. The program began in December 2017 and the data have been downloaded weekly since that time. A real-time data logger was installed in the 160 Valleyview Drive monitoring well on October 18, 2019. The monitoring program is intended to provide on-going and updated information about the water table elevation in the bedrock aquifer in the vicinity of HDD S3-0360. This robust data set allows for an accurate representation of background water levels and potential deviations from background levels caused by HDD construction.

Pilot drilling for HDD S3-0360-16 was resumed on July 14, 2020 from the northwest entry/exit. A seep water and groundwater discharge management system was established at the southeast end of the HDD including: use of produced groundwater to mix mud, temporary frac tank storage, vac truck removal and controlled discharge to a straw-bale containment / dewatering structure. Normal drilling conditions prevailed as the pilot hole was advanced to approximately 1,560 feet through 8/6/2020. At that point, drilling from the northwest was suspended, waiting for the pilot intercept boring to connect from the southeast. From July 14, 2020 to August 6, 2020, the seep flowed clear at a constant rate of between approximately 1.0 to 2.5 gallons per minute (gpm).

Advancement of the intercept pilot from the southeast consisted of drilling out the former pilot hole, which was partially filled with grout cement. From August 1, 2020 to August 8, 2020, the intercept pilot was advanced with little resistance and consisted of tripping in tooling to a horizontal distance of approximately 1,916 feet. At this position, the northwest section of pilot hole and the southeast section of pilot hole overlapped by approximately 648 feet without connecting. Planned further advance of the southeast section of pilot hole would consist of drilling through fresh bedrock and steering the southeast section of pilot hole to intercept with the northwest section of pilot hole.

The cutting of new pilot hole from the southeast was initiated on August 6, 2020 and continued through August 7, 2020 without incident. During that time, the HDD was advanced to 1,822 feet northwest from the southeast entry/exit, and the seep on the north side of Shoen Road maintained a low flow and was clear. Approximately 94 feet of hole was advanced to a horizontal distance of 1,916 feet on August 8, 2020 during which time a change in the flow and quality of the seep was observed. Primary sand bag containment was placed around the seep and a secondary containment was established 100 feet east of the primary containment, on the north side of Shoen Road. A small volume of seep water and sediment flowed outside the containment and was cleaned up before the discharge was completely controlled. In response to the observed change in water quality at the seep, SPLP decided to voluntarily suspend operations to assess conditions. In addition, the groundwater discharge at the southeast entry/exit began again on August 10, 2020.

The approved Restart Report for 16-inch line construction established a protocol for determining whether the quality of water emitting from the seep was impacted by drilling fluid. As per the protocol, water from the seeps was field tested for pH, specific conductance and color. These measurements did not indicate an impact from drilling fluids. If they had, a sample would have been sent for laboratory analysis of bentonite clay minerals, to verify presence of drilling fluid. Further HDD construction was temporarily suspended by the Department. In response, SPLP issued a Restart Report on August 17, 2020 and drilling was allowed to resume on August 25, 2020. The groundwater discharge at the southeast entry/exit varied between 25 and 50 gpm during times of suspended drilling activity. On August 29, 2020, all seepage from the seep

area stopped and no discharge from the seep area was observed for the remainder of 16-inch HDD construction, until October 2, 2020 in response to grouting of the annulus.

The 16-inch pipe was pulled on September 26, 2020. The southeast section of the HDD annulus was grouted on September 28, 2020 by inserting a tremie pipe 360 feet into the annulus and injecting 40 cubic yards of flowable fill grout. The northwest section of the HDD annulus was grouted on October 2 and 3, 2020. On October 2nd a tremie pipe was inserted 180 feet into the annulus and 54 yards of flowable fill grout was placed in the annulus. On October 3rd, an additional 68 cubic yards of flowable grout fill was gravity fed into the annulus from the northwest entry/exit mud pit. At approximately 0700 hours on October 3rd, an incident occurred near the seep on the north side of Shoen Road. Approximately 50 gallons of grout mixed with groundwater emerged five feet west of the original seep location. The discharge flowed through the existing seep sand bag containment, approximately 100 feet within the existing road ditch and was contained by a second existing sand bag containment. At the request of the Department, an additional sandbag containment was installed down gradient within the road ditch. The grout/groundwater mixture was recovered using sump pumps, hand tools, water pressure sprayers and vac trucks. After cleanup, a slightly turbid groundwater discharge continued to flow from the seep at approximately 1 to 2 gpm. This discharge is being addressed as per the protocol established for seep discharges in the Seep Monitoring Work Plan. On October 6th, the discharge appeared to be slightly turbid with an elevated pH representative of the grout. The discharge waters is being contained and managed while the pH drops to level suitable for the protection of aquatic life. An incident report describing the grout / groundwater mixture discharge was issued to the Department on October 5, 2020.

The groundwater discharge from the HDD annulus at the southeast entry/exit has been greatly reduced in response to grouting and is currently flowing at approximately one gpm, as compared to 25 to 50 gpm during down times when the HDD was under construction. This nearly complete reduction in the groundwater discharge is causing water levels to rise in the five monitoring wells associated with the S3-0360 HDDs.

3.2 On Other HDD Alignments in Similar Hydrogeologic Settings

It is not uncommon for an HDD pilot hole to create temporary groundwater discharge at locations where the local water table elevation is greater than that of an entry/exit point. This does not typically occur when the HDD is designed to pass under a surface water resource because the entry/exit points are usually elevated on either side of the resource. However, temporary groundwater discharges have occurred at HDDs associated with the Mariner East II project in hilly terrane where the water table along the alignment exceeds the elevation of one of the entry/exit points. Typically, groundwater discharges of this type have been not been of the magnitude or duration seen during the pilot drilling for the 16-inch line at HDD S3-0360 and have not been in areas with as high of density of private water wells as formerly existed proximal the HDD S3-0360 alignments. The groundwater discharges that have occurred at other ME II HDDs have been managed by transporting discharge water to the mud plant and using it for the mixing of drilling fluid, by reducing drilling downtime (24-hour per day drilling is optimal), by sealing water producing zones with loss control materials (LCMs), and by standard completion of HDD construction. Production of groundwater, similar to that at S3-0360, was experienced at HDD S3-0290-20 (currently under suspension) and at the completed ME 2 HDD S3-0400 for the 16-inch line, especially in the western half of the drill within the Conestoga Formation (a karst bedrock with variable weathering and potential to produce large groundwater flow rates). Unlike S3-0360, no local private water wells were impacted by the temporary production of groundwater at HDD S3-0400-16. The plan to prevent similar groundwater production during installation of the 20-inch line at HDD S3-0400 includes use of the Direct Pipe drilling method for HDD construction.



4.0 SUMMARY AND CONCLUSIONS

4.1 HDD Site Conceptual Model

The proposed alignment for the ME II 20-inch line at HDD S3-0360 is located between Devon Drive in Uwchlan Township and Shoen Road in West Whiteland Township, Chester County, Pennsylvania. The topography along HDD S3-0360 consists of the prominent ridge named North Valley Hills, dropping in elevation approaching the southeast entry/exit and Chester Valley to the south. The proposed P&P for the HDD (rev. 11/15/17) is slightly shorter and runs deeper than the permitted profile. The entry and exit angles for the proposed profile are both two degrees steeper at 12 degrees and the profile achieves the lowest elevation of 279 ft amsl (versus that of the permitted profile at 318 ft amsl) along the horizontal central portion of the profile. The overall horizontal length of the proposed profile is 2,827 feet with northwestern and southeastern entry/exit elevations at 576 and 353 ft amsl, respectively.

From southeast to northeast, the completed HDD will transect the Harpers Formation (phyllite and quartzite) and extend into the Chickies Formation (predominantly quartzite), with a contact at approximately Station 4+25 on the proposed profile. Based on geotechnical borings, the depth of unconsolidated materials at the northwest entry/exit is approximately 34 feet and the depth of unconsolidated materials at the southeast entry/exit is 130 feet or greater.

At the ME II HDD S3-0360 site, groundwater occurs and flows through an interconnected network of bedrock fractures and within unconsolidated materials derived from bedrock weathering. In the southeast section of the alignment, groundwater flow in the upper portion of the aquifer is through unconsolidated materials derived from heavily weathered phyllite and quartzite.

Studies to locate zones of bedrock fracturing along the HDD alignment have included geotechnical borings, review of geologic publications, fracture trace analysis, and geophysical surveys (see **Section 2**). Fracture trace analysis has identified potential zones of bedrock fracturing concentration at Stations 17+10, 22+00, 24+20 and 26+10 (proposed profile). The Ketch Fault is mapped transecting the alignment at approximately Station 16+80. During the initial pilot hole drilling at HDD S3-0360, a groundwater production zone was encountered at approximately Station 12+00, unrelated to any potential fracture zones identified by the above listed studies. Geophysical surveys performed by Rettew covered the southeastern most 400 feet of the alignment and identified potential fracture zones at Stations 0+80, 3+05, 3+40, and 4+10 on the proposed profile. Some or all of these may be relic features within the weathered rock zone above the Harpers phyllite and quartzite, especially further to the southeast.

Background and during-HDD construction groundwater levels have been simulated using a numerical groundwater flow model and measured using a network of five monitoring wells (see **Section 2**). Groundwater generally flows south and east from the recharge zone in North Valley Hills, through the Chickies and Harpers bedrock formations, into Chester Valley and a tributary to West Valley Creek. The southeast entry/exit is located at a lower elevation than the background water table, over approximately 87 percent of the proposed path (horizontal distance). As such, the pilot hole, final reamed hole, and completed HDD S3-0360-20 will connect water-producing zones within the bedrock formations and create a preferential pathway for groundwater flow and discharge at the southeast entry/exit, as occurred during construction of the 16-inch line.

The groundwater seep north of Shoen Road showed two responses to HDD construction. One occurred August 8, 2020 after pilot drilling from the southeast entry/exit was initiated and contained sediment and groundwater. Shortly thereafter the discharge from the seep stopped. The second was a discharge five feet west of the primary seep that occurred October 3, 2020 in response to grouting of the 16-inch pipe annulus.



This discharge contained a grout / groundwater mixture. These responses were managed according to the Seep Monitoring Plan in the Restart Report of January 15, 2020 and standard ME II cleanup procedures.

The continuous groundwater discharge that occurred at the southeast entry/exit during HDD construction was mitigated by the replacement of all private water wells on properties within 450-feet of the HDD alignment with public water hook-ups and the response of local groundwater levels to HDD construction activities was monitored using five monitoring wells established at five of the residences where public water was provided. The water level monitoring data show the decline in water levels in response to the groundwater discharge and the subsequent rebound of water levels in response to grouting of the HDD annulus.

No losses of circulation (LOCs) or IRs were noted during construction of the 16-inch line. This may be due to the hydrostatic pressure on the HDD bore during construction. The deepest, horizontal section of the profile for the as-built 16-inch pilot hole is 20 feet higher in elevation than on the proposed profile for the 20-inch line (279 versus 299 ft amsl); therefore, a similar absence of LOCs and IRs is predicted during construction of the 20-inch line.

4.2 Conclusions and Recommendations

As illustrated in the previous section, steps are required to mitigate a groundwater discharge and an associated lowering of the water table caused by construction of the 20-inch line at HDD S3-0360. SPLP already mitigated potential impacts by supplying public water to each property owner with a private well within 450-feet of the HDD alignment. The same water level monitoring program conducted during construction of the 16-inch line will be conducted during construction of the 20-inch line. Installing a grout plug in the southeast end of the 16-inch pilot caused local groundwater levels to rebound while the 16-line construction was suspended between October 2019 and August 2020. Similarly, local water levels declined in response to the groundwater discharge that occurred during construction of the 16-inch pipe between July 2020 and October 2020. Grouting of the southeast section of the 16-inch line after the pipe was pulled is causing a rebound in the water levels. As such, it is expected that grouting of the annulus for the pending 20-line will result in a similar recovery.

Field monitoring of pH, specific conductance and color at the seep on the north side of Shoen Road, as described in the Seep Monitoring Work Plan addendum in the Restart Report of January 15, 2020, was performed during construction of the 16-inch line, and should be continued during construction of the 20-inch line to assure proper management of seep fluids.

REFERENCES

Geyer, A. R. and J. P. Wilshusen, (rev. 1982) *Engineering Characteristics of the Rocks of Pennsylvania*. PaDER, ORM, Pa Geol. Survey, 4th ser., EGR-1.

Kochanov, W. E. 2016. *Bedrock Geologic Map of Part of the Chester Valley Area, Chester, Delaware, Montgomery, and Philadelphia Counties, Pennsylvania*. PA DCNR Geologic Survey.

Low, D., L., D. J. Hippe, and D. Yannacci. 2002. *Geohydrology of Southeastern Pennsylvania*. U.S. Geological Survey Water Resources Investigations Report 00-4166. 347 p.

PAGWIS, Pennsylvania Groundwater Information System
(<http://dcnr.state.pa.us/topogeo/groundwater/pagwis/records/index.htm>).

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

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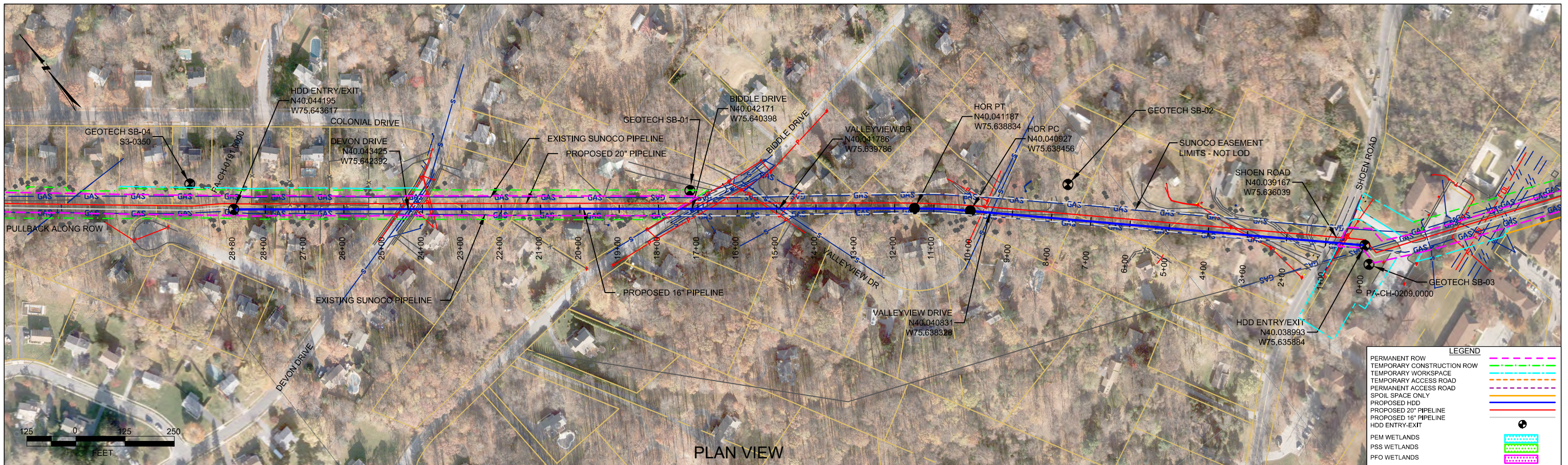


Attachment A

Permitted and Proposed Plan and Profiles

Permitted Plan and Profile, rev. 10/7/16 (16-inch line)

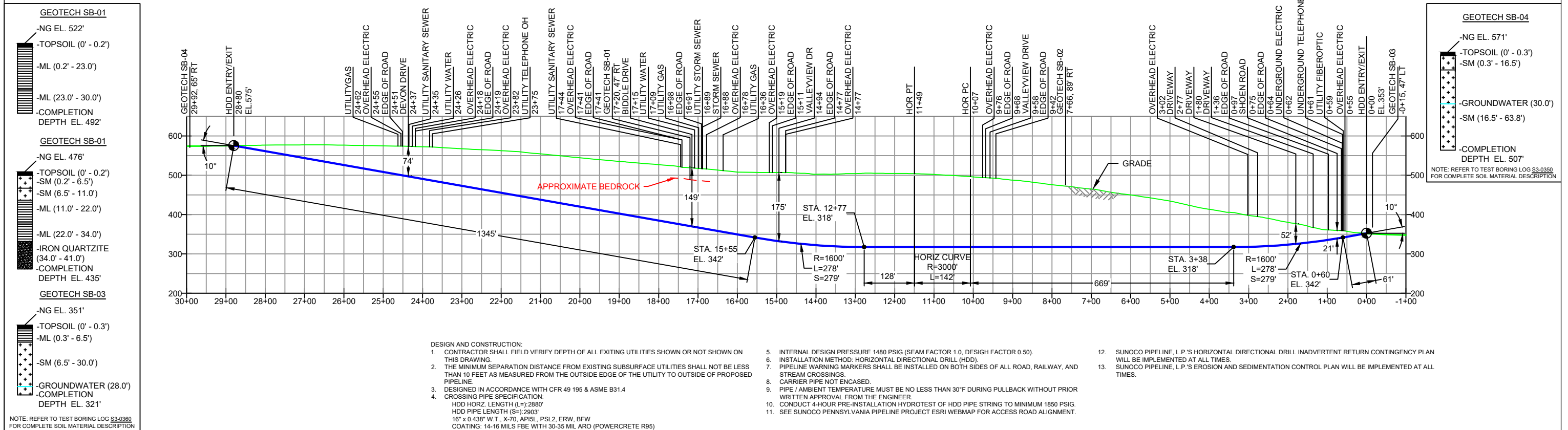
Proposed Plan and Profile showing geology, rev. 11/15/17



PLAN VIEW

CHESTER COUNTY, PENNSYLVANIA- UWCHLAN TOWNSHIP
S3-0360-16

PROFILE VIEW



DESIGN AND CONSTRUCTION:

- CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
- 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.
- DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
- CROSSING PIPE SPECIFICATION:
HDD HORZ. LENGTH (L)=2880'
HDD PIPE LENGTH (S)=2903'
16" x 0.438" W.T., X-70, API5L, PSL2, ERW, 8FW
COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
- INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50).
- INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
- PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
- CARRIER PIPE NOT ENCASED.
- PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
- CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
- SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
- SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
- SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTE: REFER TO TEST BORING LOG S3-0360 FOR COMPLETE SOIL MATERIAL DESCRIPTION

NOTES

- ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
- STATIONING IS BASED ON HORIZONTAL DISTANCES.
- 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.
- CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
- SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING

ES-6.42	TO	ES-6.44	EROSION & SEDIMENT PLAN
SHEET 25	TO	SHEET 26	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16
EP1	REVISED PER PADEP COMMENTS
EP	
A	ISSUED FOR BID

DWG NO	DWG NO	DESCRIPTION	NO.	DESCRIPTION

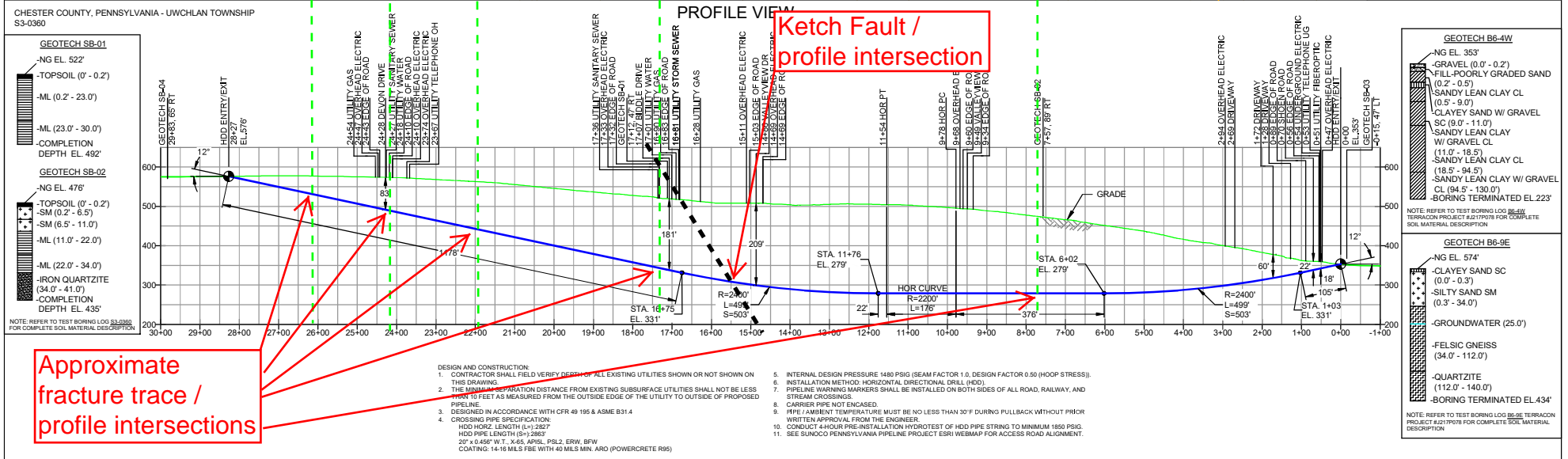
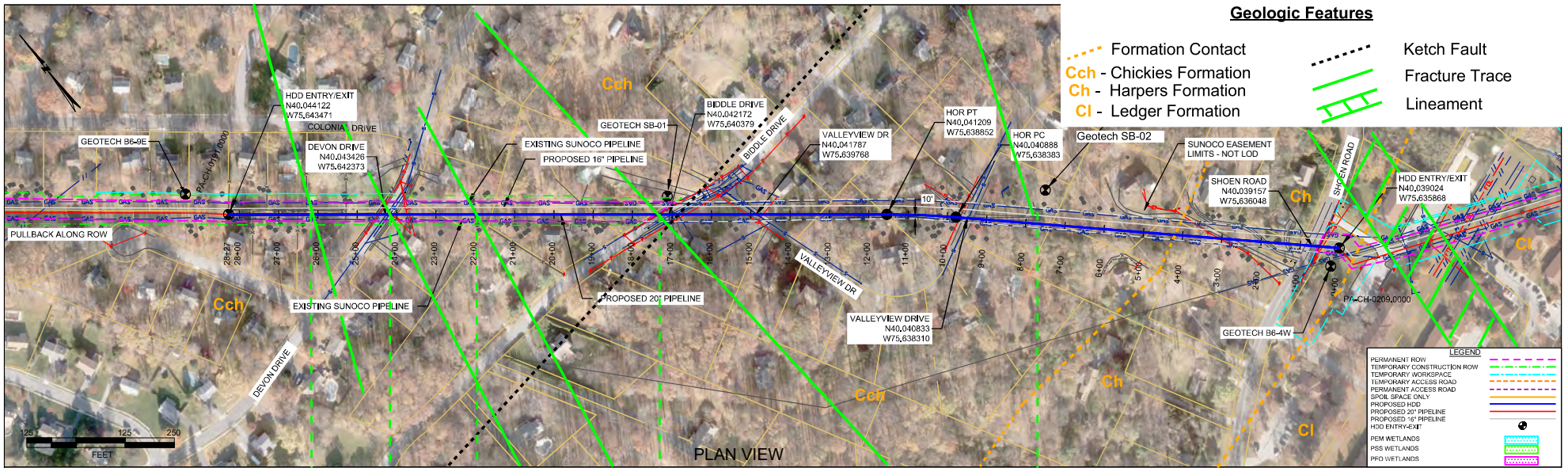
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

