HORIZONTAL DIRECTIONAL DRILL ANALYSIS
SPINNER ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E11-352
PA-CA-0069.0000-RD
(SPLP HDD No. S2-0080)

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This reanalysis of the horizontal directional drill (HDD) installation of a 20-inch and 16-Inch diameter pipeline crossing under Wetland N17, Streams S-N17, Spinner Road, S-N34, and Wetland N18 (east to west), is in accordance with Stipulated Order issued under Environmental Hearing Board Docket No. 2017-009-L for HDDs listed on Exhibit 2 of the Stipulated Order. This HDD is number 8 on the list of HDDs included on Exhibit 2. This HDD was not initiated before the issuance of the Order.

PIPE INFORMATION

20-Inch: 0.456 wall thickness; X-65
16-Inch: 0.438 wall thickness; X-70

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

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 20-INCH

- Horizontal length: 1,990 foot (ft)
- Entry/Exit angle: 12 degrees
- Maximum Depth of cover: 109 ft
- Depth under North Branch Little Conemaugh: 28 ft
- Depth under adjacent wetlands: Nearly zero at eastern entry/exit
- Pipe design radius: 2,000 ft

ORIGINAL HORIZONTAL DIRECTIONAL DRILL DESIGN SUMMARY: 16-INCH

- Horizontal length: 1,951 foot (ft)
- Entry/Exit angle: 12-13 degrees
- Maximum Depth of cover: 112 ft
- Depth under North Branch Little Conemaugh: 31 ft
- Depth under adjacent wetlands: Nearly zero at eastern entry/exit
- Pipe design radius: 1,600 ft

GEOLOGIC AND HYDROGEOLOGIC ANALYSIS

The HDD S2-0080 location is underlain by the bedrock of the Pennsylvanian Age Casselman Formation; part of the Conemaugh Group. It contains alternating layers of shale, sandstone, and siltstone, including freshwater limestone, claystone, and non-persistent coal. Casselman Formation rock properties are as follows:

- Well-bedded sandstone, thick bedded to massive; shale is thin; claystone bedding is very poor; limestone varies from nodular to well-bedded;
- Poor to moderately well-formed joints; open and vertical; and
- Moderately spaced and distributed; moderate to fast drilling rate.

Discontinuities in the form of joints and faults are imprinted in the broadly folded bedrock in the region. These fractures can act as conduits for groundwater movement and/or represent areas of weakness in the rock. Fold axes can be areas of increased density of fracturing. Mapping conducted by Nickelsen and Hough (1967) indicates two fracture traces intersect at a location east-central along HDD profile. Although mining of the Lower Kittanning coal occurred beneath HDD profiles, approximately 585 feet of rock exists between the 20-inch HDD and the roof of the mine and approximately 565 feet of rock exists between the 16-inch HDD and the roof of the mine.

Based on published geologic data, no karst features are anticipated within the limit of disturbance associated with HDD S2-0080; therefore, the use of geophysics assessments was not conducted because this type of assessment would not provide additional data for use in analysis of this HDD.

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

Coal Mining and Subsidence

TetraTech mine engineers complete a study and subsidence analysis of the coal mining below the proposed HDDs. A copy of the TetraTech Subsidence Report is provided in Attachment 2. The Bethlehem Mines Corporation’s Cambria Division operated the Cambria Slope Mine #33 underground mine in Munster Township, Cambria County from the 1960’s into the mid-1990’s. The Lower Kittanning seam was mined using the longwall mining method directly below the HDD from 1989 to 1993. The depth of the coal from surface is about 900 feet at Station 0+00 (the beginning of the HDDP) and about 850 feet at Station 29+57 (the end of the HDDs).

The mining method employed at the Cambria Slope Mine #33 was longwall mining. Three entry (gate-roads) were driven using mechanized continuous mining machine parallel to each other so that a 600 foot wide coal pillar remained between them. This coal pillar was 11,500 feet long. To keep the miners safe, a row of hydraulic roof supports (chocks or shields) was used to support about a 10 foot wide section of the overlying roof from the face of the coal pillar. As the mining progressed through the pillar, the roof supports were advanced. As the roof supports advanced, the mine’s roof collapsed behind them. By allowing the roof to collapse, the weight of the strata on the roof supports and coal pillars was reduced. When the strata collapsed into the remaining void, surface subsidence would occur. Most subsidence would occur almost immediately, and most ground movements would be completed within a few weeks.

The gate-road pillars remained after mining. The mine plan included three entries in each gate-road. Pillar sizes in the gate-roads varied. These pillars probably failed soon after mining and thus the subsidence due to yield pillar failure has probably already occurred.

Mine subsidence occurs in one of two physical forms, a trough or a sinkhole. A trough is a shallow, often broad, dish-shaped depression that develops when the overburden sags downward into a mine opening in response to roof collapse, the crushing of mine pillars, or the punching (pushing) of pillars into the mine floor. Trough subsidence typically occurs in areas of deeper overburden, typically more than 100 feet deep. The depth and extent of the trough are closely related to the depth, dimensions and thickness of the extracted coal, and the physical properties of the overburden. A sinkhole is a depression in the ground surface that occurs due to localized collapse of the overburden directly into a mine opening (a room or entry). This is often called “chimney” type subsidence. Sinkhole subsidence typically occurs in areas of shallow overburden, primarily 100 feet or less.

Mining-induced subsidence is caused when a seam of coal is extracted and overlying rock layers cave into the voids left by mining such that there is movement on the ground surface. The probability of subsidence is greater in areas where a high percentage of coal is removed. In an analysis of underground mines, subsidence potential can be classified into the following three general categories:

Category 1 – Subsidence probably occurred during or soon after mining.

Category 2 – Well supported areas where subsidence is unlikely.

Category 3 – Areas where subsidence may occur in the future if it has not already occurred.

Longwall mining, the method of mining used in the project area, is a method of mining where full recovery (generally over 95 percent recovery) of the coal seam was practiced. The roof of the mine is allowed to cave in a predictable controlled manner immediately following coal extraction. This controlled caving process systematically relieves built-up stresses caused by the cantilever action of the mine roof thereby reducing the risk of catastrophic strata failure where men are working. The limits and extents of the subsidence are relatively predictable where longwall mining is employed because subsidence normally occurs soon after mining. Category 1 refers to areas where nearly full extraction of the coal occurred as a result of longwall mining and there is very low probability of extensive future subsidence. Category 2 refers to areas where the mine configuration and pillars are adequately designed to provide permanent support to the ground surface. Category 3 refers to areas underlain by room and pillar mines with a high percentage of coal removed and where retreat mining was not performed. In Category 3 areas, it is uncertain whether subsidence occurred and whether there remains a likelihood of subsidence in the future. Of the three categories, Category 3 would have the highest probability for future subsidence.

TetraTech reviewed the mine maps and the location and elevation of the two HDDs. Figure 1 in the report depicts the areas where potential roof failure at mine level could impact the strata at the level of both planned HDDs. Both angle-of-draws (20° and 35°) were shown on Figure 1. The area shown was created by using an angle-of-draw from the lowest HDDP's bottom elevation to the top of the coal seam. A mining height of 6 feet was assumed based on the mine maps. A 15 foot horizontal zone on each side of the HDDPs (50 feet total) was also included. Figure 2 depicts each category of potential mine subsidence. A total of 46.9 acres lies within the 20° angle-of-draw influence area, while 100.1 acres lie within a 35° angle-of-draw influence area.