16-INCH HORIZONTAL DIRECTIONAL DRILL
BIDDLE DRIVE
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'
DWG. NO: PA-CH-0199.0000-RD-16



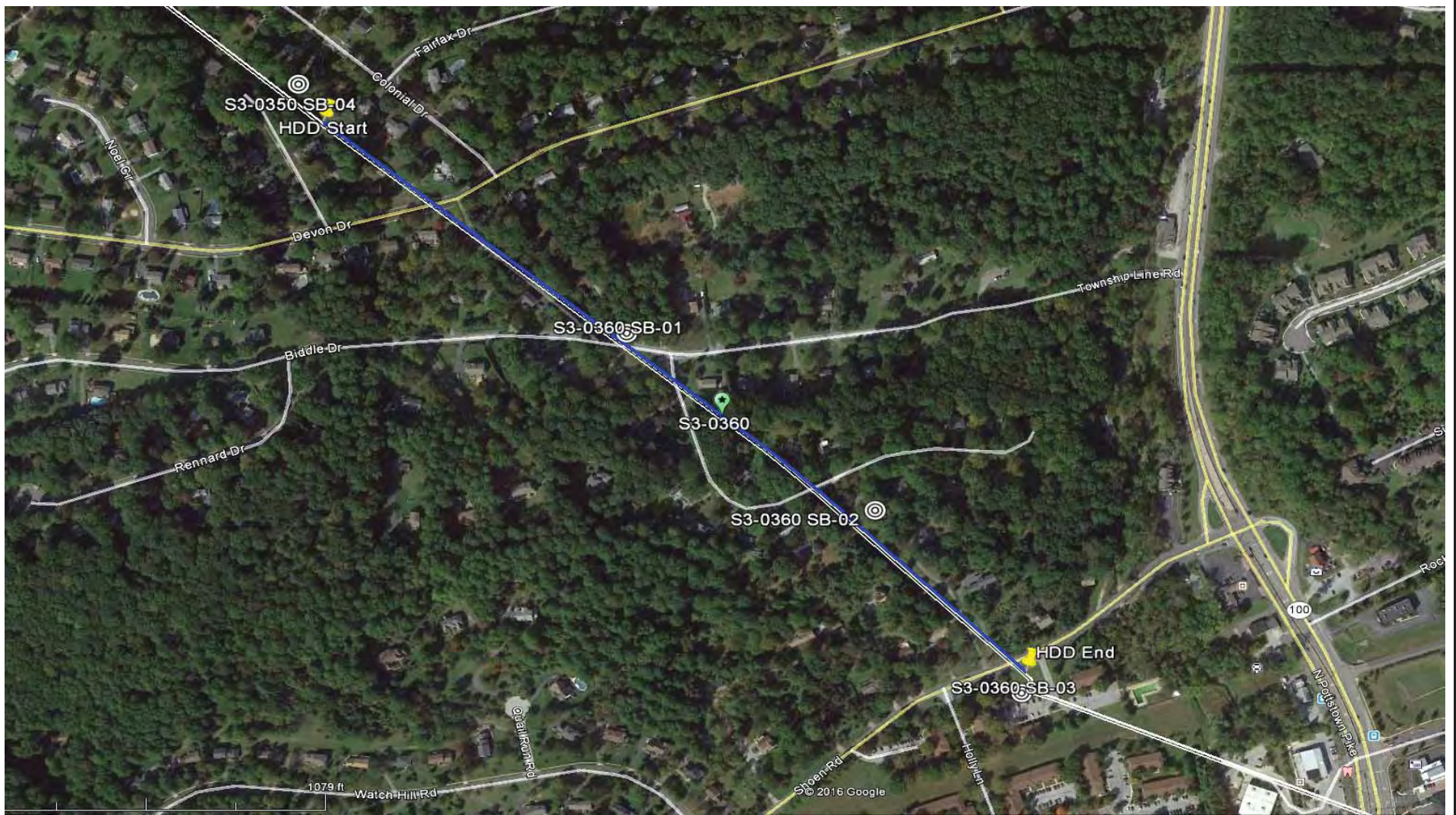
NOTES		REF. DRAWING		REVISIONS		MRS		SUNOCO PIPELINE, L.P.					
1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83	ES-6.42	TO	ES-6.44	EP3	UPDATED GEOTECH INFO PROVIDED BY DPS	MRS	11/15/17	RMB	11/15/17	AMC	11/15/17	SUNOCO PIPELINE, L.P. HORIZONTAL DIRECTIONAL DRILL BIDDLE DRIVE PENNSYLVANIA PIPELINE PROJECT	
2. STATIONING IS BASED ON HORIZONTAL DISTANCES	SHEET 25	TO	SHEET 26	EP2	UPDATED TO 20" PIPE SPEC AND CENTERLINE LOCATION PER PM. ADDED DPS GEOTECH	MRS	11/08/17	RMB	11/08/17	AMC	11/08/17		SCALE: 1"=250' DWG. NO.: PA-CH-0199.0000-RD
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.				EP1	REVISED PER PADEP COMMENTS	MRS	09/30/16	RMB	09/30/16	AAW	09/30/16		
4. CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.				EP	ISSUED FOR BID	MRS	05/11/16	AAW	05/11/16				
5. SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.	DWG NO		DWG NO	DESCRIPTION	C	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE	





Attachment B

Geotechnical Boring Reports



LEGEND:

⊙ Geotechnical Soil Boring (SB) Locations



GEOTECHNICAL BORING LOCATIONS
HDD S3-0360
CHESTER COUNTY, UWCHLAN/WEST WHITELAND TWP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT



TETRA TECH

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

TEST BORING LOG

Project Name: SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406		
Project Location: 317 COLONIAL DRIVE, EXTON, PA			Page 1 of 1		
HDD No.: S3-0350		Dates(s) Drilled: 01-22-16		Inspector: E. WATT	
Boring No.: SB-04		Drilling Method: SPT - ASTM D1586		Driller: E. OGDEN	
Drilling Contractor: HAD DRILLING		Groundwater Depth (ft): 30.0		Total Depth (ft): 63.8	
Boring Location Coordinates:			40° 2' 40.30" N		75° 38' 37.54" W

Sample No.	Sample Depth (ft)		Strata Depth (ft)		Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N	
	From	To	From	To									
			0.0	0.3			TOPSOIL (4")						
1	3.0	5.0	0.3		SM	14	DR, LIGHT BROWN TO ORANGE BROWN FINE SAND WITH A LITTLE SILT.	1	3	5	7	8	
2	8.0	10.0				19	DR, VARIABLE BROWN, TAN, ORANGE BROWN, REDDISH BROWN F-SAND WITH SOME SILT, TRACE F-QUARTZ GRAVEL. (USCS: SM)	1	5	9	12	14	
3	13.0	15.0				21	SAME	2	9	12	19	21	
				16.5									
4	18.0	19.8	16.5		SM	18	DR, VARIABLE BROWN, TAN, ORANGE BROWN, REDDISH BROWN FINE SAND WITH SOME SILT, W/A LITTLE F-C QUARTZ GRAVEL.	5	20	37	50/4"	57	
5	23.0	24.1				12	DR, LIGHT GRAY, ORANGE AND REDDISH BROWN FINE SAND, SOME SOME SILT, WITH A LITTLE F-C QUARTZ GRAVEL.	28	50	50/1"		>50	
6	28.0	30.0				20	SAME (USCS: SM)	5	25	36	46	61	
7	33.0	33.8				7	SAME	18	50/3"			>50	
8	38.0	38.3				4	DR, GRAY FINE TO MEDIUM SAND, SOME SILT, WITH A LITTLE F-C QUARTZ GRAVEL.	50/4"				>50	
9	43.0	43.7				5	SAME	20	50/2"			>50	
10	48.0	48.1				1	DR, GRAY FINE SAND AND SILT, WITH A LITTLE F-C QUARTZ GRAVEL. (USCS: SM)	50/1"				>50	
11	53.0	53.9				4	DR, GRAY FINE SAND AND SILT, WITH A LITTLE F-C QUARTZ GRAVEL.	16	50/5"			>50	
12	58.0	58.8				7	DR, TAN AND ORANGE BROWN FINE SAND AND SILT, WITH A LITTLE F-C QUARTZ GRAVEL.	8	50/3"			>50	
13	63.0	63.8		63.8		6	SAME	10	50/3"			>50	
								SLOW HARD AUGERING AFTER 45'.					
							WATER LEVEL THROUGH AUGERS AT 30'						
							CAVED AT 63', WATER LEVEL ON CAVE AT 30'.						

Notes/Comments:
Pocket Pentrometer Testing DR: DECOMPOSED ROCK
 HAD TO STOP DRILLING AT 63' INTERVAL BECAUSE GOT TOO DARK TO WORK SAFELY, AND NEEDED TO DEMOB. DUE TO COMING SNOW BLIZZARD.
 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:	331 BIDDLE DRIVE, EXTON, PA	Page 1 of 1	
HDD No.:	S3-0360	Dates(s) Drilled:	06-17-15
Boring No.:	SB-01	Inspector:	E. WATT
Drilling Contractor:	HAD DRILLING	Drilling Method:	SPT - ASTM D1586
		Driller:	S. HOFFER
		Groundwater Depth (ft):	NOT ENCOUNTERED
		Total Depth (ft):	30.0
Boring Location Coordinates:	40° 2' 32.202" N	75° 38' 25.037" W	

Sample No.	Sample Depth (ft)		Strata Depth (ft)		Recov. (ft)	Strata (USCS)	Description of Materials	6" Increment Blows *				N	
	From	To	From	To									
			0.0	0.2			TOPSOIL (2")						
1	3.0	5.0	0.2		12		ORANGE BROWN SILT AND FINE SAND, TRACE FINE GRAVEL.	5	8	11	11	19	
2	8.0	10.0			16		ORANGE BROWN SILT AND FINE SAND, TRACE FINE GRAVEL.	1	5	5	6	10	
3	13.0	15.0			22	ML	ORANGE BROWN SILT AND FINE SAND, TRACE FINE QUARTZ GRAVEL (USCS: ML).	4	6	5	4	11	
4	18.0	20.0			18		LIGHT BROWN AND ORANGE BROWN MICACEOUS SILT AND FINE SAND, TRACE FINE QUARTZ GRAVEL.	3	4	5	5	9	
5	23.0	25.0	23.0		24		LIGHT BROWN AND BROWN MICACEOUS SILT AND FINE SAND. (HIGHLY WEATHERED QUARTZITE?)	3	6	12	14	18	
6	28.0	30.0			21	ML	LIGHT BROWN AND BROWN MICACEOUS SILT WITH SOME FINE SAND. (USCS: ML). (HIGHLY WEATHERED QUARTZITE?)	3	26	40	40	66	
				30.0									
							AUGER GRINDING AT 23'.						
							CAVED AND DRY AT 28'.						

Notes/Comments:
Pocket Pentrometer Testing DR: DECOMPOSED ROCK
 S1: > 4 TSF
 S2: > 4 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.



TETRA TECH

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 Newark, Delaware 19713
 302.738.7551
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TEST BORING LOG

Project Name: SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406		
Project Location: 156 VALLEYVIEW, EXTON, PA			Page 1 of 1		
HDD No.: S3-0360		Dates(s) Drilled: 06-13-15		Inspector: J. COSTELLO	
Boring No.: SB-02		Drilling Method: SPT - ASTM D1586		Driller: GREGG	
Drilling Contractor: HAD DRILLING		Groundwater Depth (ft): NOT ENCOUNTERED		Total Depth (ft): 41.0	
Boring Location Coordinates:			40° 2' 26.296" N		75° 38' 15.356" W

Sample No.	Sample Depth (ft)		Strata Depth (ft)		Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N		
	From	To	From	To										
			0.0	0.2			TOPSOIL (2")							
1	3.0	5.0	0.2		10	SM	BROWN TO PURPLISH BROWN FINE TO MEDIUM SAND AND SILT	1	1	3	4	4		
				6.5			TRACE FINE GRAVEL (QUARTZ).							
2	8.0	10.0	6.5		18	SM	DR SHIST WEATHERED TO A TAN AND WHITE FINE TO MEDIUM SAND	3	25	29	30	54		
				11.5			WITH SOME SILT, A LITTLE FINE GRAVEL.							
3	13.0	14.0	11.5		11	ML	DR WEATHERED TO A BROWN SILT WITH SOME FINE SAND,	10	50/6"			>50		
							POTENTIAL WEATHERED SCHIST. (USCS: ML).							
4	18.0	20.0					RIG HAMMER BROKE - CUTTINGS: DR SCHIST WEATHERED TO A	-	-	-	-	-		
							BROWN SILT AND FINE SAND.							
5	21.0	21.8			9	ML	YELLOWISH BROWN SILT AND FINE TO MEDIUM SAND (DR), TRACE	14	50/4"			>50		
				22.0			FINE GRAVEL.							
6	26.0	26.7	22.0		8	SM	DR SHIST WEATHERED TO A YELLOWISH BROWN FINE TO MEDIUM	4	50/3"			>50		
				30.0			SAND AND SILT, WITH A LITTLE F-C ROCK FRAGMENTS. (USCS: SM).							
7	31.0	31.6	30.0	34.0	6		PARTIALLY WEATHERED QUARTZITE.	20	50/1"			>50		
							AUGER REFUSAL AT 34'.							
							<u>ROCK CORING</u>							
RUN 1	34.0	37.0	34.0		24.5	ROCK	WHITE TO LIGHT BROWN QUARTZITE, WITH IRON STAINING.	TCR: 68%, SCR: 54%, RQD: 47%						
							MODERATELY TO INTENSELY FRACTURED.							
RUN 2	37.0	41.0			40	ROCK	WHITE TO LIGHT BROWN QUARTZITE, WITH IRON STAINING.	TCR: 83%, SCR: 68%, RQD: 56%						
				41.0			MODERATELY TO INTENSELY FRACTURED.							
							<u>CORE TESTING RESULTS (RUN 1, DEPTH 35 TO 36')</u> :							
							COMPRESSIVE STRENGTH: 3,130 PSI							
							UNIT WEIGHT: 149.0 PCF							
							CAVED AND DRY AT 31'.							

Notes/Comments: Pocket Pentrometer Testing DR: DECOMPOSED ROCK

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

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



TETRA TECH

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TEST BORING LOG

Project Name: SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406		
Project Location: SHOEN ROAD, EXTON, PA			Page 1 of 1		
HDD No.: S3-0360		Dates(s) Drilled: 06-14-15		Inspector: J. COSTELLO	
Boring No.: SB-03		Drilling Method: SPT - ASTM D1586		Driller: GREGG	
Drilling Contractor: HAD DRILLING		Groundwater Depth (ft): 28.0		Total Depth (ft): 30.0	
Boring Location Coordinates:			40° 2' 19.944" N		75° 38' 9.409" W

Sample No.	Sample Depth (ft)		Strata Depth (ft)		Recov. (ft)	Strata (USCS)	Description of Materials	6" Increment Blows *				N	
	From	To	From	To									
			0.0	0.3			TOPSOIL (4")						
1	3.0	5.0	0.3		22	ML	YELLOWISH BROWN SILT WITH A LITTLE FINE SAND, TRACE FINE GRAVEL (USCS: ML).	1	6	7	9	13	
				6.5									
2	8.0	10.0	6.5		14	SM	DR WEATHERED TO A GRAY FINE TO COARSE SAND WITH SOME SILT, WITH A LITTLE FINE TO COARSE GRAVEL.	1	8	10	15	18	
3	13.0	15.0			16		DR WEATHERED TO A BROWNISH GRAY TO BROWN, FINE TO MEDIUM SAND WITH SOME SILT, TRACE UNWEATHERED FINE GRAVEL.	2	4	4	8	8	
4	18.0	20.0			14		YELLOWISH BROWN FINE TO COARSE SAND WITH SOME SILT, WITH A LITTLE UNWEATHERED FINE GRAVEL. (DR)	3	4	13	13	17	
5	23.0	25.0			25		DR WEATHERED TO A YELLOWISH BROWN TO REDDISH BROWN, FINE TO MEDIUM SAND, SOME SILT, WITH A LITTLE F-C GRAVEL.	1	4	8	9	12	
6	28.0	30.0			14		DR WEATHERED TO A YELLOWISH BROWN TO REDDISH BROWN, FINE TO MEDIUM SAND, SOME SILT, WITH A LITTLE F-C GRAVEL.	2	11	22	20	33	
				30.0									

Notes/Comments: Pocket Pentrometer Testing DR: DECOMPOSED ROCK
 S1: 3.25 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.

**ROCK CORE DESCRIPTION SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0360**

Location	Boring No.	Core Run	Core Depth (ft)		TCR (%)	SCR (%)	RQD (%)	Depth (ft)		Weathering	Classification	Bedding Thickness (ft)	Color	Discontinuity Data
			From	To				From	To					
S3-360	SB-2	1	34	37	68	54	47	34	41	Slight	Quartzite	Massive	White to very light brown	Microfoliations, but no bedding; Fractures ranging from 30° to 70°, Avg 54°
		2	37	41	83	68	56							

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0360

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, %	
S3-0350	SB-04	2	8.0	10.0	4.9	38.0	NV	NP	NP	SM
		4	18.0	19.8	5.5	33.6	-	-	-	-
		6	28.0	30.0	11.5	38.9	NV	NP	NP	SM
		9	43.0	43.7	11.2	39.3	-	-	-	-
		10	48.0	48.1	16.2	47.9	30	20	6	SM
		12	58.0	58.8	18.1	40.1	-	-	-	-
		13	63.0	63.8	16.3	47.3	-	-	-	-
S3-0360	SB-01	2	8.0	10.0	17.1	62.9	-	-	-	-
		3	13.0	15.0	16.2	53.0	NV	NP	NP	ML
		4	18.0	20.0	13.7	54.5	-	-	-	-
		5	23.0	25.0	10.1	69.4	-	-	-	-
		6	28.0	30.0	10.4	79.9	31	25	6	ML
	SB-02	2	8.0	10.0	5.3	42.9	-	-	-	-
		3	13.0	14.0	9.3	70.9	35	27	8	ML
		5	21.0	21.8	10.1	61.1	-	-	-	-
		6	26.0	26.7	6.4	30.6	NL	NP	NP	SM
		7	31.0	31.6	3.9	19.5	-	-	-	-
	SB-03	1	3.0	5.0	22.6	81.1	36	27	9	ML
		2	8.0	10.0	12.2	33.3	-	-	-	-
		3	13.0	15.0	16.5	35.8	-	-	-	-
		4	18.0	20.0	11.3	26.1	-	-	-	-
		5	23.0	25.0	16.3	29.3	-	-	-	-

Rock Core Testing Results				
Boring No.	Core Run	Approximate Depth (ft)	Compressive Strength (psi)	Unit Weight (pcf)
SB-02	1	35.0-36.0	3,130	149.0

Notes:

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

**REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S3-0360**

HDD No.	NAME	BORING NO.	REGIONAL GEOLOGY DESCRIPTION	GENERAL TOPOGRAPHIC SETTING	BEDROCK FORMATION	GENERAL ROCK TYPE	APPROX MAX FM THICKNESS (FT)	DEPTH TO ROCK (Ft bgs) based on nearby well drilling logs	NOTES / COMMENTS
S3-350		SB-04	Chickies Formation - Light-gray, hard, massive, Scolithus-bearing quartzite and quartz schist; thin, interbedded dark slate at top; conglomerate (Hellam Member) at base.	Generally level, slight slope to the NE	Chickies Formation (Cambrian)	Quartzite, schist, slate, conglomerate	600	Ranges from 35 to 70 ft bgs, Avg. 55 ft bgs (.5 mile radius)	
S3-360		SB-01		Gentle slope to the SW				Ranges from 20 to 78 ft bgs, Avg. 51 ft bgs (.5 mile radius)	
		SB-02		Gentle to moderate slope to the SW				Ranges from 35 to 70 ft bgs, only two wells found within .25 miles	
		SB-03		Generally level, slight slope to the south				Ranges from 20 to 78 ft bgs, Avg. 51 ft bgs (.25 mile radius)	

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

October 13, 2017



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

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

Re: Geotechnical Site Characterization
Mariner East 2 Pipeline Project
Spread 6 – Glendale Road/Concord Ave
Commonwealth of Pennsylvania
Drawing #PA-CH-0167.0000-RD
PO #20170818-1
Terracon Project No. J217P078

Dear Mr. Sessions:

This letter provides a summary of the bedrock characterization for the Mariner East 2 Pipeline Project crossing to be located at Glendale Road/Concord Ave (Drawing # PA-CH-0167.0000-RD) in the Commonwealth of Pennsylvania. Our services were performed in general accordance with our proposal number PJ2175108 dated July 28, 2017. Our scope of services included advancing two borings, designated as B6-9W and B6-9E, visual classification and photography of the rock core samples, and laboratory testing of representative rock samples.

Test borings, B6-9W and B6-9E were drilled between August 28 and 31, 2017 to depths of 80 and 140 feet, respectively as shown on the attached **Test Boring Location Plan**. Bedrock typically consisted of metamorphic rock comprised of gneiss at B6-9W and metamorphic rock comprised of gneiss and quartzite at B6-9E. Final test boring logs documenting overburden soil and bedrock conditions as well as photographs of the rock core samples are attached.

Rock compressive strength testing was performed on samples from approximately 20-foot intervals within the bedrock strata at each boring location. As an exception to the planned 20-foot intervals, a rock sample from 74 feet at B6-9E was not tested due to highly weathered and fractured conditions. Unconfined compressive strength test results are shown on the attached reports.



Geotechnical Site Characterization

Mariner East 2 Pipeline – Spread 6 Glendale Road/Concord Ave ■ Pennsylvania
Drawing #PA-CH-0167.0000-RD / PO #20170818-1
October 13, 2017 ■ Terracon Project No. J217P078



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

Sincerely,

Terracon Consultants, Inc.

A handwritten signature in blue ink, appearing to read "Lawrence J. Dwyer".

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

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

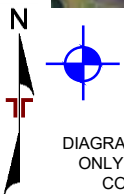
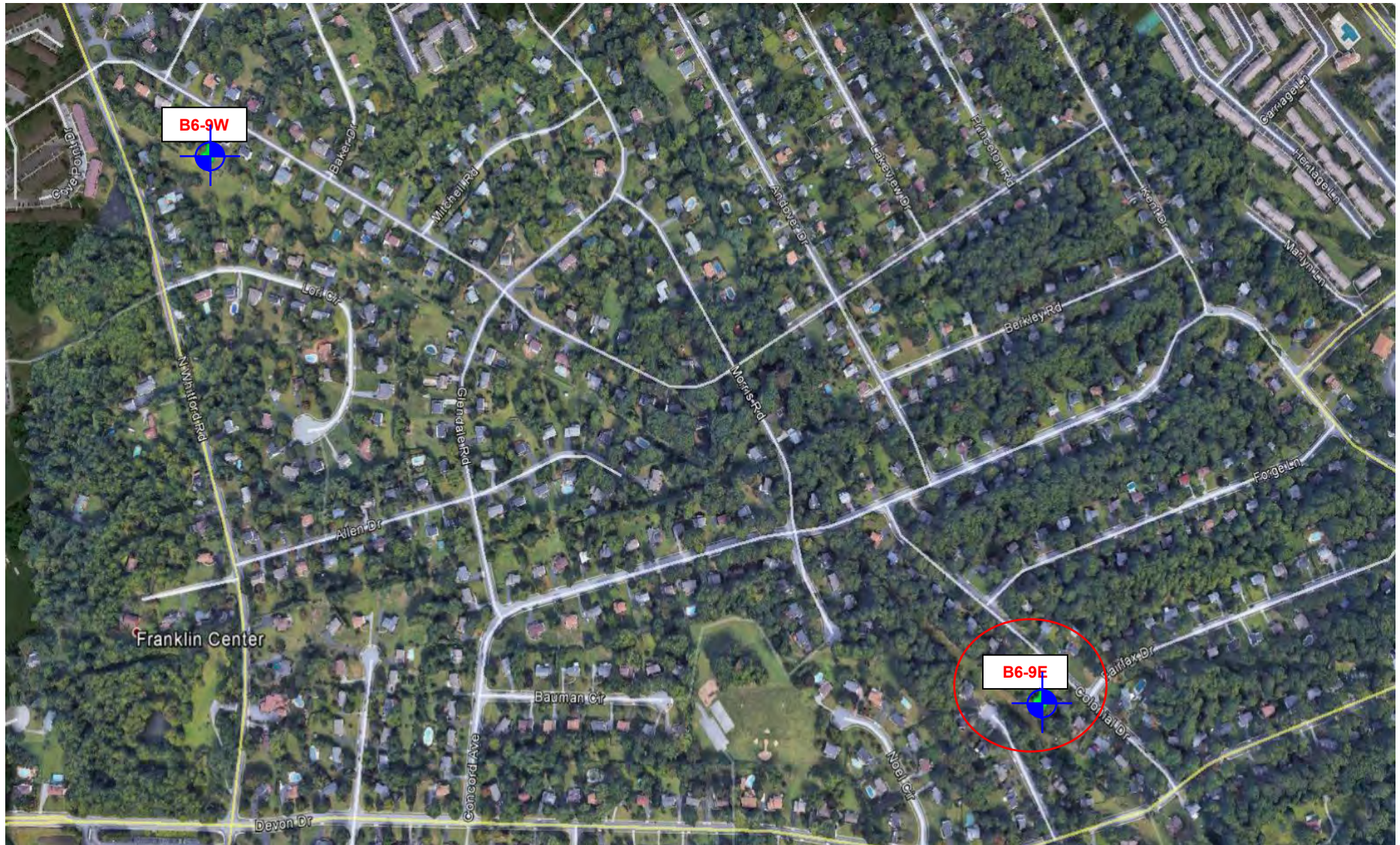
Attch:

TEST BORING LOCATION PLAN

EXPLORATION RESULTS (Boring Logs, Laboratory Data, Rock Core Photographs)

SUPPORTING INFORMATION (Unified Soil Classification System, Description of Rock Properties)

TEST BORING LOCATION PLAN



**APPROXIMATE
BORING
LOCATION**

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

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

Terracon
Consulting Engineers & Scientists

201 Hammer Mill Road Rocky Hill, Ct 06067
PH. (860) 721-1900 FAX. (860) 721-1939

TEST BORING LOCATION PLAN

Glendale Road/ Concord Ave HDD Cores B6-9W and B6-9E
PA-CH-0167.0000-RD
Chester County, Pennsylvania

Exhibit

A-2

EXPLORATION RESULTS

BORING LOG NO. B6-9E Glendale Road/Concord Ave East Page 1 of 5

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG
LOCATION PA-CH-0167.0000-RD
20170818-1
Latitude: 40.044422° Longitude: -75.643658°

Approximate Surface Elev: 574 (Ft.) +/-
ELEVATION (Ft.)

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
-------------	--------------------------	-------------	----------------	--------------------	---------	--------------------	-------------------------

0.3							
5			16	5-9-7 N=16			
10			18	8-24-21 N=45			
15			14	14-25-26 N=51			
20			7	50/6"			
25	▽		14	28-46- 50/3.5"			
30			2.5	50/2.5"			

DEPTH
0.3 **CLAYEY SAND (SC)**, brown 573.5+/-

SILTY SAND (SM), light brown, medium dense to very dense,
(residual soil)

Possible boulders from 20 to 34 feet

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

Hammer Type: Automatic

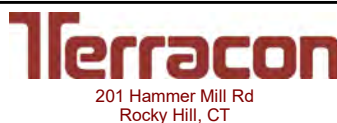
Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS

▽ 25' on 8/31/17



Boring Started: 08-28-2017

Boring Completed: 08-31-2017

Drill Rig: CME-850XR

Driller: Terracon/Allen S.

Project No.: J217P078

Exhibit: A-2

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON_DATATEMPLATE.GDT 10/13/17

BORING LOG NO. B6-9E Glendale Road/Concord Ave East Page 2 of 5

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG	LOCATION PA-CH-0167.0000-RD 20170818-1 Latitude: 40.044422° Longitude: -75.643658° Approximate Surface Elev: 574 (Ft.) +/- ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
--------------------	--	--------------------	---------------------------------	--------------------	-----------------------	---------------------------	----------------	---------------------------	--------------------------------

	SILTY SAND (SM), light brown, medium dense to very dense, (residual soil) <i>(continued)</i>									
34.0	540+/-	35		15	0	50/0.5"	7	1 0.5 0.5 1.5 1 1		
Run 1, Completely weathered FELSIC GNEISS, yellowish gray										
Casing deflected at an angle on the rock surface, offset 5 feet and auger to 39.5 feet to begin core										
40.0	534+/-	40		10			0	0.5 1 1.5 1 1		
Run 2, Similar										
45.0	529+/-	45		54			5	1 1 1 1.5 1.5 1 1 1 1		
Run 3, Soft, highly weathered, grayish red, coarse grained, FELSIC GNEISS										
55.0	519+/-	55		28				0.5 1 0.5 1 0.5		
Run 4, Similar										
60		60								

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS
 25' on 8/31/17

Notes:



Boring Started: 08-28-2017

Boring Completed: 08-31-2017

Drill Rig: CME-850XR

Driller: Terracon/Allen S.

Project No.: J217P078

Exhibit: A-2

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON DATATEMPLATE.GDT 10/13/17

BORING LOG NO. B6-9E Glendale Road/Concord Ave East Page 3 of 5

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG	LOCATION PA-CH-0167.0000-RD 20170818-1 Latitude: 40.044422° Longitude: -75.643658° Approximate Surface Elev: 574 (Ft.) +/- ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
--------------------	--	--------------------	---------------------------------	--------------------	-----------------------	---------------------------	----------------	---------------------------	--------------------------------

DEPTH									
65.0	Run 4, Similar (continued)	65		28			0	1 0.5 0.5 0.5 1.5	
75.0	Run 5, Similar	70		25			0	0.5 1 1 1 0.5 2 1 1 1 1.5	
85.0	Run 6, Soft, highly weathered, yellowish gray, coarse grained, FELSIC GNEISS	75		30			0	1 1 1.5 1 1.5 1.5 1.5 2.5 1.5	
90	Run 7, Similar	85		24				1.5 1.5 2.5 1.5 1.5	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS
25' on 8/31/17



Boring Started: 08-28-2017	Boring Completed: 08-31-2017
Drill Rig: CME-850XR	Driller: Terracon/Allen S.
Project No.: J217P078	Exhibit: A-2

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON DATATEMPLATE.GDT 10/13/17

BORING LOG NO. B6-9E Glendale Road/Concord Ave East Page 4 of 5

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG	LOCATION PA-CH-0167.0000-RD 20170818-1 Latitude: 40.044422° Longitude: -75.643658° Approximate Surface Elev: 574 (Ft.) +/- ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
--------------------	--	--------------------	---------------------------------	--------------------	-----------------------	---------------------------	----------------	---------------------------	--------------------------------

	Run 7, Similar (continued)								
95.0	479+/-	95		24			7	1 1 1 1 1.5	
100.0	474+/-	100		16			0	1 1.5 1 2 2.5	
105.0	469+/-	105		48			10	0.5 1.5 2.5 1.5 3.5	
110.0	462+/-	110		28			4	1 1 1 2 3.5 2.5 2.5	
115.0	459+/-	115		36			27	1.5 3 2	
	Run 12, No recovery			0				1 2 1.5 2 2	

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

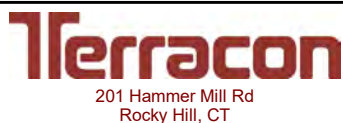
Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS
25' on 8/31/17



Boring Started: 08-28-2017	Boring Completed: 08-31-2017
Drill Rig: CME-850XR	Driller: Terracon/Allen S.
Project No.: J217P078	Exhibit: A-2

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON DATATEMPLATE.GDT 10/13/17

BORING LOG NO. B6-9E Glendale Road/Concord Ave East Page 5 of 5

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG	LOCATION PA-CH-0167.0000-RD 20170818-1 Latitude: 40.044422° Longitude: -75.643658° Approximate Surface Elev: 574 (Ft.) +/- ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
--------------------	--	--------------------	---------------------------------	--------------------	-----------------------	---------------------------	----------------	---------------------------	--------------------------------

DEPTH									
125.0	Run 12, No recovery (<i>continued</i>)	125		0			0	2 2 2 1.5 1.5	
135.0	Run 13, Similar to Run 11, grading to yellowish gray	130		46			10	1.5 1.5 2.5 2 1.5 2 1.5 1.5 3	
140.0	Run 14, Very hard, moderately severe to highly weathered, dark gray, fine grained, QUARTZITE	135		21			6	1.5 2 1.5 1.5 1.5	
	Boring Terminated at 140 Feet	140							

Stratification lines are approximate. In-situ, the transition may be gradual.
Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS
 25' on 8/31/17

201 Hammer Mill Rd
Rocky Hill, CT

Notes:	
Boring Started: 08-28-2017	Boring Completed: 08-31-2017
Drill Rig: CME-850XR	Driller: Terracon/Allen S.
Project No.: J217P078	Exhibit: A-2

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON DATATEMPLATE.GDT 10/13/17

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

Boring No.: B6-9E
 Sample No.: 1
 Sample Depth: 52 feet
 Sampling Date: 8/28/17

Lithology : Gneiss
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 0 min

Diameter: 1.93 in
 Length: 2.91 in
 L/D: 1.51
 End Area: 2.93 in²

Maximum Axial Load at Failure: 1,330 lb
 Compressive Strength: 455 psi
 Compressive Strength: 3.13 Mpa
 Unit Weight 130 pcf

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


Before the Test



After the Test



Drawing # : PA-CH-0167.0000-RD
 PO # : 20170818-1
 Crossing : Glendale Road/Concord Ave
 Spread : Spread 6

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No.	J217P078		Test Date:	9/13/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/13/2017

The information contained in this report may not be reproduced except in its entirety without the express written consent of Terracon, Inc. Reports are relevant only to the items tested and may not be attributed to other work. Testing was performed in general accordance with the stated ASTM test method.

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

Boring No.: B6-9E
 Sample No.: 3
 Sample Depth: 94 feet
 Sampling Date: 8/28/17

Lithology : Gneiss
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 7 min

Diameter: 1.97 in
 Length: 4.08 in
 L/D: 2.07
 End Area: 3.05 in²

Maximum Axial Load at Failure: 23,440 lb
 Compressive Strength: 7,690 psi
 Compressive Strength: 53.02 Mpa
 Unit Weight 153 pcf

Before the Test



After the Test



Drawing # : PA-CH-0167.0000-RD
 PO # : 20170818-1
 Crossing : Glendale Road/Concord Ave
 Spread : Spread 6

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 6
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	9/13/2017
Reviewed By :	L. Dwyer
Review Date :	10/13/2017

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

Boring No.: B6-9E
 Sample No.: 4
 Sample Depth: 106 feet
 Sampling Date: 8/28/17

Lithology : Gneiss
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 6 min

Diameter: 1.98 in
 Length: 2.86 in
 L/D: 1.44
 End Area: 3.08 in²

Maximum Axial Load at Failure: 18,870 lb
 Compressive Strength: 6,128 psi
 Compressive Strength: 42.25 Mpa
 Unit Weight 155 pcf

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


Before the Test



After the Test



Drawing # : PA-CH-0167.0000-RD
 PO # : 20170818-1
 Crossing : Glendale Road/Concord Ave
 Spread : Spread 6

Project:	Mariner East Pipeline	 77 Sundial Ave., Suite 401 W Manchester, New Hampshire	Performed by:	A. Suprunenko
Project No:	J217P078		Test Date:	9/13/2017
Location:	Spread 6		Reviewed By :	L. Dwyer
Client :	Directional Project Support Inc.		Review Date :	10/13/2017

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

Boring No.: B6-9E
 Sample No.: 5
 Sample Depth: 114 feet
 Sampling Date: 8/28/17

Lithology : Quartzite
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 27 min

Diameter: 1.99 in
 Length: 3.21 in
 L/D: 1.61
 End Area: 3.11 in²

Maximum Axial Load at Failure: 88,580 lb
 Compressive Strength: 28,480 psi
 Compressive Strength: 196.36 Mpa
 Unit Weight 161 pcf

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

Before the Test



After the Test



Drawing # : PA-CH-0167.0000-RD
 PO # : 20170818-1
 Crossing : Glendale Road/Concord Ave
 Spread : Spread 6

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 6
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	9/13/2017
Reviewed By :	L. Dwyer
Review Date :	10/13/2017

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

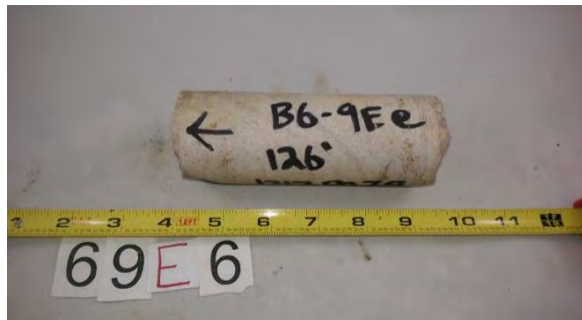
Boring No.: B6-9E
 Sample No.: 6
 Sample Depth: 126 feet
 Sampling Date: 8/28/17

Lithology : Quartzite
 Moisture Content : As received
 Lab Temperature : 70° F
 Loading Rate: 55 psi/s
 Time to Failure: 23 min

Diameter: 1.99 in
 Length: 4.40 in
 L/D: 2.21
 End Area: 3.11 in²

Maximum Axial Load at Failure: 76,010 lb
 Compressive Strength: 24,438 psi
 Compressive Strength: 168.50 Mpa
 Unit Weight 161 pcf

Before the Test



After the Test



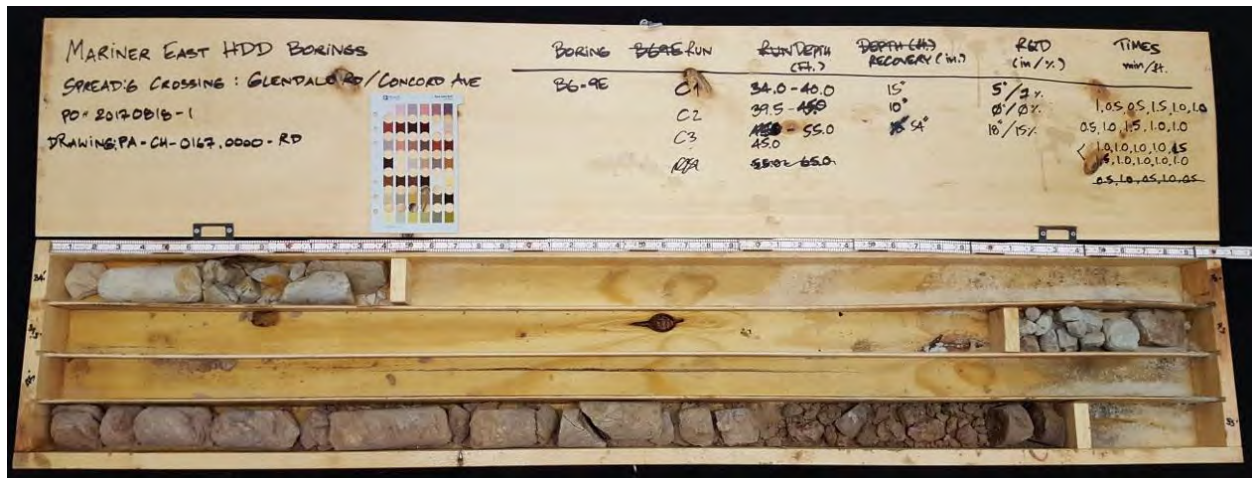
Drawing # : PA-CH-0167.0000-RD
 PO # : 20170818-1
 Crossing : Glendale Road/Concord Ave
 Spread : Spread 6

Project:	Mariner East Pipeline
Project No.	J217P078
Location:	Spread 6
Client :	Directional Project Support Inc.