The HDDs start on the eastern most location at about 900 feet above the coal. The descending borings will be approximately 620 feet above the coal when they level off about 1000 feet horizontally from its start. The borings would then be fairly level for another 500 feet to a location where it will be approximately 585 feet above the coal. From there the borings will ascend upward until it reaches the surface about 2,960 feet from its start. At the surface exit location, the boring would be about 850 feet above the coal. It should be noted that the two HDDs are approximately 20 feet horizontally from each other and can also be up to 20 feet vertically from each other. Due to the historic longwall mining, most of the area that the HDDs cross over is Subsidence Category 1 (subsidence probably occurred during or soon after mining). The three gate-road areas located between the longwall panels are categorized either as Subsidence Category 2 (support area where subsidence is unlikely) or Subsidence Category 3 (area where subsidence may have occurred or may occur in the future) depending on the size of pillar used. The larger pillars (80 foot or 100 foot wide) were included a Subsidence Category 2 while the smaller pillars (60 foot wide) were included as Subsidence Category 3. In TetraTech's opinion, the small (25 foot wide) pillars were designed as "yield" pillars and were expected to fail shortly after the longwall passed them. In that case, subsidence due to their failure would have already occurred. Thus, the area where these small pillars were located was included as Subsidence Category 1.

The two HDDs lie above four longwall panels that were mined between 1989 and 1993. A fourth longwall panel lies to the west of the HDDP but within the 35° angle-of-draw. The longwall panels are separated by gate-roads, three entry developments sections. The model estimated that the surface above the longwall panels subsided up to 2.75 feet following mining. Additional subsidence due to the longwall mined areas is unlikely. The mine lies between 700 and 900 feet below the ground surface and about 585 feet below the HDDs at the deepest point.

The estimated maximum subsidence that the pipelines may experience in the future is the difference between the subsidence estimated using the original strength (900 psi) of coal and the subsidence estimated using a degraded strength (750 psi) of coal. The differential in subsidence between the two coal strengths is plotted in Figure 6 in the TetraTech report, along with the associated strains. There are three areas of potential increased subsidence. These three areas are located above the three gate-roads. The largest increased subsidence would be estimated to be about 0.074 feet (0.89 inches) - above the western most gate-road (centered at Station 700). The second area of increased subsidence occurs above Station 1650 - above the center gate-road. The estimated additional subsidence in this area is estimated to be about 0.081 feet (0.97 inches). The third area of increased subsidence occurs above Station 2700 - above the eastern gate-road. The estimated additional subsidence in this area is estimated to be about 0.037 feet (0.44 inches).

The maximum strain values range from -0.0005 to = +0.0006 strain (compression is positive), and fluctuate continuously along the pipeline length, but being highest above the gate-roads.

Based upon the data obtained from the subsidence analysis, and the results of a Finite Elements Analysis (pipe stress), the pipeline engineers has concluded “no concern” regarding the redesigned HDDs. The findings by the pipeline engineers is included within the TetraTech report provided in Attachment 2.

HYDROGEOLOGY, GROUND WATER, AND WELL PRODUCTION ZONES

Groundwater in the Casselman Formation is stored and moves through an interconnected network of joints and other fractures in bedrock. During the recent geotechnical coring, wet sand-sized shale fragments were encountered at 21.5 feet below ground surface (bgs) in the core log taken at the eastern extent of HDD S2-0080. Within 16 hours of drilling termination, a water level was measured at 22.3 feet bgs.

The Pennsylvania Groundwater Information System (PaGWIS) reported four wells within a one mile of HDD S2-0080. PA Well ID 80851 and 80852 are part of a residential well cluster located approximately 3,070 feet northeast of the eastern entry/exit. Both wells were completed to 90 ft bgs and reported static water levels of 30 ft bgs. The reported well yield is 12 gpm for Well ID 80851 and 30 gpm for Well ID 80852. PA Well ID 81975 is a domestic well located approximately 4,910 feet north-northeast of the eastern entry/exit and is completed at 150 ft bgs. Static water is reported at 95 ft bgs and yield at 12 gpm. PA Well ID 80375 is a domestic well located approximately 5,260 feet southwest of the western entry/exit and is completed at 137 ft bgs. No static water level is reported for this well, but the yield is reported as 8 gpm.

There are no SPLP or landowner identified water supplies within 450 ft of these HDD profiles.

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

INADVERTENT RETURNS DISCUSSION

An HDD has not been initiated at this location.

No IRs were reported along the alignment of the HDD S2-0080 on the list of IRs for Mariner East I as documented in the IR Preparedness, Prevention and Contingency (PPC) Plan for Cambria County. Furthermore, no IRs were reported for Mariner East I as documented in the IR PPC Plan for sites underlain by Casselman Formation bedrock.

Sunoco Pipeline, L.P. (SPLP) HDD consultants reviewed the HDD design and geotechnical data for this area and determined that the risk of IRs to the waters overlying the HDD could be reduced by increasing the depth of the HDD. Based on the revised HDD profile and recent geotechnical boring, the revised drilling path for HDD S2-0080 will encounter competent Casselman Formation throughout the entire profile. The revised profile is anticipated to be installed into more competent mudstone/claystone with tighter fractures and better rock quality designations (RQDs), thus reducing the risk of IRs.

The results of the new core borings at the entry and exit points show the HDD will encounter improving bedrock strength conditions as depth to profile increases. At maximum depth of profile, which is also the depth of profile under the North Branch Little Conemaugh River and adjacent wetlands, the rock layer has a recovery value of 100 and RQD values of 80-88. This is indicative of good integrity and very good strength, which assists in suppression of IRs. Additionally, during the pilot hole phase SPLP's drilling contractor will complete the pilot hole by intercept drilling, using a HDD rig and drilling from each end and meeting in the horizontal run of the design profile. The benefit of intercept drilling at this HDD is the process minimizes annular pressure requirements to return cuttings laden fluids to the point of entry, compared to returning fluids through a single pilot hole run.

ADJACENT FEATURES ANALYSIS

This HDD location is approximately 2.6 miles southwest of Ebensburg, Pennsylvania set within deciduous woodlands. Adjacent land uses include managed or unmanaged forests, agriculture, and strip mining. Residences are few and widely dispersed. The HDD would cross under two streams and one forested wetland. The crossings of streams S-N17 and S-N34 are located approximately 600 feet west and 70 feet east, respectively, of Spinner Road. The crossing of Wetland N18, a forested wetland, is located immediately east of Spinner Road. Streams S-N15 and S-N16 are located north of this HDD.