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

Performed by:	A. Suprunenko
Test Date:	9/13/2017
Reviewed By :	L. Dwyer
Review Date :	10/13/2017

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Photograph 1: B6-9E, Samples C-1 to C-3 (34 to 55 feet)



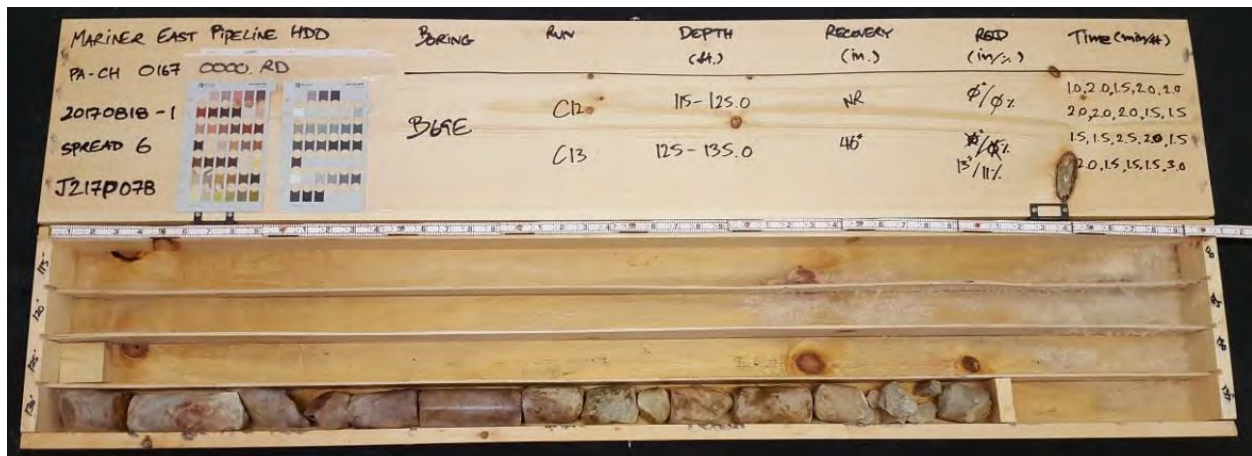
Photograph 2: B6-9E, Samples C-4 to C-5 (55 to 75 feet)



Photograph 3: B6-9E, Samples C-6 to C-7 (75 to 95 feet)



Photograph 4: B6-9E, Samples C-8 to C-11 (95 to 115 feet)



Photograph 5: B6-9E, Samples C-12 to C-13 (115 to 135 feet)



Photograph 6: B6-9E, Sample C-14 (135 to 140 feet)



**APPROXIMATE
BORING
LOCATION**

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

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

Terracon
Consulting Engineers & Scientists

201 Hammer Mill Road Rocky Hill, Ct 06067
PH. (860) 721-1900 FAX. (860) 721-1939

TEST BORING LOCATION PLAN

North Pottstown Pike HDD Cores B6-4W and B6-4E
PA-CH-0212.0000-RD
Chester County, Pennsylvania

Exhibit

A-2

EXPLORATION RESULTS

BORING LOG NO. B6-4W North Pottstown Pike West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG	LOCATION PA-CH-0212.0000-RD 20170804-19 Latitude: 40.038964° Longitude: -75.636034° Approximate Surface Elev: 353 (Ft.) +/- DEPTH _____ ELEVATION (Ft.) _____	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
--------------------	---	--------------------	---------------------------------	--------------------	-----------------------	---------------------------	----------------	---------------------------	--------------------------------

0.2	Gravel	0.5							
0.2	353+/-	0.5	362.5+/-	9.0	344+/-	16	7-11-9 N=20		1.5
FILL - POORLY GRADED SAND (SP) , brown SANDY LEAN CLAY (CL) , red brown, stiff									
9.0	344+/-	11.0	342+/-	14	1-3-7 N=10				1.0
CLAYEY SAND WITH GRAVEL (SC) , red brown, very stiff SANDY LEAN CLAY WITH GRAVEL (CL) , dark brown to red brown, stiff									
18.5	334.5+/-	16	1-2-3 N=5						2.0
SANDY LEAN CLAY (CL) , trace gravel, red brown, very soft to medium stiff									
30		17	1-1-3 N=4						1.0
30		9	1-2-3 N=5						1.0

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

WATER LEVEL OBSERVATIONS
Not encountered

Notes:



Boring Started: 08-15-2017	Boring Completed: 08-16-2017
Drill Rig: CME-850XR	Driller: Terracon/Allen S.
Project No.: J217P078	Exhibit: A-1

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON DATATEMPLATE.GDT 10/13/17

BORING LOG NO. B6-4W North Pottstown Pike West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG	LOCATION PA-CH-0212.0000-RD 20170804-19 Latitude: 40.038964° Longitude: -75.636034° Approximate Surface Elev: 353 (Ft.) +/- ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
-------------	---	-------------	--------------------------	-------------	----------------	--------------------	---------	--------------------	-------------------------

	SANDY LEAN CLAY (CL), trace gravel, red brown, very soft to medium stiff (continued)	35		9		1-1-1 N=2			1.0
		40		18		1-1-2 N=3			1.5
		45		0		wor-1-2			
	Sand seam at 49.5 feet	50		17		1-2-3 N=5			1.75
		55		18		4-4-3 N=7			0.75
58.5	294.5+/-	60		15		1-2-6 N=8			1.75
	SANDY LEAN CLAY (CL), trace gravel, red brown to dark brown to black, soft to medium stiff								

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS
<i>Not encountered</i>



Boring Started: 08-15-2017	Boring Completed: 08-16-2017
Drill Rig: CME-850XR	Driller: Terracon/Allen S.
Project No.: J217P078	Exhibit: A-1

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON_DATATEMPLATE.GDT 10/13/17

BORING LOG NO. B6-4W North Pottstown Pike West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG	LOCATION PA-CH-0212.0000-RD 20170804-19 Latitude: 40.038964° Longitude: -75.636034° Approximate Surface Elev: 353 (Ft.) +/- DEPTH _____ ELEVATION (Ft.) _____	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
--------------------	---	--------------------	---------------------------------	--------------------	-----------------------	---------------------------	----------------	---------------------------	--------------------------------

	SANDY LEAN CLAY (CL) , trace gravel, red brown to dark brown to black, soft to medium stiff (<i>continued</i>)	65		18		1-1-1 N=2			1.5
		70		18		1-1-3 N=4			2.25
		75		18		1-2-3 N=5			2.0
		80		18		2-3-5 N=8			0.75
82.0	271+/-								
	SANDY LEAN CLAY WITH GRAVEL (CL) , red brown, very stiff								
85.0	268+/-	85		6		11-13-8 N=21			
	SANDY LEAN CLAY (CL) , trace gravel, with sand seams, red brown, stiff								
		90		18		3-6-5 N=11			

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

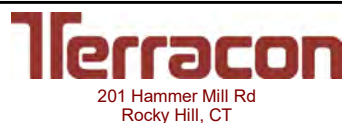
Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS
Not encountered



Boring Started: 08-15-2017

Boring Completed: 08-16-2017

Drill Rig: CME-850XR

Driller: Terracon/Allen S.

Project No.: J217P078

Exhibit: A-1

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON_DATATEMPLATE.GDT 10/13/17

BORING LOG NO. B6-4W North Pottstown Pike West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG	LOCATION PA-CH-0212.0000-RD 20170804-19 Latitude: 40.038964° Longitude: -75.636034° Approximate Surface Elev: 353 (Ft.) +/- DEPTH _____ ELEVATION (Ft.) _____	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
--------------------	---	--------------------	---------------------------------	--------------------	-----------------------	---------------------------	----------------	---------------------------	--------------------------------

94.5	<p>SANDY LEAN CLAY (CL), trace gravel, with sand seams, red brown, stiff <i>(continued)</i></p>	95		17		8-6-50/5"			
258.5+/-	<p>SANDY LEAN CLAY WITH GRAVEL (CL), brown to red brown, hard, (DEGRADED BEDROCK), occasional sand seams Attempted to core from 96 to 110 feet. Frequent quartzite boulders.</p>	100		6			0	1 1 15s 8s	
		105		10			0	0.5 0.5 0.5 1	
		110		14			0	1.5 1 2.5 1 1.5	
		115		10		10-10-22 N=32			
		120		18		8-16-37 N=53			

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

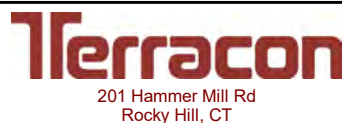
Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS
Not encountered



Boring Started: 08-15-2017

Boring Completed: 08-16-2017

Drill Rig: CME-850XR

Driller: Terracon/Allen S.

Project No.: J217P078

Exhibit: A-1

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON_DATATEMPLATE.GDT 10/13/17

BORING LOG NO. B6-4W North Pottstown Pike West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 6

GRAPHIC LOG	LOCATION PA-CH-0212.0000-RD 20170804-19 Latitude: 40.038964° Longitude: -75.636034° Approximate Surface Elev: 353 (Ft.) +/- DEPTH _____ ELEVATION (Ft.) _____	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
--------------------	---	--------------------	---------------------------------	--------------------	-----------------------	---------------------------	----------------	---------------------------	--------------------------------

DEPTH	SANDY LEAN CLAY WITH GRAVEL (CL) , brown to red brown, hard, (DEGRADED BEDROCK), occasional sand seams (<i>continued</i>)	125				21-23-34 N=57			
130.0	Boring Terminated at 130 Feet	130				8-10-16 N=26			

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

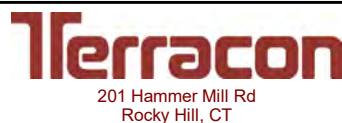
Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

Notes:

WATER LEVEL OBSERVATIONS
<i>Not encountered</i>



Boring Started: 08-15-2017	Boring Completed: 08-16-2017
Drill Rig: CME-850XR	Driller: Terracon/Allen S.
Project No.: J217P078	Exhibit: A-1

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL - J217P078 - SPREAD 6.GPJ TERRACON_DATATEMPLATE.GDT 10/13/17



Photograph 1: B6-4W, Samples C-1 to C-3 (96 to 110 feet)



Tetra Tech
 240 Continental Drive
 Suite 200
 Newark, DE 19713

TETRA TECH, INC.

OW-1

Northing: 264073.012
Easting: 2560223.516

Shallow Well Elevation (TOC): 355.575
Deep Well Elevation (TOC): ---

Starting Date: 6/21/17
Completion Date: 6/23/17
Project Name: N/A

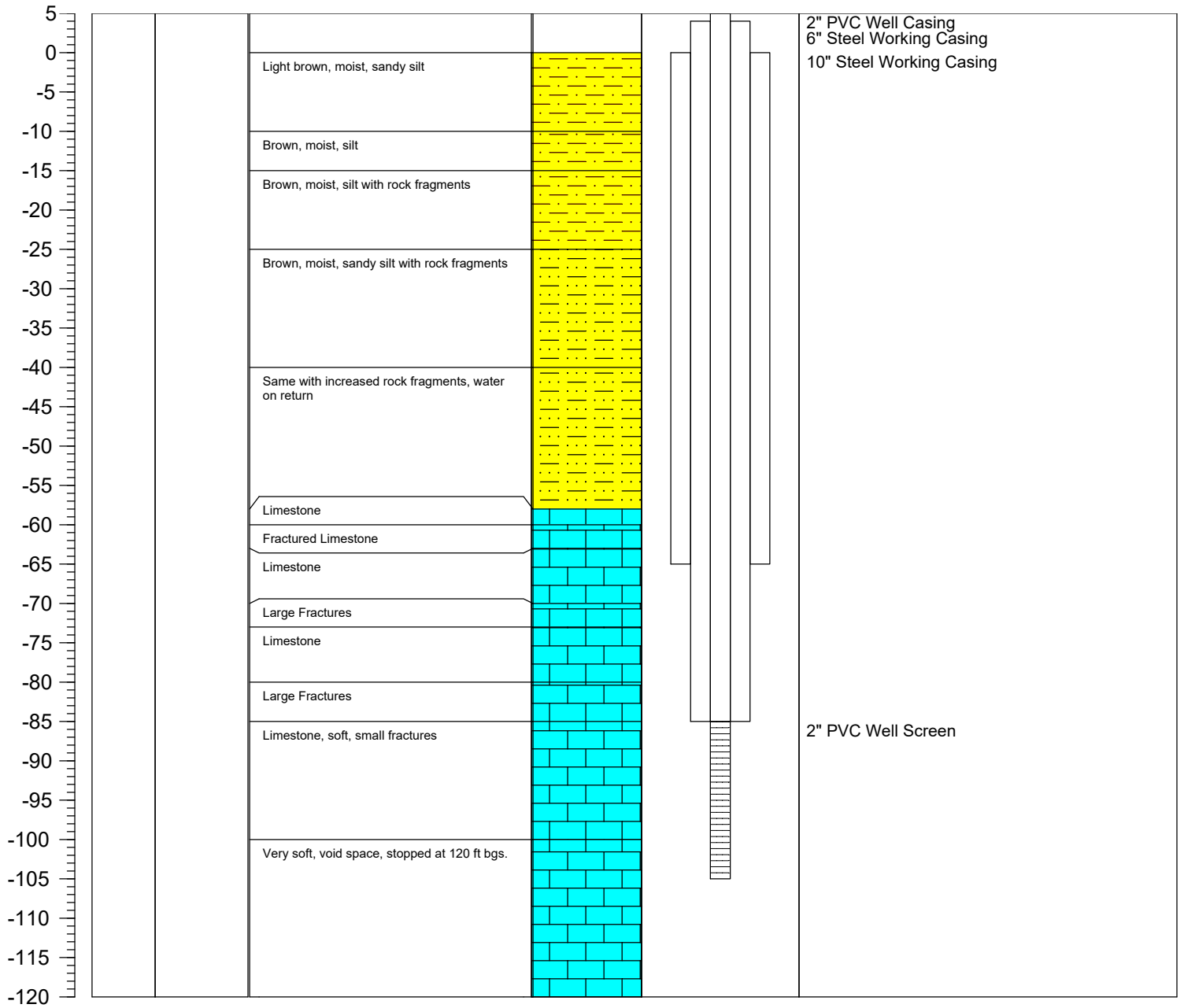
Supervisor: CWS
Drilling Co.: Raab Well Drilling
Sample ID: N/A

Elevation (Ground): 355.575
Elevation (Outer-casing): 360.368

PID Reading
 Moisture Content

Lithology

Well Construction



Total Depth = 120



Attachment C

Skelly & Loy, Inc., Seep Investigation Memorandum



SEEP INVESTIGATION MEMORANDUM



To: Josh Prosceno
From: Ben Berra
CC: Andy Brookens, Pat Green
Subject: PPP HDD-360 Seep Evaluation
Date: July 2, 2018

Skelly and Loy, Inc. conducted an investigation of a seep area on June 28, 2018, in proximity to HDD-360 in West Whiteland Township, Chester County, Pennsylvania. The area of investigation is located at approximately 40.0392° north latitude and -75.6360° west longitude. The subject seep area and associated drainage pattern is located within the roadway right-of-way (ROW) on the north side of Shoen Road.

The seep investigation included both off-site and on-site reviews. The off-site investigation consisted of reviewing the following existing information: USGS mapping (Malvern); USGS StreamStats application; U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) mapping; Chester County Soil Survey; readily available (Internet) aerial photography; Pennsylvania Department of Environmental Protection eMapPA online application (www.emappa.dep.state.pa.us); United States Department of Agriculture – Natural Resources Conservation Service Web Soil Survey (<http://websoilsurvey.sc.egov.usda.gov>); and the Pennsylvania County Listing of Hydric Soils. The off-site review of the USGS mapping revealed the site is within the Valley Creek Watershed, and the reviewed NWI mapping did not identified any NWI wetlands in the study area.

The off-site review of the soil survey revealed that the study area is mapped as Edgemont channery loam (EdB) soils. According to the Pennsylvania County Listings of Hydric Soils, Edgemont soils are not considered hydric. Edgemont soils are known to have minor components of Buchanan and Andover soils. Buchanan soils are not considered hydric, but Andover soils are considered hydric soils. A review of the floodplain layer on the eMapPA online application indicates that this project is not located within the mapped 100-year FEMA floodplain.

The on-site seep investigation primarily consisted of a wetland evaluation to determine if the seep is a recent development or a persistent hydrologic condition that predates the HDD activities. The wetland evaluation was conducted using the Routine On-Site Wetland Delineation Method described in the U.S. Army Corps of Engineers' (USACE) Wetland Delineation Manual, Technical Report Y-87-1 (1987) and the Regional Supplement to the USACE's Wetland Delineation Manual: Eastern Mountains and Piedmont Region (2012). Dominant vegetation, soil characteristics, and indicators of hydrology were evaluated for

potential wetland and upland habitat in the study area. The Munsell Soil Color chart was used to determine matrix and mottle colors for each soil sample.

The land use/land cover features in the vicinity of the study area include single-family homes, townhouse/apartment complexes, wooded lots, mowed lawn, flat and hilly terrain, primary and secondary roadways, driveways and parking lots. The seep area and associated drainage pattern is located at a point of inflection in the terrain where the toe of a hillslope intersects a relatively flat, gently sloping mowed grass area abutting Shoen Road. The origin of the seep is somewhat diffuse and the associated drainage pattern conveys hydrology from the seep to the east/northeast along Shoen Road. The drainage pattern is 1 to 2 feet wide and extends approximately 250 feet from the seep to its confluence with a small, spring-fed unnamed tributary to Valley Creek.

In proximity to the origin of the seep, vegetation includes burdock, curly dock, sedge, grass, and mile-a-minute. Soil pits in the area of the seep revealed silty clay loams having a dark olive brown (2.5Y3/3) and olive brown (2.5Y4/3) mixed matrix with no mottles from 0 to 4 inches, and a dark grayish brown (2.5Y4/2) matrix with olive brown (2.5Y4/4) mottles from 4 to 10 inches. From 10 to 16 inches, tight silt loams were present having a grayish brown (2.5Y5/2) and light olive brown (2.5Y5/3) mixed matrix with olive brown (2.5Y4/4) mottles. The soils are saturated and inundated, contained oxidized root channels, and there was water in the soil pits at 1 inch.

The vegetative composition of facultative-wet, facultative, and facultative-up plants along with the soils that exhibit hydric characteristics (redoximorphic features, oxidized rhizospheres, saturated and inundated conditions) support the theory that some form of an intermittent seep has been present at the current location for several years. Furthermore, the drainage pattern associated with the seep contains water-stained leaves in various stages of decomposition that appear to be from multiple years.

While the primary seep investigated is a low-flow, intermittent source of hydrology to the area, there was also drainage pattern evidence observed upgradient of the seep, along the hillside, where other (less regular) seasonal seeps and/or ephemeral surface water/run-off hydrologic contributions flow downslope. These additional seeps and surface water flows are intercepted by the primary seep and aforementioned drainage pattern and conveyed to the east along with hydrology from the primary seep.

Based on the evidence observed, it is our opinion that the toe-of-slope seep and associated drainage pattern were present in the area of investigation prior to 2017. Although the exact quantity of hydrology related to this seep prior to the initiation of HDD-360 cannot be determined, it is reasonable to assume what is currently seeping from the area is similar to the seepage of hydrology prior the initiation of the HDD.



July 2, 2018

Ben Berra – Director Natural Resource Analysis

Date



Attachment D

Rettew Geophysical Survey Report

February 27, 2020

Mr. Nicolas J. Bryan, PLS
Energy Transfer
101. W. Third St., 3rd Floor
Williamsport, PA 17701

RE: Geophysical Survey
Sunoco Pipeline, LP Pipeline Project
Horizontal Directional Drill S3-0360 Biddle Drive – Downstream
Uwchlan Township, Chester County, Pennsylvania
RETTEW Project No. 096303002

Engineers

Environmental
Consultants

Surveyors

Landscape
Architects

Safety
Consultants

Dear Mr. Bryan:

RETTEW Associates, Inc. completed a multi-technique geophysical survey at the downstream S3-0360 Biddle Drive horizontal directional drill (HDD) site. Recent sightings of groundwater seepage adjacent to Shoen Road, east of the HDD, have been reported. The purpose of the survey was to detect and delineate fractures, soft zones, or subsurface voids that could potentially contribute to possible earth features at the site or could act as preferred pathways for water flow. The following report, figures, and attachments describe the methods and results of the investigation.

EXECUTIVE SUMMARY

The multi-technique geophysical survey was completed on February 12, 2020. Three different geophysical techniques were utilized to detect and delineate subsurface voids or low-density zones and provide a bedrock profile. These methods, and their general results, are as follows:

- Microgravity delineated high- and low-density zones. The low-density zones may indicate deeper rock, possibly resulting from deeper weathering along fractures. Two adjacent distinct gravity lows were identified and are recommended for further investigation.
- Seismic refraction and multi-spectral analysis of surface waves (MASW) results confirmed the presence of an undulating bedrock surface likely due to deeper weathering along suspected fracture zones, but not apparent extremely-low-velocity zones of the type associated with voids or incipient earth features.
- Electrical resistivity imaging (ERI) identified a relatively conductive surface layer over a discontinuous mildly resistive layer, with the discontinuities possibly supporting the presence of fracture zones. The lowest resistivities were recorded in the shallow subsurface adjacent to Shoen Road, and are presumed to represent saturated (and therefore electrically conductive) soils. The shape of the low-resistivity zone mimics the curvature of the HDD path as it rises into the entry/exit pit, and it extends northwards to approximately where the path seems to emerge from high seismic velocity material (possibly rock).

Results from the geophysical techniques are consistent with each other, and with the geology as mapped by the PA Geological Survey; all suggesting that the local bedrock is fractured. Subsurface low resistivities



adjacent to Shoen Road are consistent with possible water flowing along the HDD path and emerging into the soil north of Shoen Road.

SITE DESCRIPTION

The Biddle Drive HDD site is located between Devon Drive and Shoen Road in Uwchlan, Chester County, Pennsylvania (see **Figure 1**). A geophysical survey was conducted over accessible areas of the southeast (downstream) HDD exit/entry location (**Figure 2**). The actual exit/entry area was inaccessible due to wooden and plastic matting.

The site bedrock geology consists of Cambrian-aged Chickies Formation just south of the geologic contact with the Ledger Formation (The Geologic Map of Pennsylvania, PA Department of Conservation and Natural Resources Geology Interactive Map, 2017 – see **Figure 2**). The Chickies Formation is described as a light-gray, hard, massive, Scolithus-bearing quartzite and quartz schist with a thin, interbedded dark slate at top and conglomerate (Hellam Member) at base (Berg et al., 1980). The Geologic Map of Pennsylvania (PA Department of Conservation and Natural Resources Geology Interactive Map, 2017) shows several contacts and major fractures and faults within one mile of the survey area, as seen in the geologic inset on **Figure 2**, upper right (Ibid). There is considerable gain in elevation going north (upstream) from the site and location of apparent seepage (see **Figure 1**).

MICROGRAVITY SURVEY

Microgravity meters measure very small local variations in gravity. Several factors can locally affect the acceleration of gravity. One factor is the local density or mass distribution of the bedrock or soils beneath the meter. Gravity highs (mass excesses) commonly represent locally shallow bedrock pinnacles or float blocks in the soil profile or zones of particularly massive bedrock. Gravity lows (mass deficiencies) may represent locally deep bedrock cutters, or clay seams where soil displaces bedrock; air-, water- or mud-filled voids within bedrock; stoping voids in the soil above bedrock; or zones where soils have been made less dense by removal of fines. Voids below the top-of-rock are not expected in the mapped gneiss bedrock.

The residual microgravity data are shown on **Figure 3**. The values depict the general plan-view shallow mass distribution beneath the survey area. Relative lower values (red) represent local mass deficiencies (air- or clay-filled voids, or locally deeper, disturbed or poorly-compacted soils). Higher values (blue) represent local mass excesses (shallow bedrock or erosional remnant float blocks). Specific survey parameters are listed in **Appendix A**.

SEISMIC MASW AND REFRACTION SURVEY

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

The seismic survey consisted of three profiles parallel to the 16-inch alignment (see blue triangles, **Figure 2**). Color-contour velocity models of the seismic profiles for the seismic refraction and MASW are presented on **Figures 4** and **5**, respectively. The vertical scale represents relative elevation in feet, and the horizontal axis represents an along-profile distance in feet. The color contours represent average seismic

velocity variations (compressional or P-wave velocities for refraction, and shear or S-wave velocities for MASW), with increasing velocities from blue to yellow to orange to brown (seismic refraction profiles, **Figure 4**), and purple to grey to tan to brown (seismic MASW profiles, **Figure 5**). Please note that high- and low-velocity data along the first and last fifteen feet of any profile have higher uncertainty. Specific seismic refraction and MASW survey parameters are listed in **Appendix A**.