Stream S-N34 (North Branch) is a designated PADEP Chapter 93 Coldwater Fishery (CWF) and a Pennsylvania Fish and Boat Commission (PAFBC) approved trout water (ATW). Stream S-N17 (unnamed tributary to North Branch) is designated by PADEP Chapter 93 as a waterbody that "drains to CWF" and is a PAFBC-designated waterbody that "drains to ATW." Wetland N18 is composed of palustrine forested (PFO), palustrine scrub-shrub (PSS), and palustrine emergent (PEM) vegetative cover and this HDD avoids direct surface impacts to these streams and adjacent wetlands.

Pre-construction, SPLP identified and attempted to contact all landowners with a parcel of land within 150 feet of the HDD alignments. No water wells were identified as a result of that outreach. Based on review of 2017 aerial photography, the nearest structures that appear to be residences are 678 ft north and 1,082 ft south of the HDD.

SPLP subsequently identified all landowners with property located within 450 ft of the HDD alignment. While there do not appear to be any residences within 450 ft of the HDD alignment, there are three (3) individual landowners who own five 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 on October 30, 2017, that included an offer to sample the landowner's private water supply/well in accordance with the terms of the Order and the Water Supply Assessment, Preparedness, Prevention and Contingency Plan. The letter also requested that each landowner contact the Right-of-Way agent for the local area and provide SPLP with information regarding: (1) whether the landowner has a well; (2) where that well is located, and its depth and size if known; and (3) whether the landowner would like to have the well sampled. In accordance with paragraph 10 of the Order, copies of the certified mail receipts for the letters sent to landowners have been provided to Karyn Yordy, Executive Assistant, Office of Programs at the Department's Central Office.

No private water wells have been identified within 450 ft of the HDD profile as a result of these communications. Two owners confirmed the presence of water wells at greater than 1,500 ft south of the alignment and accepted SPLP's offer to sample the wells. No owner accepted an offer of temporary water during HDD construction.

SPLP does not believe any potential private water wells are of concern for this HDD. A copy of SPLP's landowner communications is provided with this Reevaluation Report as Attachment 3.

ALTERNATIVES ANALYSIS

As required by the Order, the reanalysis of S2-0080 includes an evaluation of open cut alternatives and a re-route analysis. As part of the PADEP Chapter 105 permit process for the Mariner II East Project, SPLP developed and submitted for review a project-wide Alternatives Analysis. During the development and siting of the project, SPLP considered a number of different routings, locations, and designs to determine whether there was a practicable alternative to the proposed impact. SPLP performed this determination through a sequential review of routes and design techniques, which concluded with an alternative that has the least environmental impacts, taking into consideration cost, existing technology, and logistics. The baseline route provided for the pipeline construction was to cross every wetland and stream on the project by open cut construction procedures. The Alternatives Analysis submitted to PADEP conceptually analyzed the potential feasibility of any alternative to baseline route trenched resource crossings (e.g., reroute, conventional bore, HDD). The decision-making processes for selection of the HDD instead of an open cut crossing methodology is discussed thoroughly in the submitted alternatives analysis and was an important part of the overall PADEP approval of HDD plans as currently permitted. As described below, the open cut and re-route analyses have confirmed the conclusions reached in the previously submitted Alternatives Analysis.

Open-cut Analysis

Conversion to an open cut trenched crossing method would result in direct but temporary impacts to Stream S-N34, a PADEP-designated CWF and PAFBC designated ATW, as well as direct but temporary impacts to Stream S-N17, a PADEP-designated "drains to CWF" and PAFBC-designated "drains to ATW." SPLP specifications require a minimum of 48 inches of cover between the installed pipeline and the bottom of the watercourse. To meet this cover requirement, during trenched construction through the two streams (Stream S-N17 and S-N34), a workspace with a width up to 75 feet would be required to accommodate the pipelines and provide sufficient space for trench excavation, spoil storage, and sufficient separation between pipelines (including the existing Sunoco pipeline and the two new ones) for integrity management. The assessed area of impact by this open cut plan would directly affect approximately 6.1 acres of stream bed. Both Stream S-N17 and S-N34 have perennial flow regimes. Conventional crossings of these streams would require using upstream and downstream sandbag diversion dams or coffer dams, pumping stream flow around the trench/workspace, pumping out (from the in-stream workspace or excavated areas) any produced groundwater discharge or seepage around/under the dams (through water filter bags), for the duration of the crossing event. Although the temporary impacts would be controlled and managed using these appropriate best management practices, SPLP's preferred method is to drill below these resources.

In addition, converting to an open cut trenched crossing method through this area would result in 0.61 acre of temporary and permanent impacts to Wetland N18, inclusive of approximately 0.42 acre, 0.05 acre, and 0.14 acre of impacts to PFO/PSS/PEM vegetative cover types, respectively. The HDD will largely avoid surface impacts to biological features and as currently proposed, only results in 0.26 acre (approximately 0.01 acre in PFO and 0.25 acre in PEM portions of Wetland N18) of impacts from travel lane use, resulting in a minimization of impacts to 0.35 acre of wetlands compared to the open cut alternative.

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Re-Route Analysis

In accordance with state and federal guidance, SPLP has co-located the Mariner II route within the existing SPLP pipeline or other utility corridors to avoid new “greenfield” routing alignments, to the maximum extent practicable. This avoids and minimizes new and permanent impacts on previously undisturbed land, new land use encumbrance, and site-specific and cumulative impacts on land, environmental, and community resources.

Due to the location of streams (Streams S-N15 and S-N16) north of this HDD and Wetland N18, which extends further to the north and to the south, no practicable re-route option lies to the north or south of the proposed route that would not ultimately cross streams or wetlands.

There is an existing cleared corridor 0.6 miles north of the Spinner Road HDD location, which could be accessed 2.1 miles west during initial routing; however, this corridor turns towards the northeast in the area of the Spinner Road HDD and continues to deviate further away as progressing east, and as a result is not a viable alternative route.

An existing cleared corridor occurs 0.76 miles south of the Spinner Road HDD location, which could be accessed 4.1 miles west and generally parallels the route of the Mariner II project as proceeding east; however, this corridor has residences in the immediate vicinity of the easement, while the existing route does not. Therefore, this existing cleared corridor would not be a preferred route.

RECONSIDERATION OF THE HORIZONTAL DIRECTIONAL DRILL

SPLP HDD consultants reviewed the HDD designs and geotechnical data for this location. Based upon this review, it was determined that the risk of IRs to regulated resources overlying the HDD could be reduced by increasing the depth of the original permitted HDD profile. Additional geologic investigations have been completed and utilized in the redesign of the planned HDD. The redesign adjusts the HDD profile deeper to place the HDD pathway through bedrock having better structural integrity than a shallower profile and increase the overall length of the HDD due to pipe design requirements. A summary of the redesign factors is provided below.