ERI SURVEY

Electrical resistivity measurements involve driving an electrical current into the ground using current electrodes at the ground surface. The apparent resistivity of the subsurface is determined by measuring the potential difference, or voltage, between two potential electrodes with a known separation and position/orientation relative to the current electrodes. The depth and volume of the subsurface zone represented by the measured apparent resistivity is a function of the geometry of the current and potential electrodes. Apparent resistivities are converted to model or true resistivities by performing a joint inversion of all the measured apparent resistivities along a profile (or profiles, in the case of 3D resistivity).

Due to site access limitations on the eastern portion of the survey area (Shoen Road), a 2D resistivity survey was performed only on the western portions of the HDD (see orange dots, **Figure 2**). The apparent resistivity data were mathematically inverted using EarthImager 2D by AGI to provide a resistivity model of the subsurface. **Figure 6** shows three resistivity profiles. Specific ERI survey parameters are listed in **Appendix B**.

RESULTS

The microgravity data are depicted on **Figure 3**, as plan-view color contours representing the relative density of the subsurface, with blue for high-density, green for “site normal,” and red for locally low-density areas. The microgravity data display a subtle alternating pattern of high- and low-gravity anomalies perpendicular to the pipelines. These gravity highs and lows could represent an alternating pattern of deeper and shallower rock, with the gravity lows representing deeper (and possibly less dense) soils, indicative of fracture zones. These areas would present a slightly elevated risk for potential subsurface voids as well as pathways for water migration. There are distinctly negative (low density - red) anomalies over the pipeline at 15081+00 and just short of 15081+50. These may be roughly where the HDD emerges from high-velocity material (rock), and warrant direct investigation.

The seismic refraction data are presented as cross-sectional profiles on **Figure 4**. The data indicate a general three-layer stratigraphy consisting of a residual or sedimentary soil mantle, a weathered rock zone, and competent bedrock. The uppermost layer has average P-wave velocities generally less than 5,000 feet per second (fps) with a thickness of approximately 25-35 feet. This is consistent with a relatively compact soil mantle (shaded blue to yellow). The deepest layers have velocities over 10,000 fps (shaded orange to brown), consistent with competent bedrock (Carmichael, R. S., 1989). The seismic refraction results show multiple low-velocity zones indicative of possible fracture zones. The suspected fracture zones are highlighted on the seismic profiles in magenta.

The MASW seismic cross sections are presented on **Figure 5**. The MASW velocity models show lateral velocity changes within the bedrock layer across the profiles and are relatively consistent with the seismic refraction models. Low-velocity zones below the bedrock surface could indicate fractures but are not indicative of open voids.

The electrical resistivity results are shown in **Figure 6**. The electrical profiles show a general three-layer model with a relatively conductive surface layer over a discontinuous mildly resistive layer over a more conductive layer. The upper layer is relatively discontinuous, with irregularities that could represent near-surface disturbances given the site development history. The deeper conductive (blue) anomalies below the inferred top-of-rock may represent water- or clay-bearing fractures or weathered seams within bedrock. The lowest resistivities are on the south end of the profiles, and extend from roughly where the HDD may emerge from rock to the south end of the site on Shoen Road – where possible seepage has been observed. This is consistent with wet soils.

CONCLUSIONS

In general, the geophysical survey results display anomalies along the alignment indicative of fractures that are possible locations for slightly-elevated subsidence hazards. **Figure 7** summarizes the anomalous areas with various colored double-arrows. Overlapping and/or adjacent arrows, and the gravity mass deficiency anomalies (red hachures) indicate the highest risk of subsidence and possible enhanced water migration. The location of these anomalies at the bottom of the hill increase the possibility of water seepage out of the ground rather than increased infiltration into the ground. RETTEW recommends further geo-technical investigations in the three areas labeled “A” through “C” as well as continued monitoring of all the anomalous locations as further drilling is conducted in the area. Area “C” is cited for further investigation due to its location beneath the road and proximity to the exit/entry. The resistivity profiles are consistent with water emerging from the HDD in rock and saturating the soils. The elevated topography (and presumably water table) could provide the hydraulic head that is driving this emergence and seepage.

LIMITATIONS

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

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



Charles H. Rhine, MSc, PG
Senior Project Manager



Timothy D. Bechtel, PhD, PG
Senior Project Manager



Felicia Kegel Bechtel, MSc, PG
Director of Geophysics

Enclosures

Figure 1: Topographic Base Map
Figure 2: Data Coverage Map and Geologic Setting
Figure 3: Residual Microgravity Results
Figure 4: Seismic Refraction Survey Results
Figure 5: Seismic MASW Survey Results
Figure 6: Electrical Resistivity Survey Results
Figure 7: Geophysical Survey Results Summary
Appendix A: Geophysical Survey Parameters
Appendix B: Introduction to Seismic Refraction

References

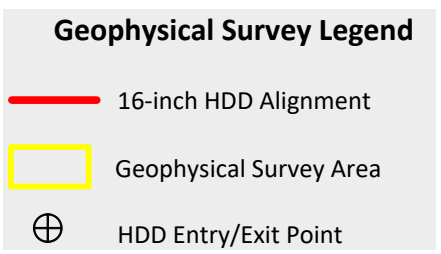
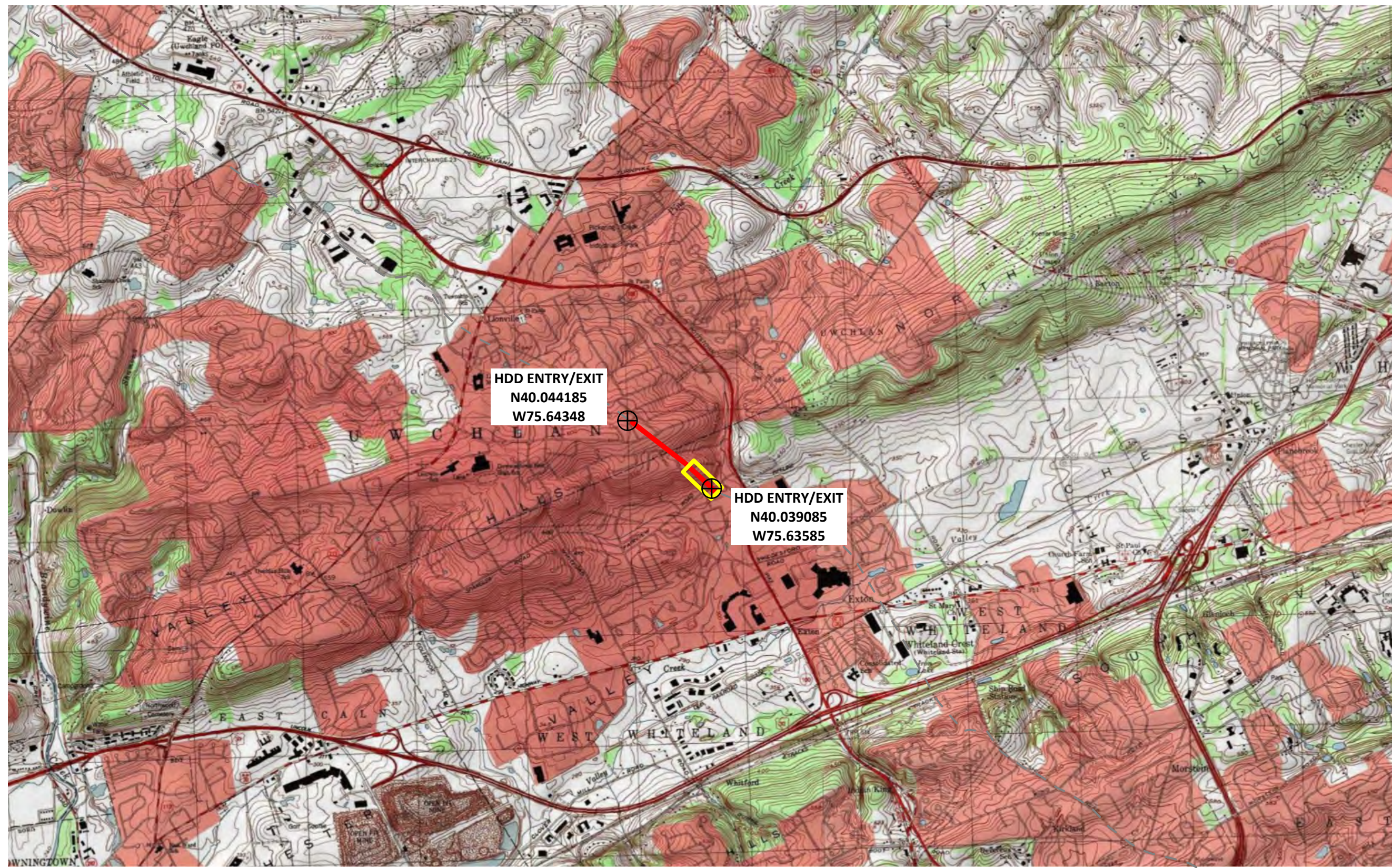
Berg, T.M., Edmunds, W.E., Geyer, A.R., and others, 1980, Geologic Map of Pennsylvania, PA Geological Survey, 4th series.

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

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

Z:\Shared\Projects\09630\096303002 - SL - Spread 6 HDDs Geophysics\GP\S3-0360_Biddle Drive (Shoen Rd)\Report\REPORT PIECES\S3-0360 Biddle Drive Geophysics Final Report 2020-02-27.docx

ENCLOSURES



Notes:
 Basemap from USGS Topographic WMS Server, extracted 09/2019.

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 DRAWN BY: CHR
 DATE: 02/25/2020
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 FIGURE NO. 1 of 7

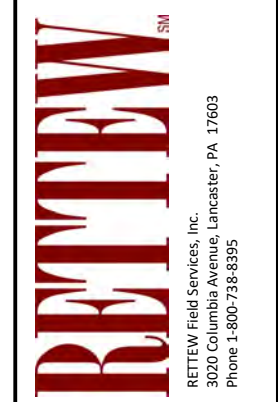
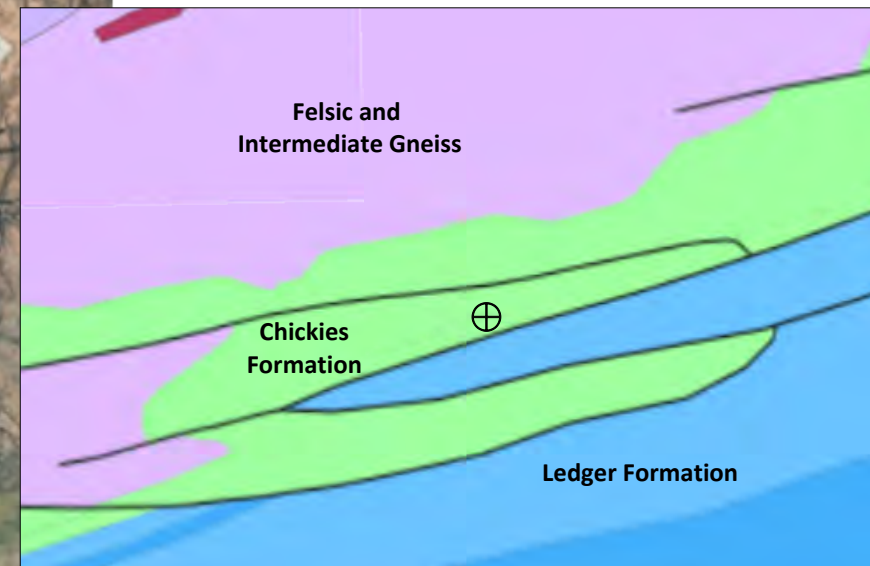
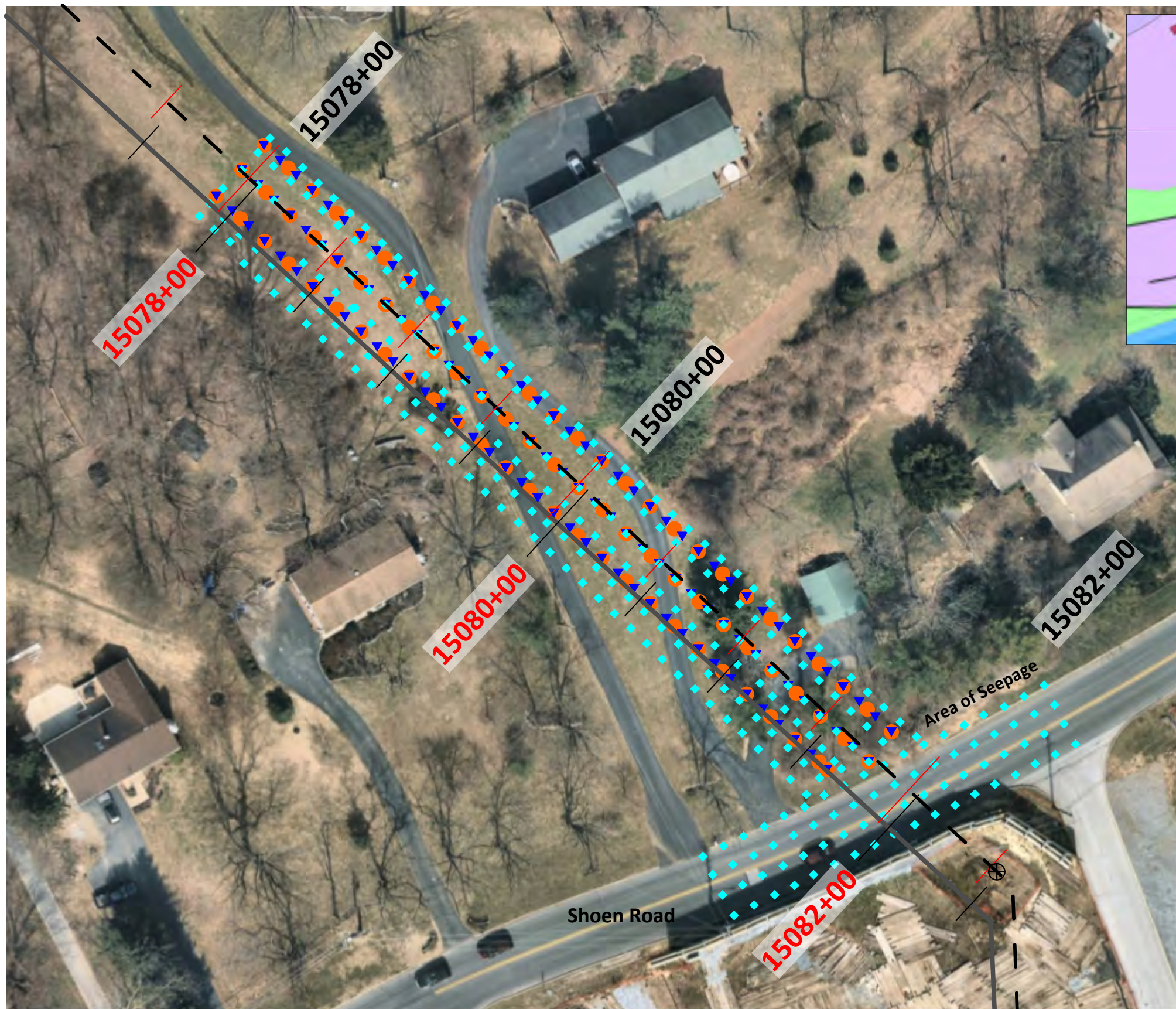
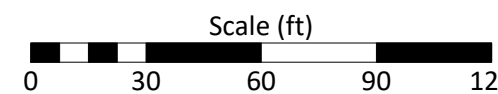


Figure 1: Topographic Basemap
 Biddle Drive
 S3-0360
 CHESTER COUNTY, PA



Geophysical Survey Legend

- Electrical Resistivity Station
- ◆ Microgravity Station
- ▼ Seismic Geophone Location
- 16-inch HDD from As-Built
- 16-inch Proposed Pipeline
- 20-inch Proposed Pipeline
- ⊕ HDD Entry/Exit Point



Notes:

- Basemap from Nearmap, extracted February 2020.
- Survey profiles/stations from RTK survey by RETTEW.
- Geologic information from DCNR WMS Server, extracted 12/2019.

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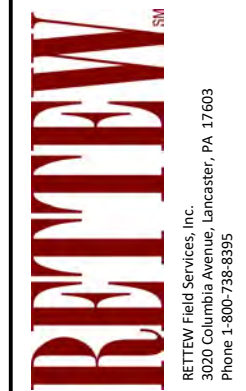
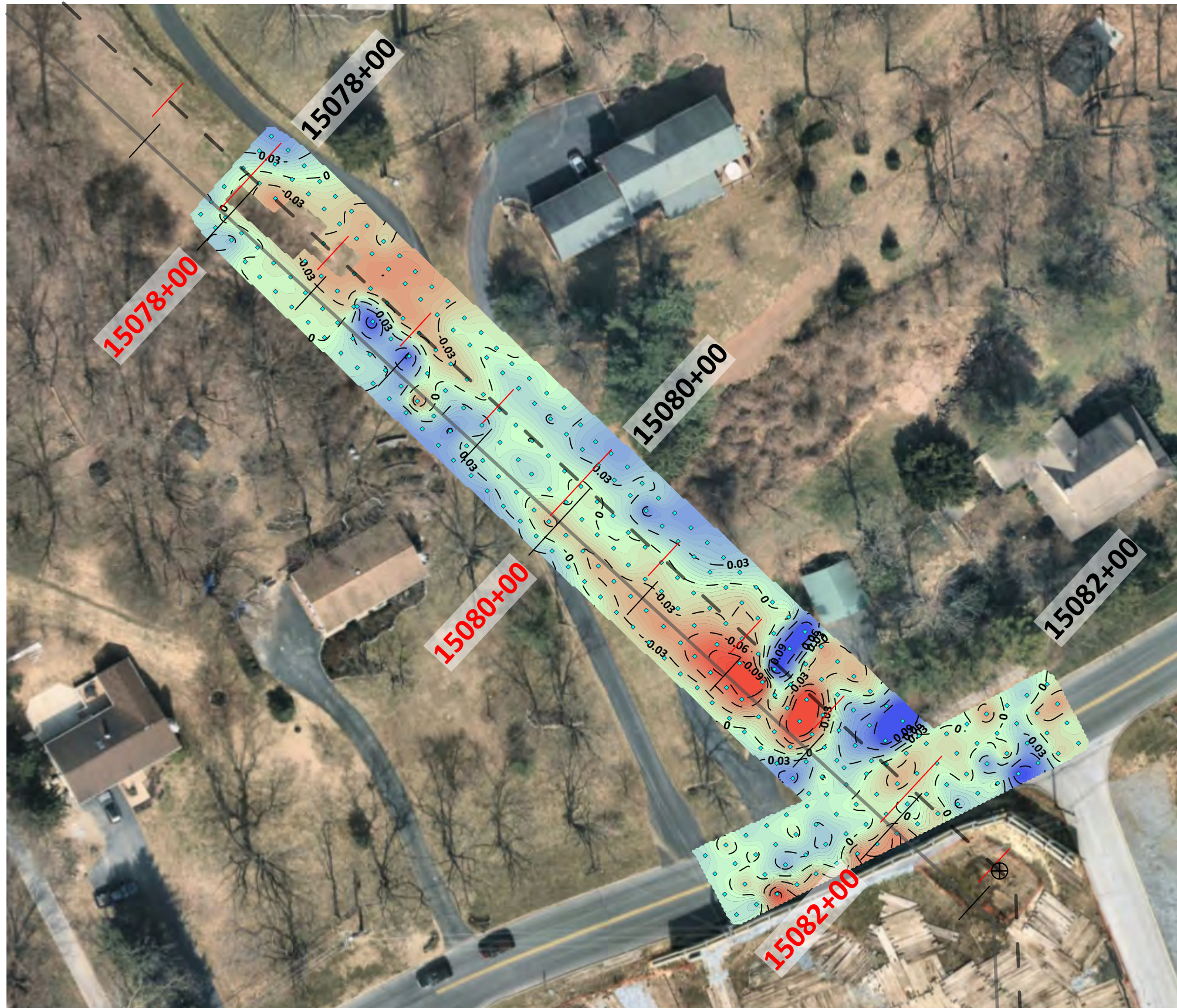


Figure 2: Data Coverage Map and Geologic Setting

Biddle Drive
S3-0360

CHESTER COUNTY, PA

LW/CHAN TOWNSHIP



Geophysical Survey Legend

- ⊕ Exit/Entry
- ◆ Microgravity Station
- 16-inch HDD from As-Built
- - - 16-inch Proposed Pipeline
- 20-inch Proposed Pipeline

SURVEY DATE: 02/12/2020
 RETTEW No.: 096303002
 REVIEWED BY: FKB
 DRAWN BY: CHR
 DATE: 02/25/2020
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 FIGURE NO. 3 of 7



Figure 3: Residual Microgravity

Biddle Drive
 S3-0360

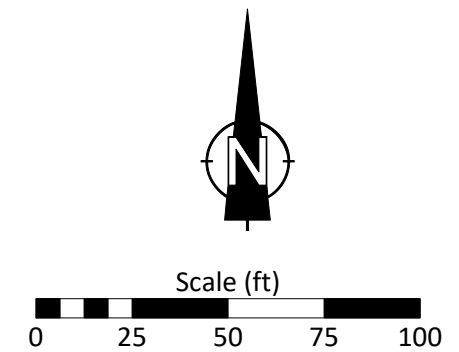
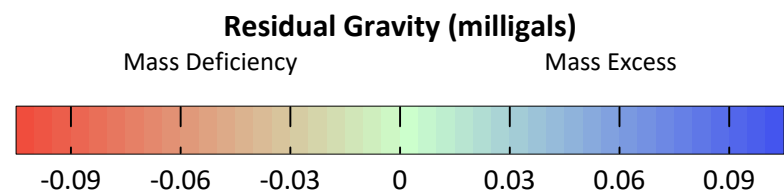
CHESTER COUNTY, PA