Revised Horizontal Directional Drill Design Summary: 20-inch

- Horizontal length: 2,961 foot (ft)
- Entry/Exit angle: 16 degrees
- Maximum Depth of cover: 155 ft
- Depth under North Branch Little Conemaugh: 73-85 ft
- Depth under adjacent wetlands: 54-85 ft
- Pipe design radius: 2,400 ft

Revised Horizontal Directional Drill Design Summary: 16-inch

- Horizontal length: 2,958 foot (ft)
- Entry/Exit angle: 15-16 degrees
- Maximum Depth of cover: 150 ft
- Depth under North Branch Little Conemaugh: 71-77 ft
- Depth under adjacent wetlands: 50-77 ft
- Pipe design radius: 1,800-2,400 ft

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

- SPLP will alter the drilling of the pilot hole into an "intercept drill" using a HDD rig at each end, so that only entry and horizontal profile pressures develop within the annulus of the profile. This lowers the pressures required to maintain return flows to the entry points, compared to a single HDD pilot hole through the exit radius to the land surface;

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

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

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

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

- During the reaming phase, the use of Loss Control Materials (LCMs) can be implemented if indications of a potential IR are noted or an IR is observed; and

- If LCMs prove ineffective to mitigate loss of returns or IRs, then grouting of the pilot hole may be implemented.

CONCLUSION

It is SPLP's intent to modify the original profile design and to pursue a deeper and longer HDD profile. Figure 1 and 3 in Attachment 4 presents the original HDD plan and profiles. Figure 2 and 4 present the revised HDD plan and profiles.

SPINNER ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E11-352
PA-CA-0069.0000-RD
(SPLP HDD No. S2-0080)

ATTACHMENT 1

GEOLOGY AND HYDROGEOLOGICAL EVALUATION REPORT

HDD HYDROGEOLOGIC REEVALUATION REPORT

Mariner East II
Spread 2
HDD S2-0080
Spinner Road
Munster Township, Cambria County, Pennsylvania

Prepared for:

Sunoco Pipeline, L.P.

Prepared by:

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

May 2018

HDD HYDROGEOLOGIC REEVALUTION REPORT

Mariner East II
Spread *2*
HDD S2-0080
Spinner Road
Munster Township, Cambria County, Pennsylvania

May 2018

Prepared for:

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

Prepared by:

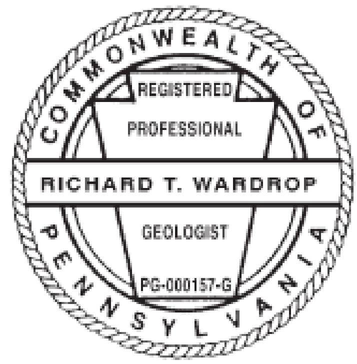
Joseph A. Maule, P.G.
Principal Hydrogeologist

Reviewed by:

Richard T. Wardrop, P.G.
Lead Hydrogeologist

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

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



May 23, 2018

Richard T. Wardrop, P. G. date

Lic. No. PG000157G

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FIGURES

ATTACHMENTS

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 signed August 10, 2017. This report discusses the hydrogeologic reevaluation for HDD S2-0080 and HDD S2-0080-16 (the 20-inch and 16-inch HDDs for this location, respectively) hereinafter collectively referred to as HDD S2-0080. The planned alignment for HDD S2-0080 is in Munster Township, Cambria County, approximately 4,500 feet southwest of the intersection of Spinner Road and Admiral Peary Highway (SR 2014). The discussion presented in this report is based on an alignment and profile developed by Tetra Tech/Rooney, revised on September, 30, 2016 and October 7, 2016 for the 20-inch and 16-inch line, respectively (original profiles) and revised profiles for HDD S2-0080 and HDD S2-0080-16 dated April 6, 2018 and January 29, 2018 for the 20-inch and 16-inch lines, respectively (revised profiles) (see **Attachment A**). The revised boring profiles were developed to increase the depth of the boreholes by extending the east and west entry/exit points and making the profile longer. The purpose is to minimize the risk of inadvertent returns (IRs) by installing the pipes deeper into competent bedrock.

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

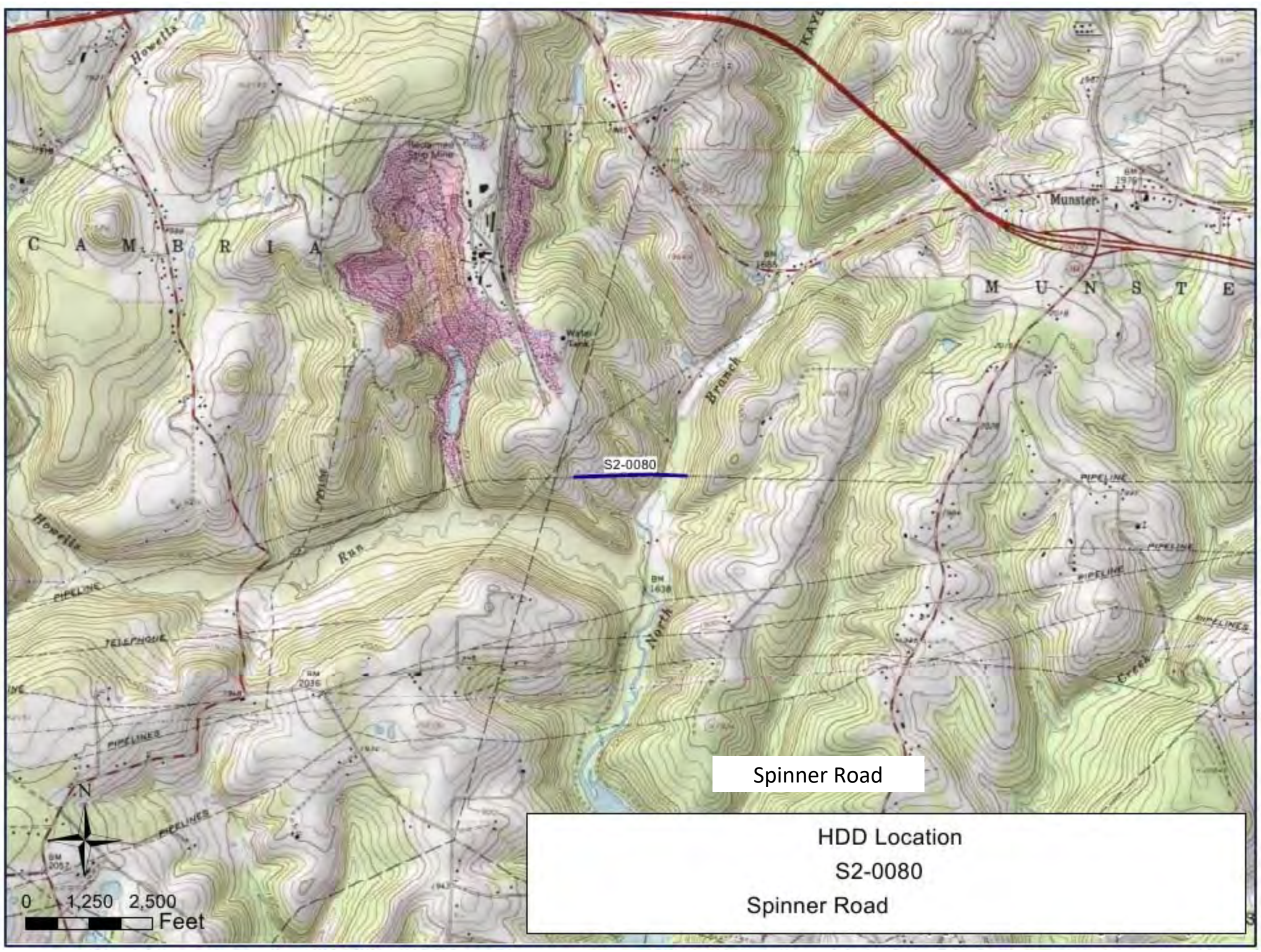


Figure 1. Site Location Map (modified from USGS Ebensburg 1:24,000 Topo. Quad., rev. 1982)

This report presents the following information:

- Geologic and hydrogeologic characteristics in the area of HDD S2-0080;
- 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 September 2014, and more recently by Terracon Consultants, Inc. (Terracon) in August 2017, in support of the HDD S2-0080 reevaluation (see **Attachment B**). Please 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 any core photographs that resulted from these programs 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.

2.0 HDD GEOLOGY / HYDROGEOLOGY

2.1 Physiography

HDD S2-0080 is located within the Pittsburgh Low Plateau Section of the Appalachian Plateaus Province, which is characterized by smooth to irregular, undulating surfaces. Valleys are narrow and relatively shallow, and strip mines and reclaimed land are prevalent. The area surrounding the HDD is comprised of rural properties.

2.1.1 Topography

The topography along HDD S2-0080 is that of a stream valley characterized by meanders in the North Branch Little Conemaugh River. The designed profile for the original 20-inch profile is approximately 1,990 feet long, horizontally. The lowest topography along the alignment is the flood plain for the River from Stations 0+50 to 4+10 at an elevation of approximately 1,645 feet above mean sea level (ft amsl). Moving east and west away from the flood plain, the elevation increases to accommodate valley walls and hilltops. The original profiles show the HDDs as straight angled bores on the western end for approximately 1,000 feet that turn to horizontal for approximately 400 feet before turning upward to the eastern entry/exit. The revised profiles relocate the entry/exit locations approximately 791 and 677 feet to the east, for the 20-inch line and 16-inch line, respectively, and relocate the entry/exit locations approximately 180 feet and 330 feet to the west for the 20-inch and 16-inch lines, respectively. This extends the overall lengths to 2,961 feet for the 20-inch line and to 2,958 feet for the 16-inch line.

The original western and eastern entry/exit points were set at elevations of approximately 1,830 and 1,658 ft amsl, respectively for the 20-inch line. These entry/exit points for the revised profile were raised as the distance increased and the points were located on local hilltops. On the revised plan for the 20-inch line the western and eastern entry/exit points were set at elevations of approximately 1,858 and 1,827 ft amsl, respectively. The adjustment to elevation at the western entry/exit for the 16-inch line was larger at 1,882 ft amsl.

2.1.2 Hydrology

The nearest surface water body to the HDD location is the North Branch Little Conemaugh River (S-N34) located at on the original 20-inch profile at Station 2+75 and a small unnamed stream (S-N17). Wetland W-N18, which is comprised of forested, grassy, and scrub shrub wetlands, is located within the lowland portion of the LOD and associated with the meanders of the North Branch Little Conemaugh River. The original 20-inch profile crosses under North Branch Little Conemaugh River at a minimum depth of approximately 28 feet. The revised profile shows the drill passing under the stream at a depth of approximately 73 feet; 45 feet deeper. Similarly, the revised profile for the 16-inch line is 40 feet deeper at this location.

2.2 Geology

2.2.1 Soils

Based on information obtained from the National Resource Conservation Service Web Soil Survey database (USDA NRCS), soils on the western and eastern valley slopes are comprised of silt loams, channery silt loam, and silty clay loam. These soils are moderately to well-drained and groundwater is at 1.5 to greater than 7 feet below ground surface (ft bgs). Bedrock is typically encountered at 2.5 to 6 ft bgs.

Surface soils in the North Branch Little Conemaugh River valley are poorly drained silt loam to gravelly sandy loam associated with stream alluvial deposits. McElroy (1998) describes the alluvium in Cambria County as gravel, silt, and clay; with no data are available as to the water-bearing characteristics or thickness of these deposits in the county.

2.2.2 Bedrock Lithology

Bedrock underlying the area of HDD S2-0080 belongs to the Pennsylvanian age Casselman Formation; part of the Conemaugh Group. The Casselman Formation is characterized by a few locally persistent red beds, calcareous claystone, freshwater limestones, thin sandstones, shales, siltstones, and generally thin, economically insignificant coal beds. Most of the shales overlying coals contain plant fossils, and several also contain freshwater fauna. . **Figure 2** is a map depicting site bedrock geology for the area surrounding HDD S2-0080 (McElroy, 1998).

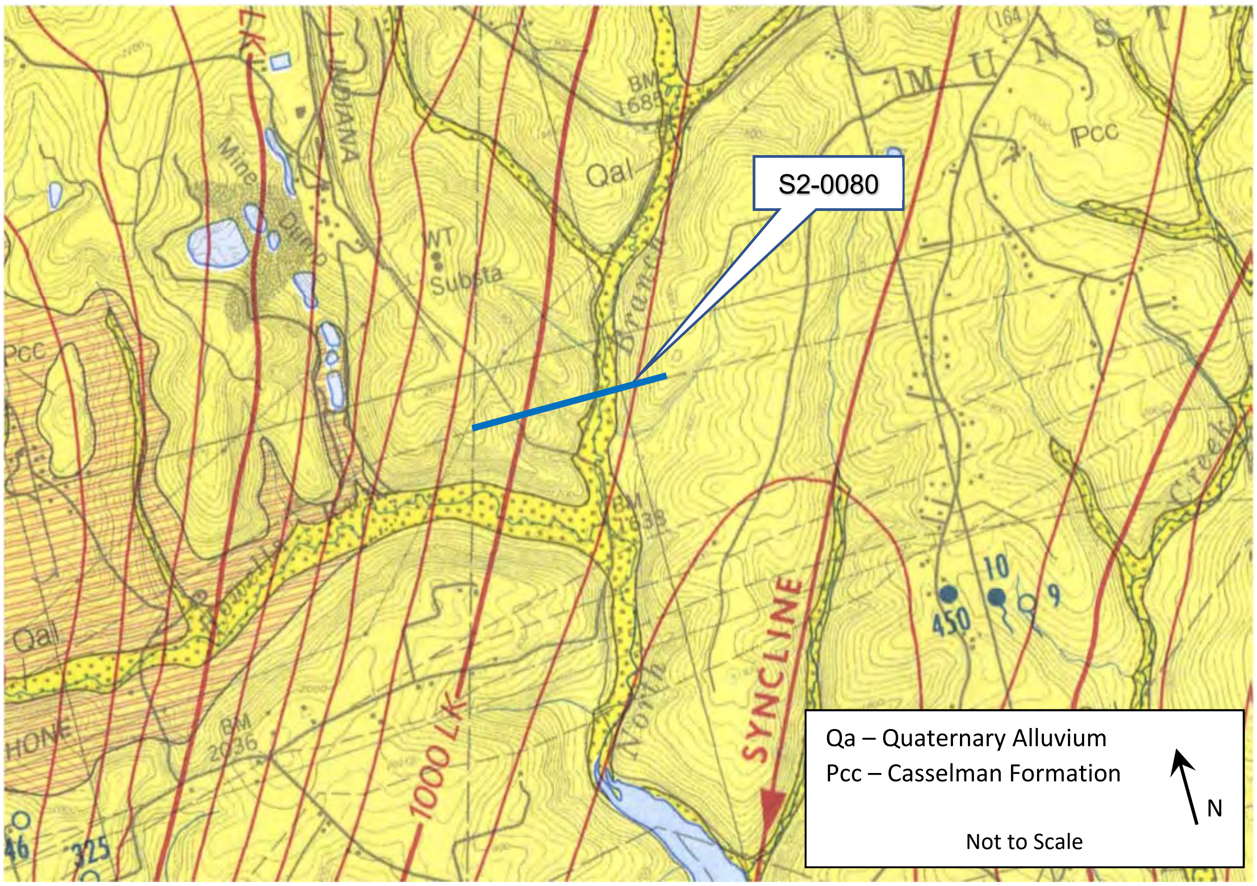


Figure 2. Bedrock Geology (modified from McElroy, 1998)