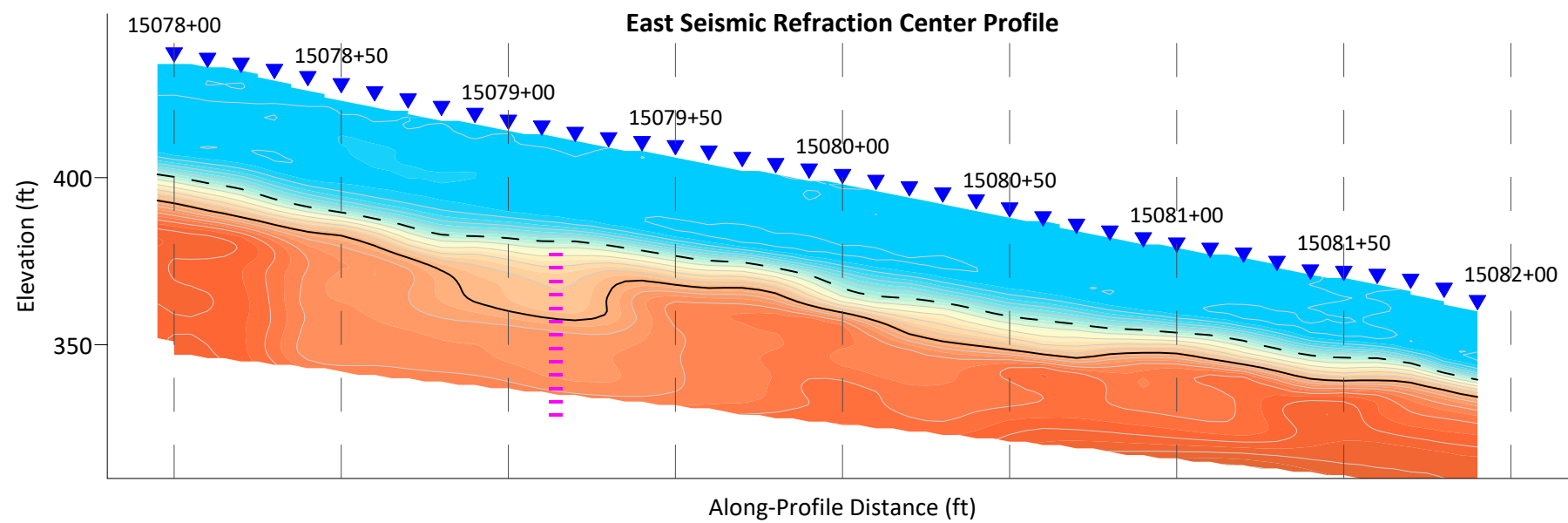
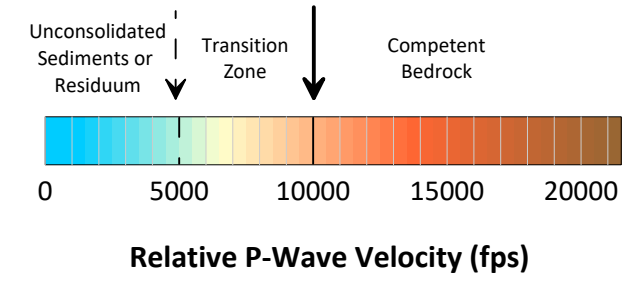
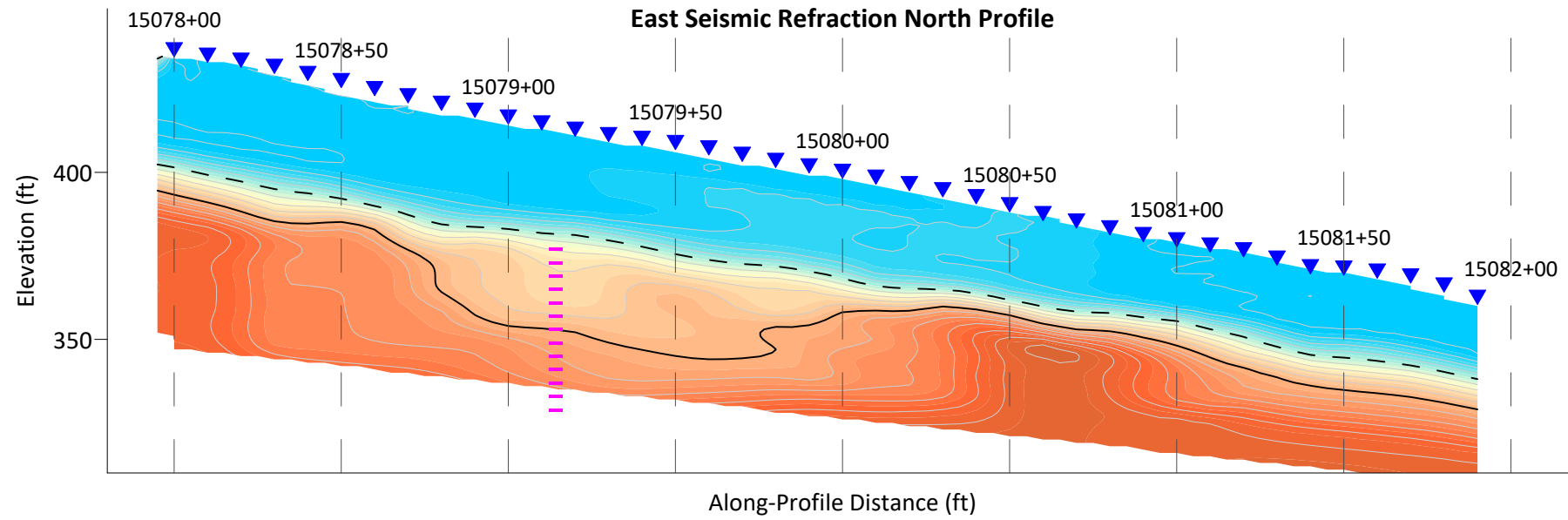
LUWCLIAN TOWNSHIP

Notes:

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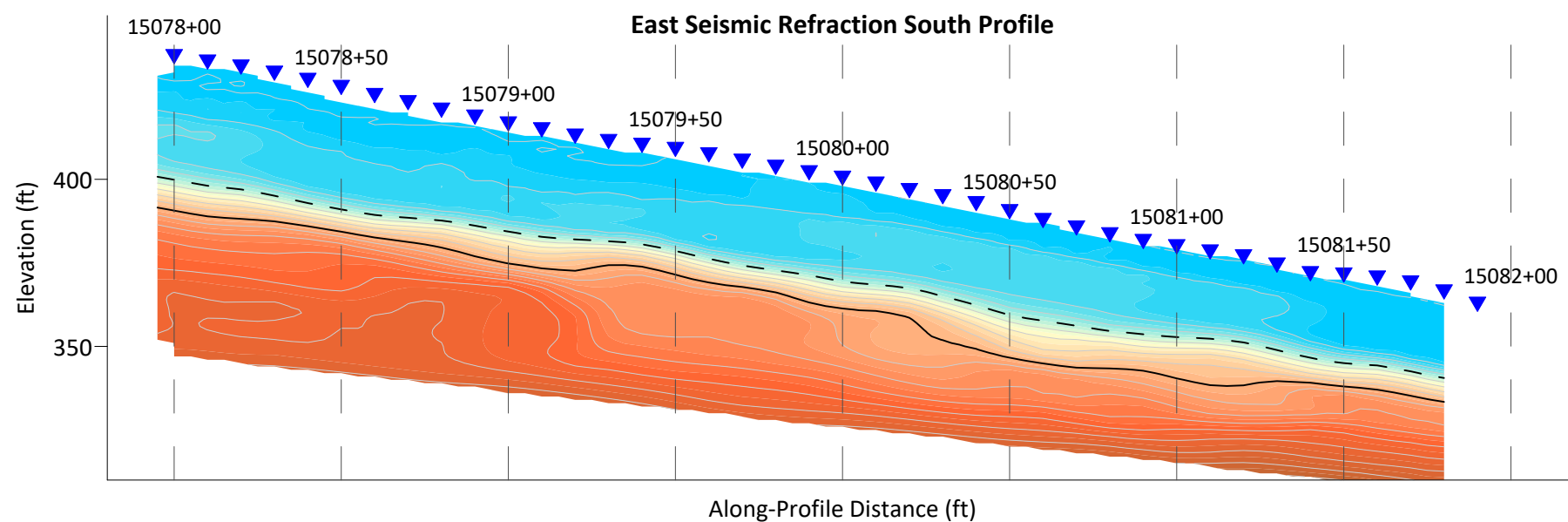
Data from Scintrex CG-5 microgravity meter with complete Bouguer correction.





Geophysical Survey Legend

- Possible Fracture Zone
- 16-inch HDD (from As-Built)
- 15338+00 Pipeline Station Number



Notes:

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

Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic and ray-tracing inversions.

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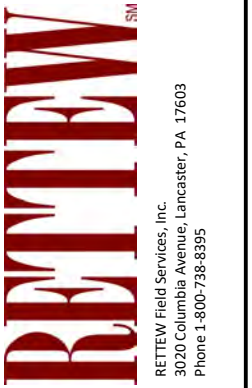
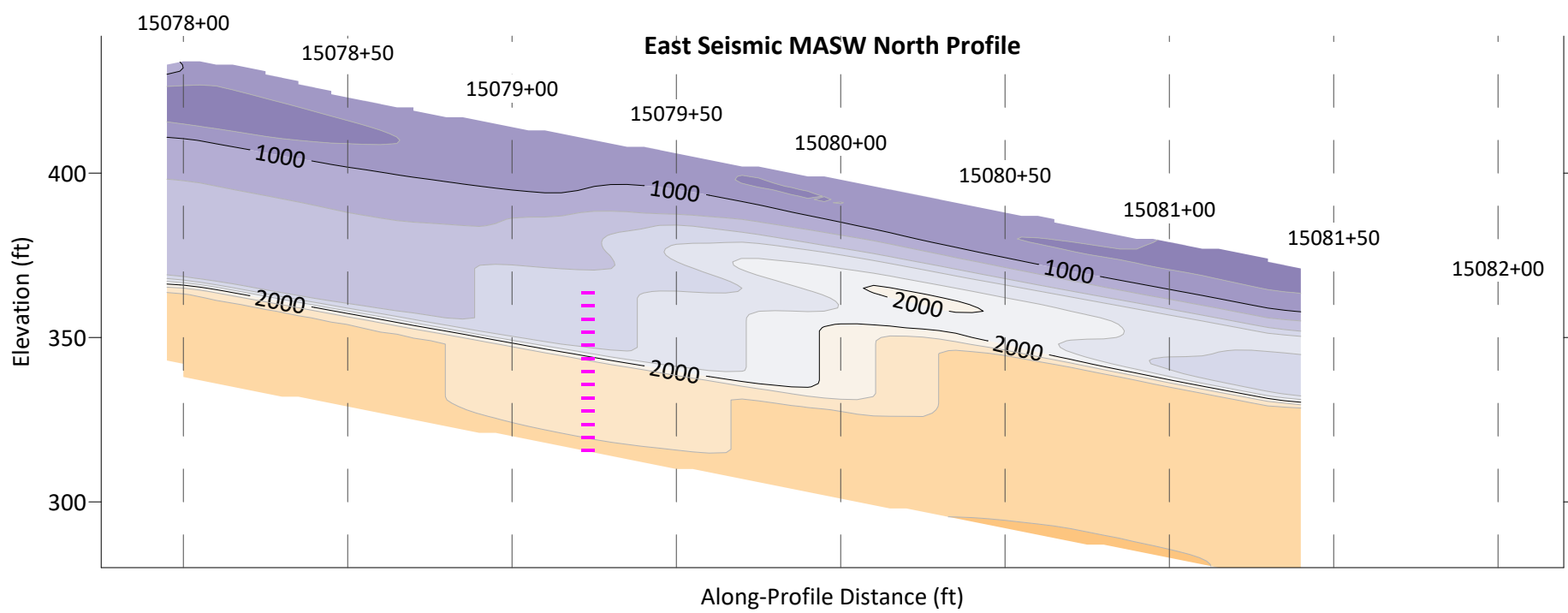


Figure 4: Seismic Refraction Profiles

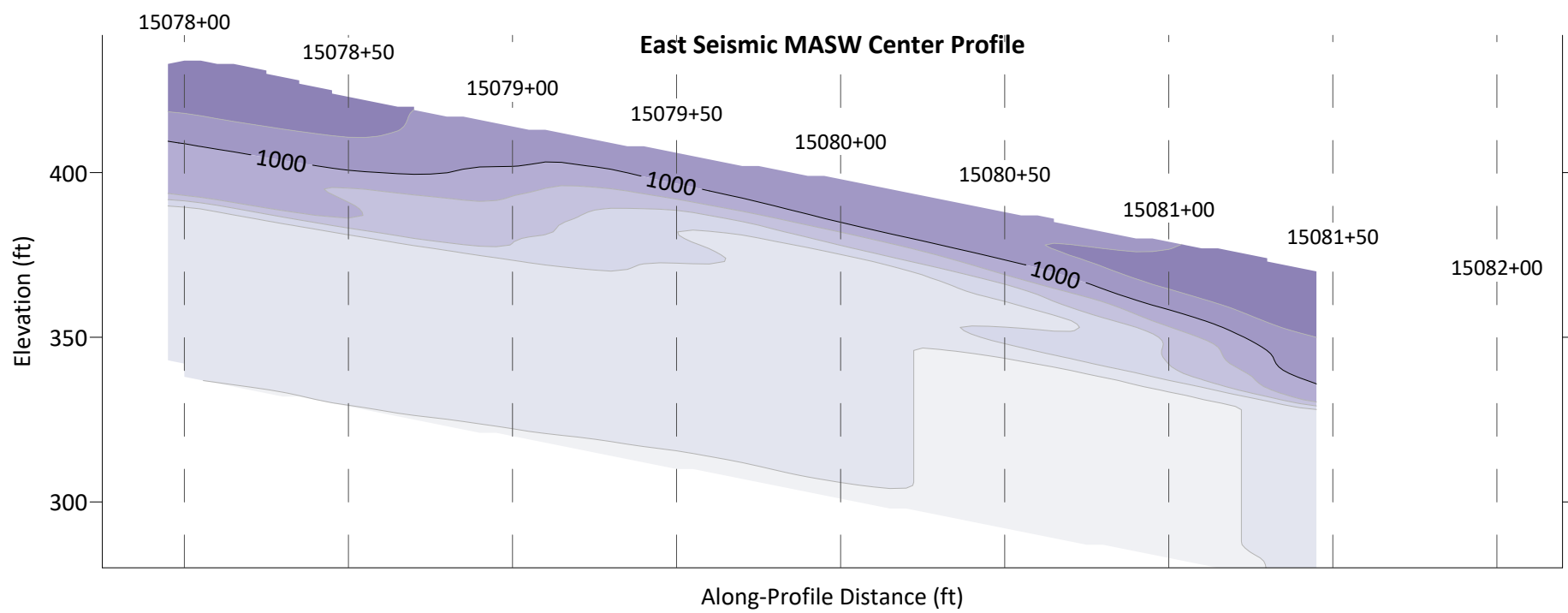
Biddle Drive
 S3-0360

CHESTER COUNTY, PA

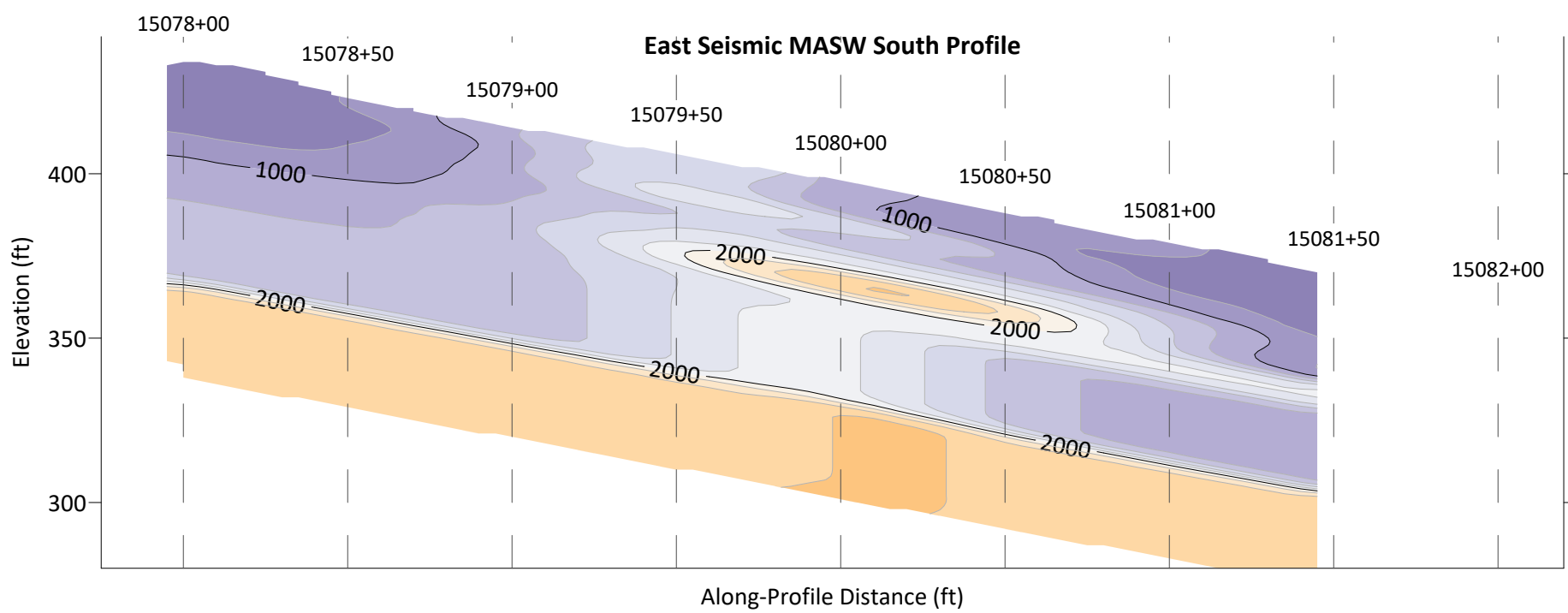
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Along-Profile Distance (ft)

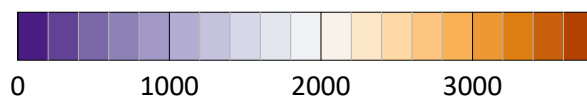


Along-Profile Distance (ft)



Along-Profile Distance (ft)

Relative S-Wave Velocity (fps)



Geophysical Survey Legend

- Possible Fracture Zone
- 16-inch HDD (from As-Built)
- 15338+00 Pipeline Station Number

Notes:
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 Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic and ray tracing inversions.

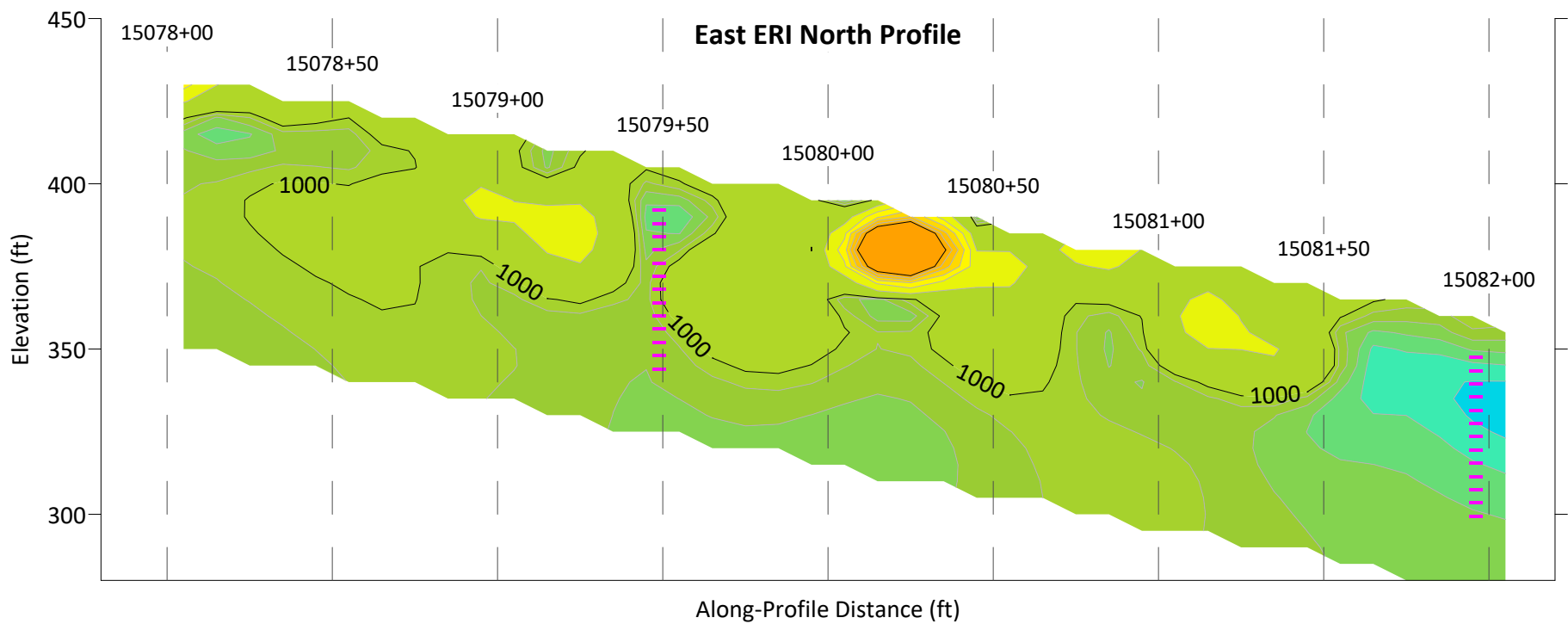
Figure 5: Seismic MASW Profiles

Biddle Drive
 S3-0360

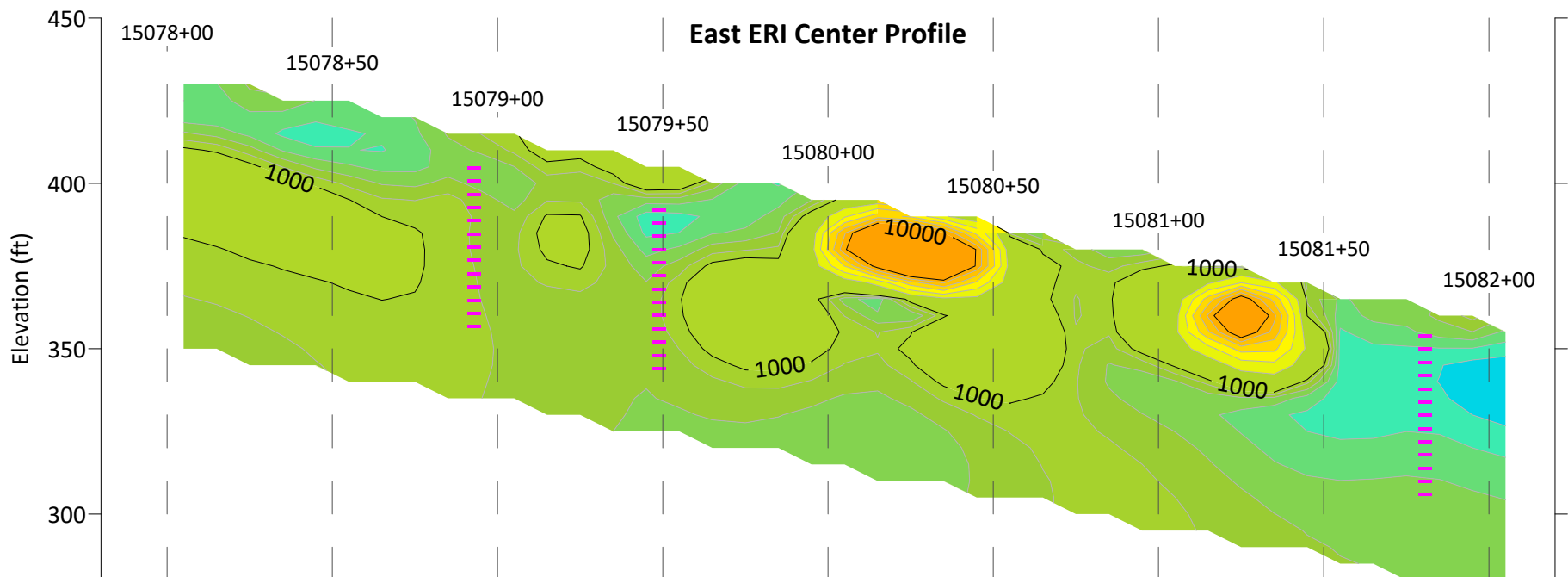


RETTEW Field Services, Inc.
 3020 Columbia Avenue, Lancaster, PA 17603
 Phone 1-800-738-8395