2.2.3 Structure

Glover (1990) provides structure contour maps for persistent coal beds in Cambria County. Using this resource and structure contours mapped for the Lower Kittanning coal, HDD S2-0080 is located within the west limb of the Wilmore Syncline. Here the beds trend northeast and are dipping approximately 1.7 degrees southeast. **Figure 3** shows the HDD S2-0080 location on the structure contour map.

Discontinuities in the form of joints, fractures, faults and bedding plane partings are imprinted on the broadly folded bedrock in the region. These features can act as conduits for groundwater movement and/or represent areas of weakness in the rock. Fold axes can be areas of increased density of fracturing (McElroy, 1998). Nickelsen and Hough (1967) conducted regional mapping of joints in shale, coal, and sandstone in the Appalachian Plateau. In the vicinity of HDD S2-0080, two systematic joint sets were mapped with approximate trends of WNW to NW. Less frequent non-systematic joints were mapped approximately orthogonal to the systematic joints.

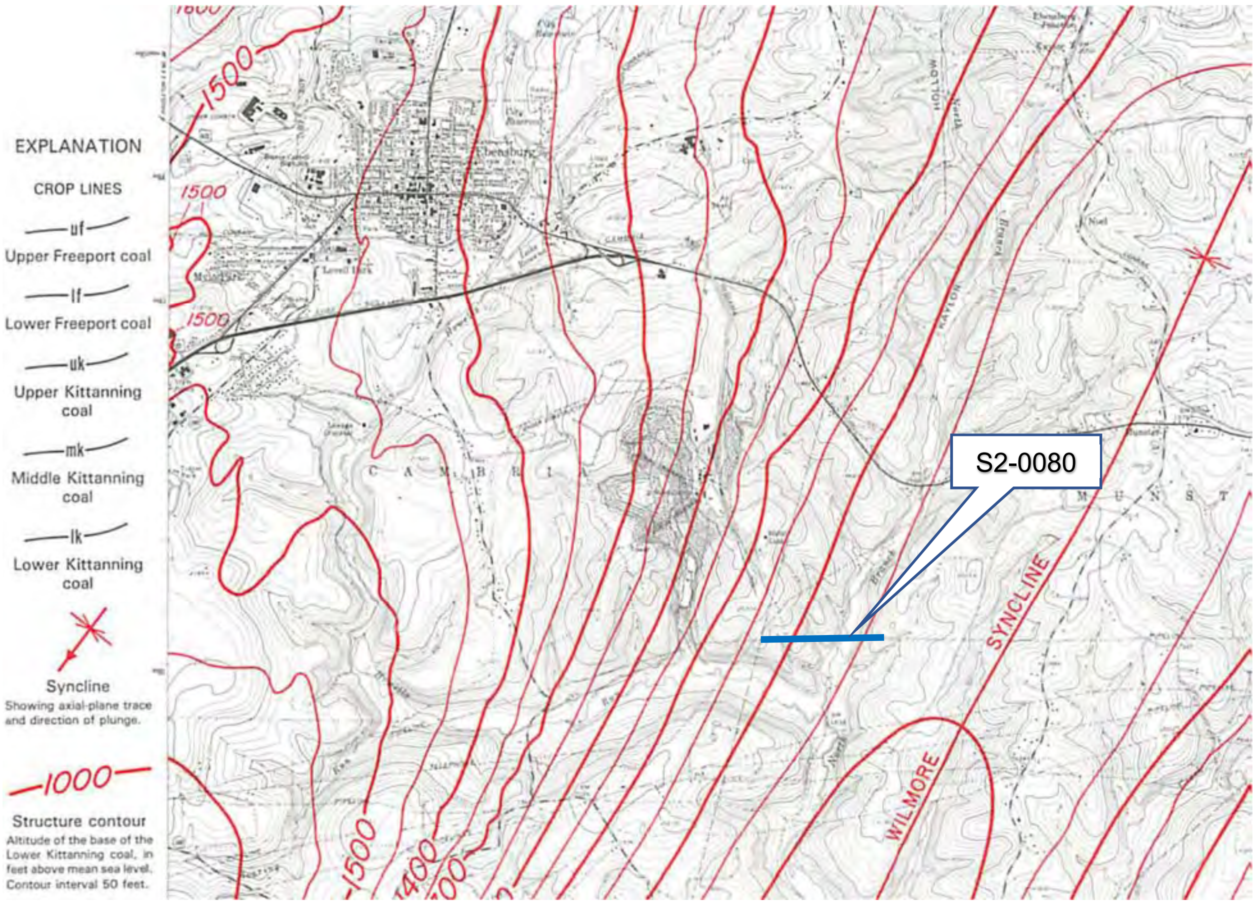


Figure 3. Structure Contour Map of the Lower Kittanning Coal (modified from Glover, 1990)

2.2.4 Fracture Trace Analysis

Fracture trace analysis using high altitude aerial photography was performed for the area of interest to identify potential zones of bedrock weakness along drill paths. Fracture traces (one mile in length or less) and lineaments (greater than one mile in length) are the surficial expression on natural landscapes of vertical 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.

Figure 4 shows a fracture trace map prepared for this reevaluation. This mapping was performed using aerial stereographic pairs flown in the spring of 1939. As such, much of the land surface appears undeveloped and fracture traces are more easily seen. Three general orientations are present in the set of fracture traces: a northwestern trending set, a northeastern trending set and an east-northeastern set. The northwestern trending set and east-northeastern trending set generally match the one of the systematic and non-systematic joint set pairs mapped by Nickelsen and Hough (1967).

The proposed path of the revised boring is shown in red on **Figure 4** and transects five of the mapped fracture traces. Two of these traces intersect at a location east-central along the drill path. Fracture trace intersections can be areas of exceptionally fractured, low strength, bedrock.

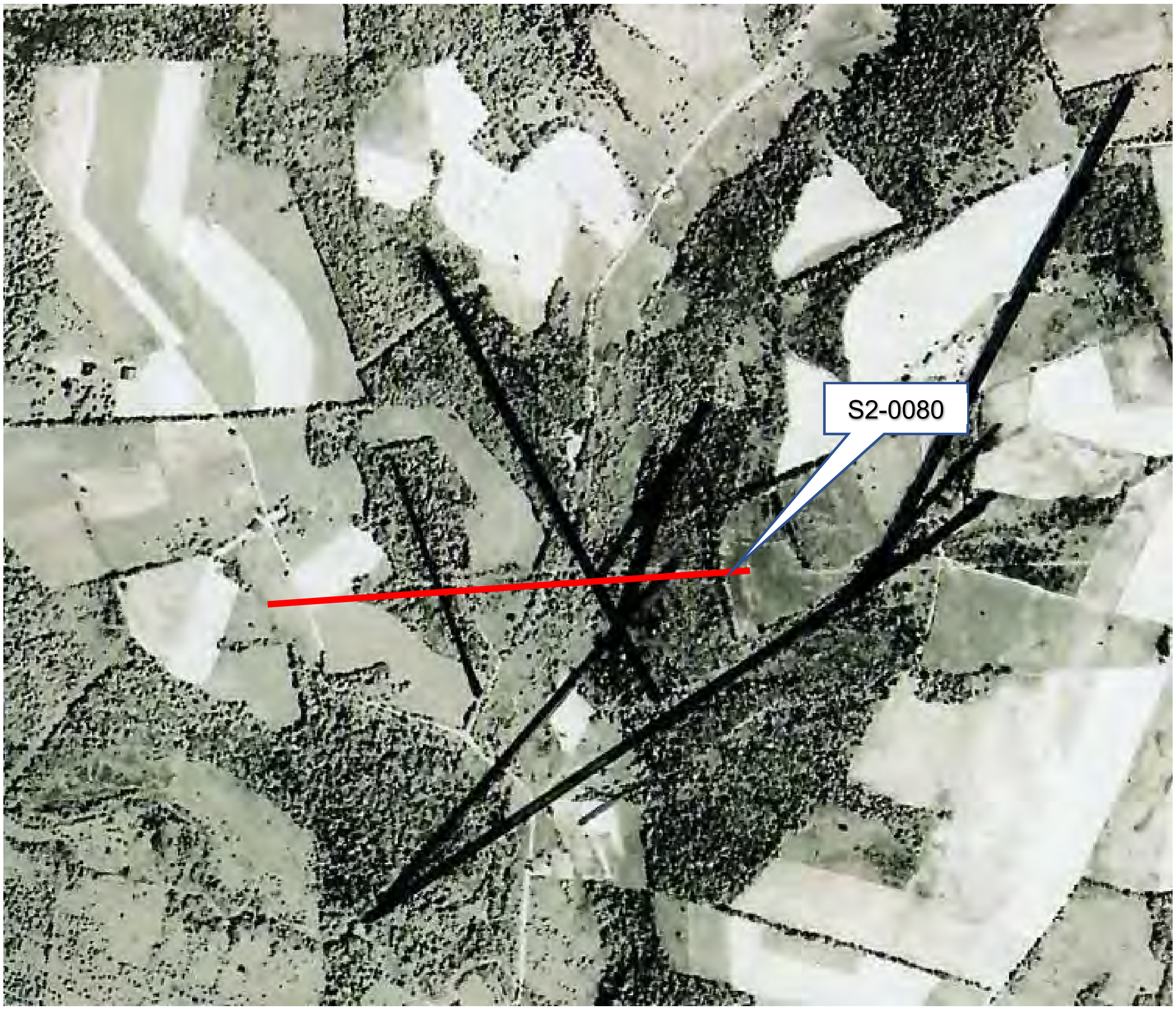


Figure 4. Fracture Trace Map

2.2.5 Karst

Based on published geologic data, no karst features are anticipated within the LOD of HDD S2-0080. The potential of karst conditions is not anticipated because limestone within the Casselman Formation is moderately resistant to weathering, is well-bedded to nodular and development of karst features is not characteristic for these rocks.

2.2.6 Mining

Deep coal mining has been extensive in the region of the HDD. Glover (1990) shows the limit of deep Lower Kittanning coal mining approximately 0.5 miles from HDD S2-0080 to the northwest and approximately 1.1 miles to the southeast; however, a search using the Pennsylvania Mine Map Atlas web site and Detailed Mine Maps provided by PADEP's Cambria County District Office (see **Attachment C**) show the former Mine 33-B Seam Mine operated by Bethenergy, Inc., underlying the HDD S2-0080 alignments. **Figure 5** shows the alignments drawn onto an image of the Beth Energy Mines, Inc., Cambria No. 33 Mine provided in the Detailed Mine Maps. The chain pillars and panel rooms shown on the maps indicate that coal was extracted here using the long-wall mining methods. No landowner complaints, including complaints associated with mine subsidence, were identified in the area of HDD-S2-0080 using PADEP eMapPA web site.