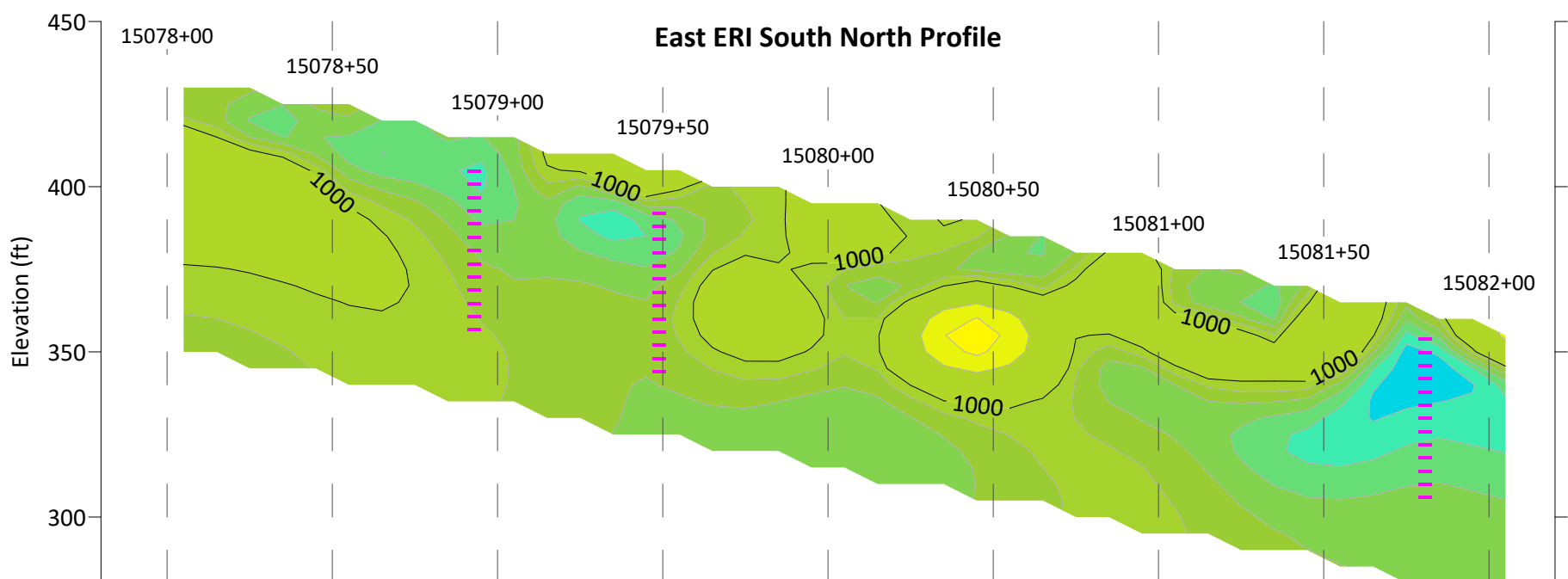
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 DATE: 02/26/2020
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 FIGURE NO. 5 of 7



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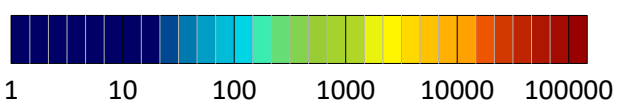


Along-Profile Distance (ft)



Along-Profile Distance (ft)

Electrical Resistivity (Ohm·m)



Geophysical Survey Legend

- Possible Fracture Zone
- 16-inch HDD (from As-Built)
- 15338+00 Pipeline Station Number

Notes:

Resistivity data from AGI Super Sting 112 channels, 15-ft electrode spacing.

Resistivity models from EarthImager3D (by AGI Corporation).

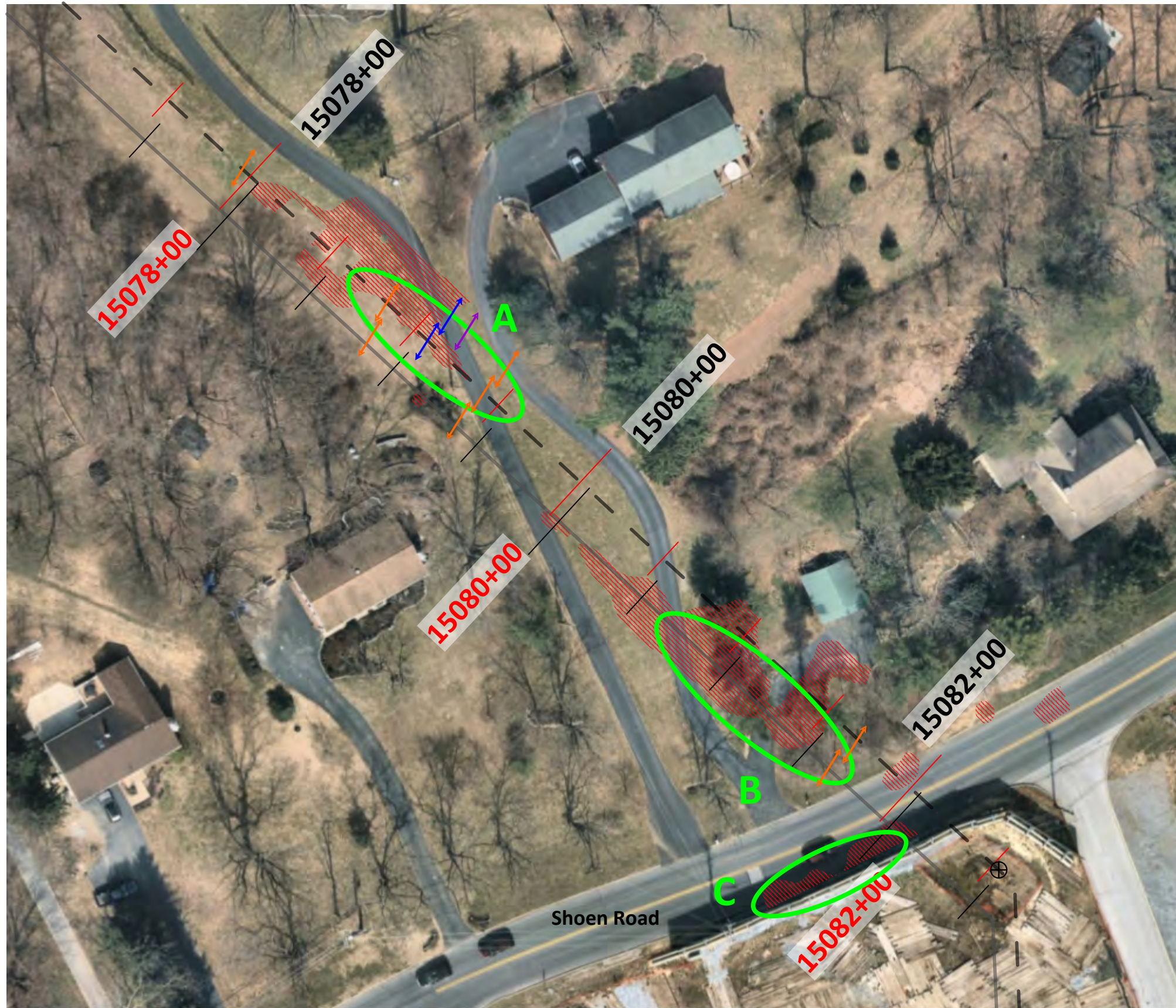
Figure 6: Electrical Resistivity Survey Results

Biddle Drive
S3-0360



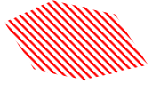






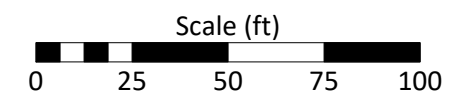
RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

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FIGURE NO.:	6 of 7



Geophysical Survey Legend

-  20-inch Proposed Pipeline
-  16-inch Pipeline & Station Number
-  Microgravity Mass Deficiencies
- Possible Fracture Zone Detected By:*
-  Electrical Imaging
-  Seismic MASW
-  Seismic Refraction
- Recommended Geotechnical Follow-up*
- 



Notes:

Basemap from Nearmap, January 2020.
Survey profiles/stations from DGPS survey by RETTEW.

SURVEY DATE: 02/12/2020
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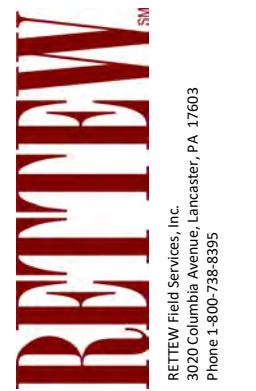


Figure 7: Geophysical Survey Results Summary

Biddle Drive
S3-0360

APPENDIX A
Geophysical Survey Parameters

Geophysical Survey Parameters -- Devon Drive S3-0360

	Spacing ¹ (feet)	Shot Interval ² (feet)	Offset ³ (feet)	Spread Length ⁴ (feet)	Array Type ⁵	Effective Depth ⁶ (feet)	Lateral Resolution ⁶ (feet)	Vertical Resolution ⁶ (percent)	System
Seismic Refraction	10	40	15	270		50	10	15	Geometrics Geode
Seismic MASW	10	10	15	270		100	10	25	Geometrics Geode
ERI	10		15	270	dipole-dipole	100	30	variable	AGI Sting R-8
MicroGravity	10		10			size-depth trade-off	depends on depth	depends on depth	Scintrex CG-5

¹ *geophone, electrode, or station*

² *Seis (27-lb slidehammer source)*

³ *distance between parallel profiles*

⁴ *ERI or Seis*

⁵ *ERI*

⁶ *rule-of-thumb only (most depend on site-specific soil properties, sampling interval, depth, and target dimensions)*

APPENDIX B
Introduction to Seismic Refraction

INTRODUCTION TO SEISMIC REFRACTION

BY TIMOTHY D. BECHTEL, PHD, PG

ENERGY

Mechanical elastic (seismic) waves generated by a hammer blow, weight drop, or explosion.

SENSITIVITY

Sensitive to elastic properties or moduli – generally strongly correlated with density.

BASIC EQUIPMENT

Recording Seismograph (generally 24 or more channels); Geophones (one for each channel); Geophone cable; Hammer or weight plus strike plate or explosives; Trigger switch.

COMMON APPLICATIONS

Determination of the depth and dip of soil horizons and bedrock surfaces. Recent processing advances allow some detection and delineation of discrete targets.

PRINCIPLES

In a uniform isotropic earth, the shock wave from a blow or explosion at the surface travels outward and downward in a hemispherical wave front like a three-dimensional ripple from a pebble in a still pond. At any point on the wave front, a straight line from the shock source to the wave front depicts the path of the seismic wave and is called a ray path (see **Figure SR-1**). In reality, there are several independent shock waves; the fast-moving primary, compressional or P wave front; the slower moving secondary, shear or S wave (both of which form hemispherical wavefronts); and several disk-like wave fronts that travel only along the surface of the earth (called surface waves or ground roll). For the purposes of most seismic refraction surveys, only the fastest moving wave front — the P wave — is considered. S-wave refraction is used in selected circumstances where complete determination of elastic moduli is desired — particularly when it may be desirable to eliminate the effects of water saturation.

In a layered earth, the hemispherical P shock wave defined by the radially distributed P ray paths are deflected according to the laws of optics (Snell's Law) at interfaces between materials with differing seismic velocities (i.e. densities or elastic properties). Figure SR-2 depicts the deflection of ray paths due to an increase in P velocity at a bedding plane. The type of deflection that a ray path will undergo is dependent upon the angle at which it strikes the interface, and falls into one of four categories:

Some direct rays (green in **Figures SR-2** and **SR-3**) travel parallel to the ground surface at the seismic velocity of the upper layer, do not strike the underlying interface, and consequently are not deflected.

Reflected rays (purple in **Figures SR-2** and **SR-3**) arise where direct rays strike the interface, and a portion of the energy is reflected symmetrically back towards the surface.



The portion of the energy of the incident direct wave that is not reflected upward is refracted or bent as it crosses the interface – making refracted waves in the lower layer (red in **Figures SR-2** and **SR-3**).

At a precise angle called the critical angle, the incident ray is refracted directly along the interface, and travels at the higher seismic velocity of the lower layer (see Critically Refracted Wave in **Figure SR-3**). As this critically refracted or head wave races along beneath the interface, it generates a secondary elastic disturbance that travels back to the surface along ray paths that define a wave front analogous to the bow wake of a ship. These returning rays again travel at the slower velocity of the upper layer.

To perform a refraction survey, a linear array of ground motion sensors or geophones is spaced out from the seismic source or shot point, forming a geophone spread. Each geophone is connected to a separate channel in a seismograph which records a wiggle trace representing the ground motion resulting from the passage of the various seismic rays.

As depicted in the time-distance (T-X) curve in Figure SR-4, the layered earth structure can be determined by analyzing the seismographic wiggle traces. At distances close to the seismic source, the first wiggle or ground motion (the first arrival after the shot) is due to passage of the direct wave travelling at the velocity of the upper layer. Reflected waves arrive later since they have by definition traveled a greater distance at the same velocity (additional later wiggles are caused by passage of the more slowly travelling S and surface waves). Beyond a distance dictated by the critical angle, the first arrival of seismic energy represents the head wave of the critically refracted ray. These refracted rays also by definition travel a greater distance than the direct wave. However, along part of their path, they have traveled at the higher velocity of the underlying more consolidated layer. At greater distances from the shot point, where the path length in the higher velocity layer becomes significant, the head wave arrivals actually race past the direct wave and become the first arrival (see labeled crossover in **Figure SR-4**). By extension, it can be shown that if a third layer with even greater velocity lies at greater depth, the head wave from this layer will become the first arrival at a sufficient distance from the shot point.

In conventional seismic refraction, only the first P wave arrivals can be reliably selected on a wiggle trace record. The later reflected P wave arrivals are generally obscured by the slower-travelling S and surface waves, and the very slow air blast or sound wave from the shot. To interpret a seismic refraction record, the first arrival travel times are measured for each wiggle trace and plotted at the appropriate point on a time-distance (T-X) curve (see Figure SR-4). In a plane-layered earth, these first arrivals define a series of line segments, each representing a discrete layer. The seismic velocity of each layer is simply the reciprocal of the slope of the associated line segment. The thickness of each layer can be calculated from the distances where the line segments intersect. The mathematics for these calculations are easily derived, and can be found in any introductory geophysics text.

True geologic strata are rarely perfectly horizontal. The effect of a dipping interface on a travel time curve cannot be recognized using a single shot point. Calculations based on a T-X curve from a single shot point should always be considered as producing apparent depths to interfaces and apparent seismic velocities for all but the uppermost layer. To determine the true depths and dips of interfaces and the true seismic velocities, it is necessary to reverse the seismic line; that is, move the shot point to a location at or beyond the farthest geophone in the spread, and repeat the shot. The calculation of true depths, dips and velocities from reversed seismic lines is also readily performed.

CAPABILITIES

Conventional seismic refraction can yield accurate measurements of depths and attitudes of soil horizons, groundwater tables, and other relatively distinct and planar strata. Modern computer analysis of multi-fold seismic refraction data (i.e. with many and overlapping shot points) can provide delineation of undulating or even irregular (as opposed to simply planar) interfaces. The latest generation of computer processing techniques require very high-fold data, but in favorable conditions, are capable of resolving even discrete targets such as foundation elements, tunnels or cavities, and can resolve gradational boundaries as well as distinct interfaces. The seismic P-wave velocities of materials are generally an indication of relative density or compaction. S-wave refraction data (collected using specialized geophones, shock sources and field procedures) can provide S-wave velocities that bear a well-constrained empirical relationship to standard penetration test (SPT) N values and therefore bearing capacity. For surveys where matching P- and S-wave velocities are determined, the dynamic elastic moduli of subsurface materials can be calculated (including Poisson's Ratio, Young's or Bulk Modulus, and Shear Modulus or Rigidity).

LIMITATIONS

Seismic data is collected at spaced geophones, and therefore does not provide continuous profile data. If geophones are spaced too widely, thin layers can be missed entirely.

Conventional refraction interpretations are only accurate where the velocity of strata increase with depth. Velocity inversions not only alter the data, but are particularly insidious since the presence of a low velocity zone at depth is not apparent in first arrival data. The latest generation of computer processing techniques do allow detection and delineation of laterally restricted low velocity zones (e.g. tunnels, cavities, gravel lenses, etc.).

Sharp or dramatic interface relief such as limestone pinnacles cannot always be resolved even with very tight geophone spacing. Therefore, refraction profiles of expectedly irregular interfaces should be assumed to represent somewhat smoothed versions of actual relief (see e.g. Figure SR-5).

Seismic records can contain noise due to heavy machinery vibrations, vehicular traffic, and sometimes even wind or distant earthquakes. Care must be taken to identify potential sources of seismic noise prior to beginning a survey.

The effective survey depth is limited to approximately 1/5 of the greatest shotpoint to geophone distance. Therefore, very deep surveys may require impractically long lines (requiring consideration of other geophysical techniques such as seismic reflection).

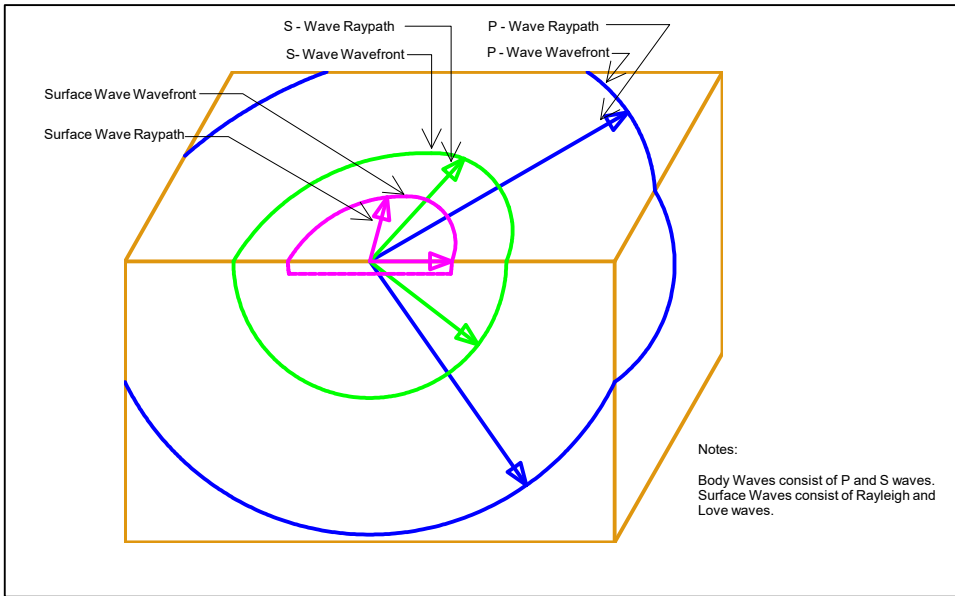


Figure SR-1

Seismic Wave Types

Rev. 04/2018

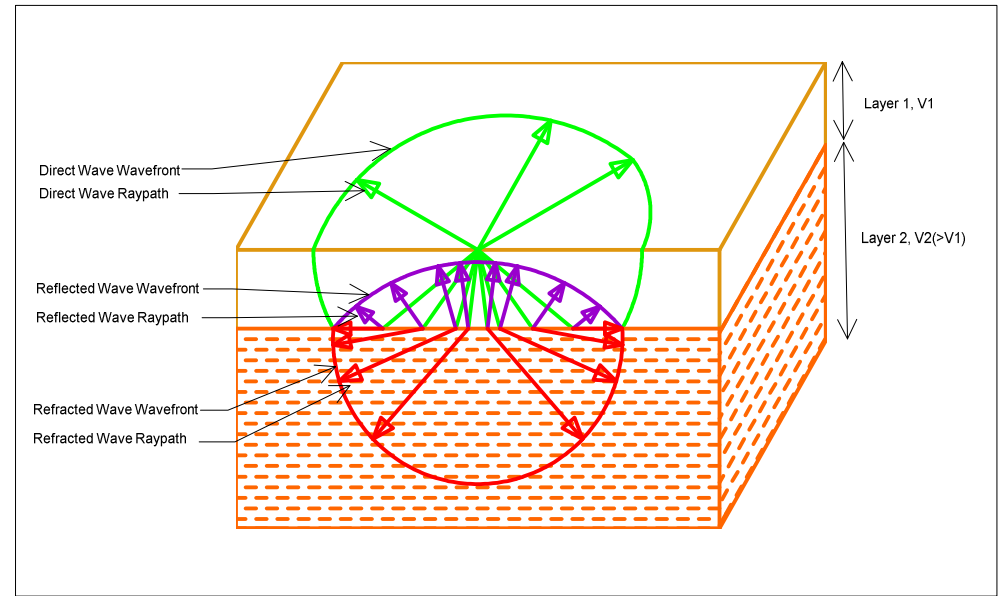


Figure SR-2

Effect of Layering
on Body Wave Raypath

Rev. 04/2018

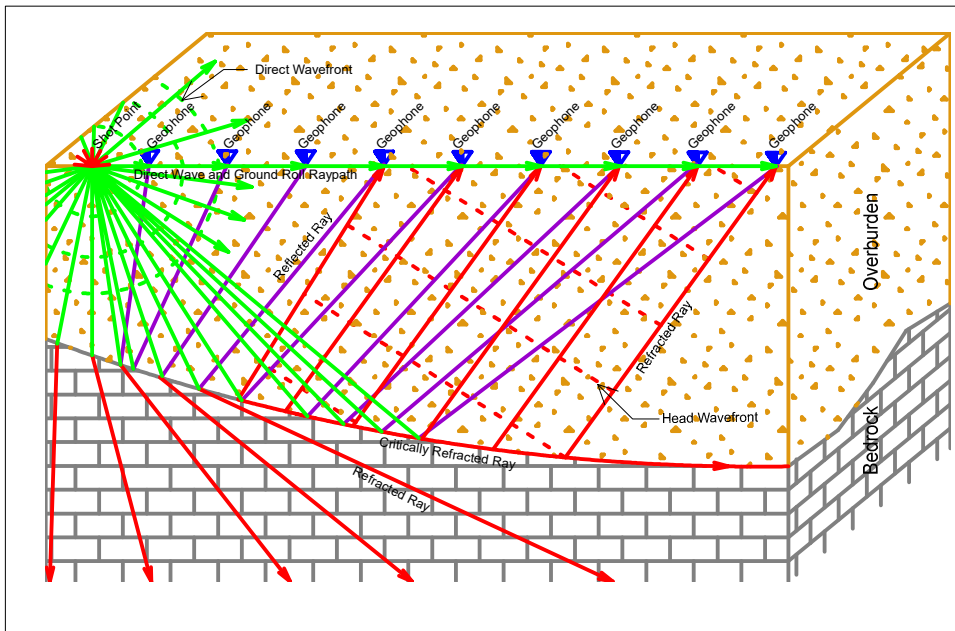


Figure SR-3

Seismic Ray Path Geometry

Rev. 04/2018

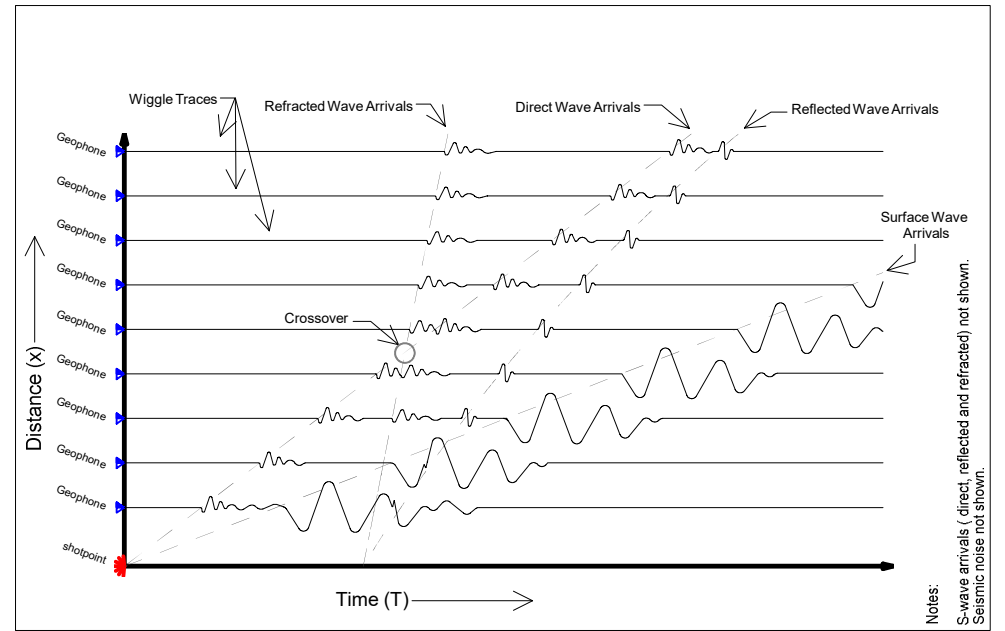


Figure SR-4

Idealized
Seismic Record
and T- X Graph

Rev. 04/2018



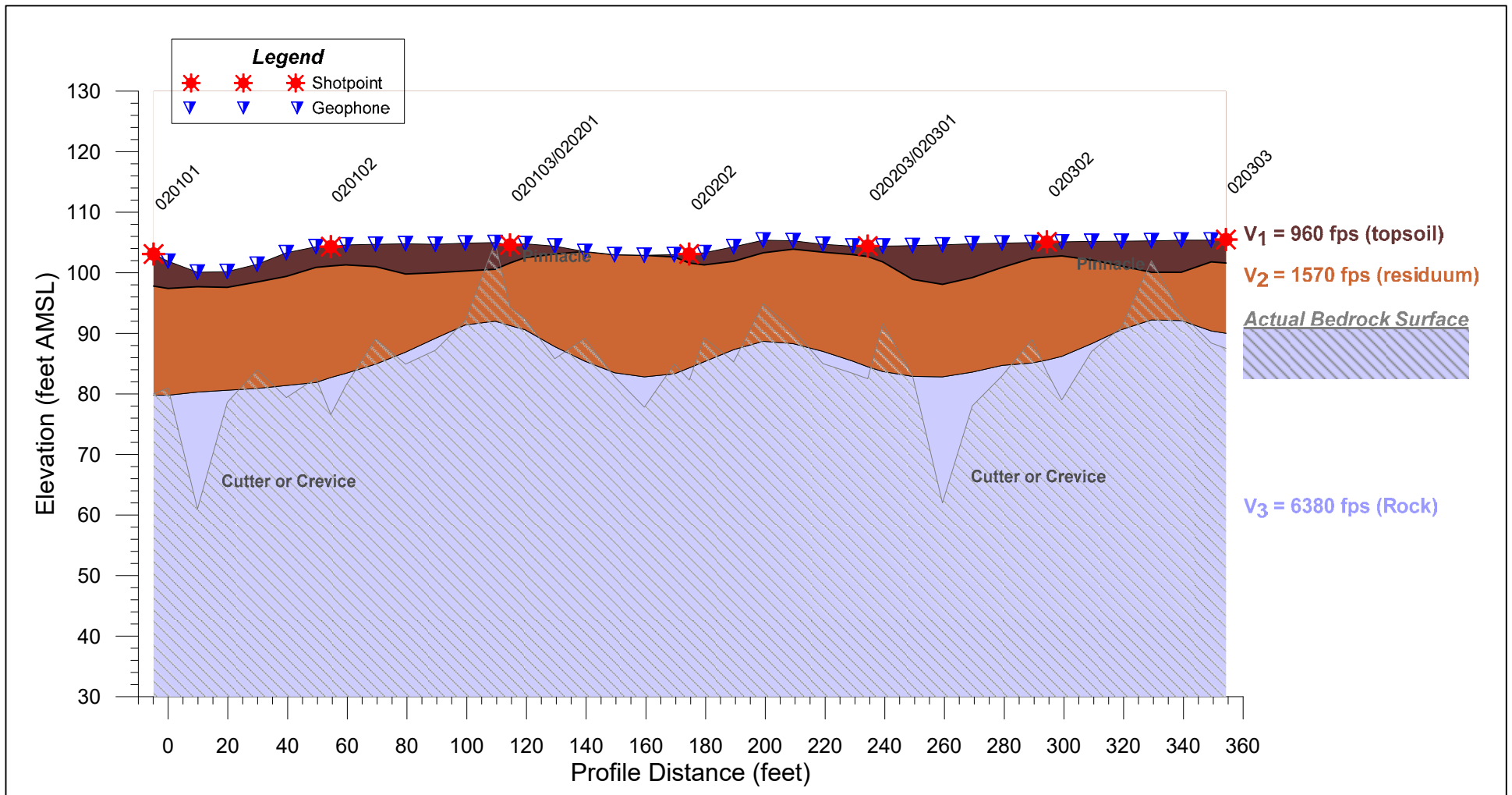


Figure SR-5

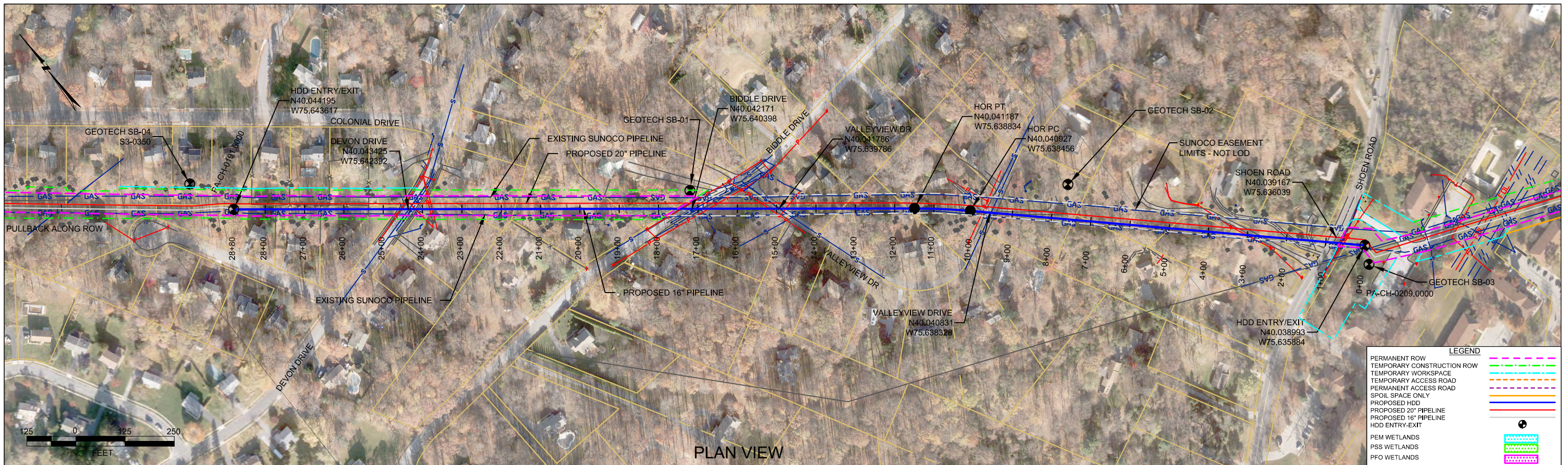
Example Karst Terrane Seismic Profile

Revised 04/2018



**BIDDLE DRIVE CROSSING
PADEP SECTION 105 PERMIT NO. E15-862
PA-CH-0199.000-RD
(SPLP HDD No. S3-0360)**

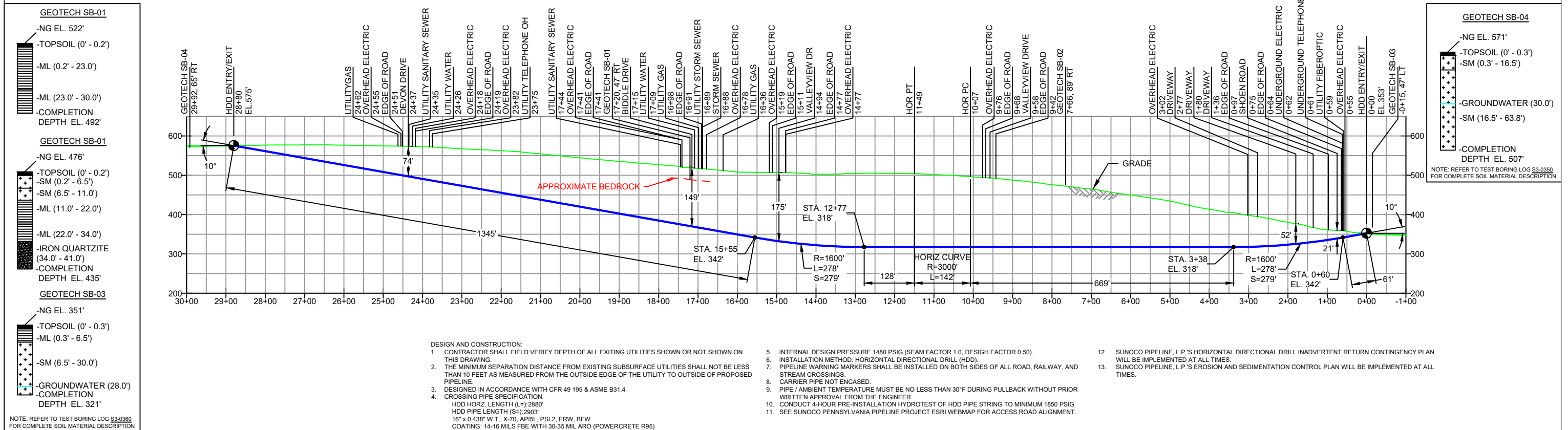
**ATTACHMENT 2
HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES**



PLAN VIEW

CHESTER COUNTY, PENNSYLVANIA- UWCHLAN TOWNSHIP
S3-0360-16

PROFILE VIEW



DESIGN AND CONSTRUCTION:

- CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
- 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.
- DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
- CROSSING PIPE SPECIFICATION:
HDD HORZ. LENGTH (L)=2880'
HDD PIPE LENGTH (S)=2903'
16" x 0.438" W.T., X-70, API5L, PSL2, ERW, 8FW
COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
- INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50).
- INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
- PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
- CARRIER PIPE NOT ENCASED.
- PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
- CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
- SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
- SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
- SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTE: REFER TO TEST BORING LOG S3-0360 FOR COMPLETE SOIL MATERIAL DESCRIPTION

NOTE: REFER TO TEST BORING LOG S3-0350 FOR COMPLETE SOIL MATERIAL DESCRIPTION

- NOTES
- ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
 - STATIONING IS BASED ON HORIZONTAL DISTANCES.
 - 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.
 - CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL UTILITIES. CONTACT ONE CALL AT 811 PRIOR TO DIGGING.
 - SUNOCO EMERGENCY HOTLINE NUMBER IS #1-800-786-7440.

REF. DRAWING		EROSION & SEDIMENT PLAN		REVISIONS						
DWG NO	DWG NO	DESCRIPTION	NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
ES-6.42	TO ES-6.44	EROSION & SEDIMENT PLAN								
SHEET 25	TO SHEET 26	AERIAL SITE PLAN								
			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	05/11/16	RMB	05/11/16	AAW	05/11/16
			EP		MRS	02/26/16	RMB	02/26/16	AAW	02/26/16
			A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	08/31/15

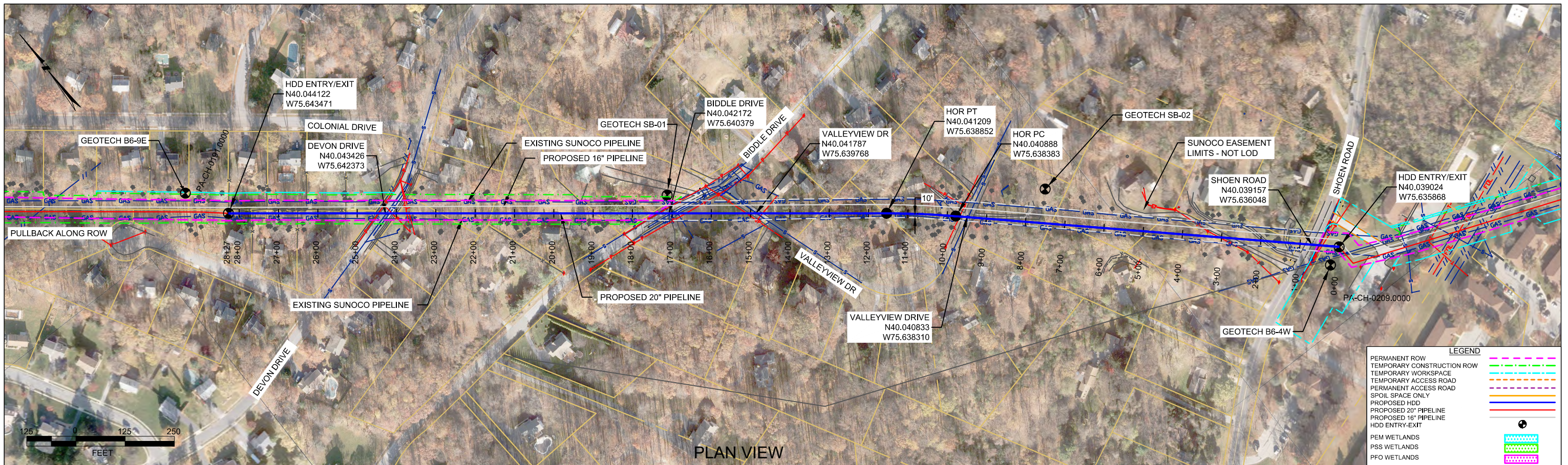
**Sunoco Logistics
Partners L.P.**

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

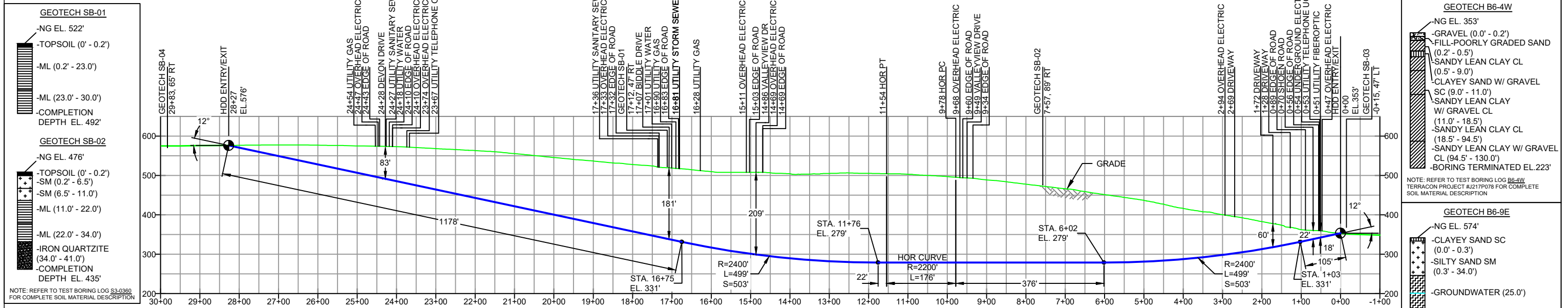
16-INCH HORIZONTAL DIRECTIONAL DRILL
BIDDLE DRIVE
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' DWG. NO: PA-CH-0199.0000-RD-16



CHESTER COUNTY, PENNSYLVANIA - WEST WHITELAND & UWCHLAN TOWNSHIP
S3-0360

PROFILE VIEW



DESIGN AND CONSTRUCTION:

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- DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
- CROSSING PIPE SPECIFICATION:
HDD HORZ LENGTH (L=): 2827'
HDD PIPE LENGTH (S=): 2863'
20" x 0.456" W.T., X-65, API5L PSL2, ERW, BFW
COATING: 14-16 MILS FBE WITH 40 MILS MIN. ARO (POWERCRETE R95)
- INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50 (HOOP STRESS)).
- INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
- PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
- CARRIER PIPE NOT ENCASED.
- PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
- CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
- SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.

NOTES

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REF. DRAWING		REVISIONS	
ES-6.42	TO ES-6.44	NO.	DESCRIPTION
SHEET 25	SHEET 26	EP4	UPDATED GEOTECH INFO PROVIDED BY DPS
		EP3	UPDATED TO 20" PIPE SPEC AND CENTERLINE LOCATION PER PM, ADDED DPS GEOTECH
		EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16
		EP1	REVISED PER PADEP COMMENTS
		EP	
		C	ISSUED FOR BID
DWG NO	DWG NO	NO.	DESCRIPTION

BY	DATE	CHK	DATE	APP	DATE
MRS	11/15/17	RMB	11/15/17	AMC	11/15/17
MRS	11/08/17	RMB	11/08/17	AMC	11/08/17
MRS	09/30/16	RMB	09/30/16	AAW	09/30/16
MRS	05/11/16	RMB	05/11/16	AAW	05/11/16
MRS	02/26/16	RMB	02/26/16	AAW	02/26/16
DLM	08/21/15	RMB	08/21/15	AAW	08/21/15

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
BIDDLE DRIVE
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' DWG. NO: PA-CH-0199.0000-RD