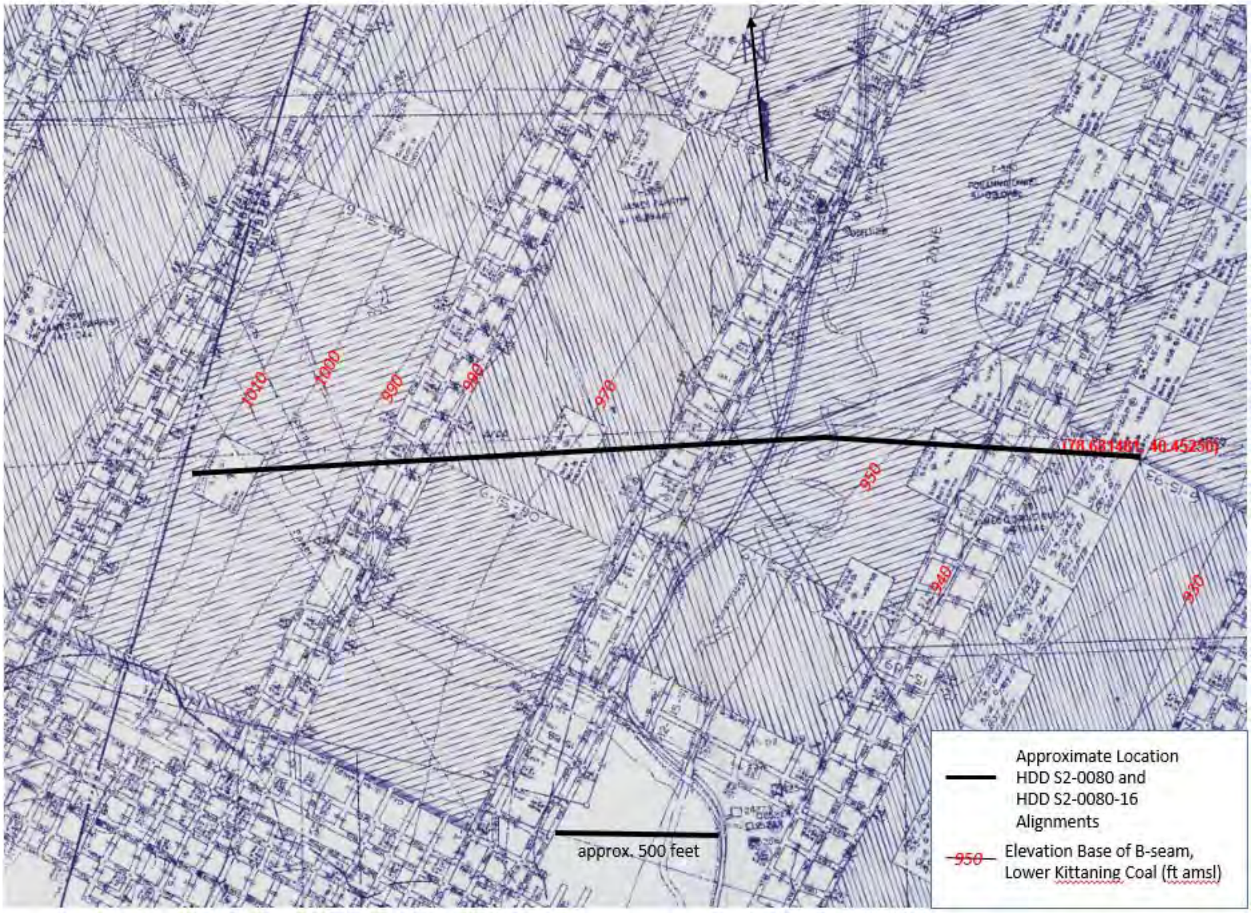


Figure 5. Bethenergy Mines, Inc., Cambria No. 33 Mine (not to scale; modified from Pennsylvania Mine Map Atlas – Sheet 2015-UMM_200_B-12)

Based on the Detailed Mine Maps and assuming a 5-foot mine void, the highest elevation of the No. 33 Mine roof is beneath the western entry/exit of the HDDs at about elevation 1015 ft amsl. Here the surface elevation is about 1,858 ft amsl, therefore there is approximately 843 feet of material between the mine roof and entry/exit point. The profile for revised 20-inch pipe is lower in elevation than for the 16-inch pipe and tracks at approximately 1,562 ft amsl at its lowest point beneath the North Branch of the Conemaugh River. Here the elevation of the mine roof is estimated to be at approximately 960 ft amsl, therefore there is approximately 602 feet of material between the mine roof and low point along the 20-inch profile. The lowest elevation of the mine roof along HDD-S2-0280 is beneath the eastern entry/exit at approximately 940 ft amsl and the surface elevation there is at about 1826 ft amsl, therefore there is approximately 886 feet of material between mine roof and the eastern entry/exit.

Several mine vents associated with the No. 33 Mine are shown on the Detailed Mine Maps. GES obtained coordinates for vents thought to be in close proximity to HDD-0280 alignments. The four vents closest to the alignments are plotted on the revised profiles in **Attachment A**. GES performed field reconnaissance with a professional land surveyor in attempt to locate vent openings at the surface. One vent, labeled Vent No. 2 on the revised profiles in **Attachment A**, was located in the field. The three other vents, with coordinates that plotted close to the alignments could not be located in the field, as indicated on the revised profiles. HDD construction plans should account for the located mine vent and the three additional mine vents that may be in close proximity to the HDDs.

If a HDD encounters a mine pool there is a potential to create a new mine pool discharge at one of the entry/exit points. The lowest part of the 20-inch profile (the lower of the two profiles) plots approximately 602 feet above the No. 33 mine therefore there is no risk of either HDD encountering the mine pool.

2.2.7 Rock Engineering Properties

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

- Well-bedded; sandstone is thick bedded to massive; shale is thin and fissile; claystone bedding is very poor; limestone varies from nodular to well-bedded.
- Poor to moderately well-formed joints; open and vertical; moderately spaced and distributed.
- Moderate to Fast drilling rate.

2.2.8 Results of Geotechnical Borings

Tetra Tech Borings

Three geotechnical borings, SB-01, SB-02, and SB-03, were installed to support the original boring profile design in September 2014 (see **Attachment B**). These borings were advanced to depths of 24.5ft bgs, 26.2 ft bgs, and 15.2 ft bgs, respectively. Boring SB-01 is located at Station 6+54 of the original boring plan for the 20-inch line with a surface elevation of 1,712 ft amsl. Boring SB-02 is located at Station 0+73 with a surface elevation of 1,646 ft amsl. Boring SB-03 is located at Station -0+45 on the original 20-inch profile with a surface elevation of 1,673 ft amsl.

Shale bedrock was encountered in SB-01 at a depth of 18.5 ft bgs (approximately 1,693 ft amsl), beneath a 12-foot layer of silty/clayey sand, beneath a 6-foot layer of silts and clays at the surface. Sandstone bedrock was encountered in SB-02 at a depth of 24 ft bgs (approximately 1,622 ft amsl), beneath a 21-foot layer of silty sand to the surface. Limestone bedrock was encountered in SB-03 at a depth of 14.5 ft bgs (approximately 1,658 ft amsl), beneath a 14-foot layer of silty sand to the surface. Groundwater was only encountered at SB-02 at 4.6 ft bgs, at an elevation of approximately 1641 ft amsl.

Terracon Borings

Two geotechnical borings, B2-1E and B2-1W, were installed to support the revised boring profile designs in August 2017 (see **Attachment B**).

B2-1E

Terracon Boring B2-1E was advanced on August 25, 2017 at Station 7+47 on the revised 20-inch profile from a surface elevation of approximately 1,677 ft amsl and to a depth of 102.5 feet. The unconsolidated overburden observed in boring B2-1E was comprised of predominantly of silty to sandy clay to a depth of 34 feet where coring was started. Slightly weathered, fine-grained to argillaceous sandy siltstone bedrock was encountered starting at 34 ft bgs with primary fracturing sub-horizontal to bedding. Gray-green mudstone/claystone was observed starting at 42.5 ft bgs with four highly weathered zones from 48.4 to 52.5 ft bgs. Dark gray to black argillaceous mudstone/shale was encountered starting at 72.5 ft bgs and transitioning into and green-gray to dark gray mudstone at 92.5 ft bgs to the total depth of 102.5 feet.

According to the Terracon log for B2-1E, core recoveries, ranged from 97 to 100% after the initial five feet of coring. Rock Quality Index (RQD) values for the cores, after the first 8.5 feet of coring, varied widely from 25 to 95 percent with a zone of elevated RQD values (80 to 92%) between 52.5 to 87.5 ft bgs (approximately 1624 to 1589 ft amsl).

Static groundwater was measured in B2-1E at 22.3 ft bgs (approximately 1,655 ft amsl), 16 hours after drilling had stopped.

A natural gas odor was noted on the log at 26 to 28 ft bgs in boring B2-1E in sand-size black shale fragments at the transition from soil to weathered bedrock. Similar notes were not shown on the log as the boring progressed.

<u>*B2-1W*</u>

Boring B2-1W was advanced on August 31, 2017, at Station 29+26 from a surface elevation of 1,855 ft amsl and to a depth of 305.5 feet (approximately 1,549 ft amsl), as shown on the revised profile for the 20-inch line. Unconsolidated overburden observed was comprised of 5 feet of clay on top of highly weathered bedrock to 26.5 feet bgs, where coring was initiated. From 26.5 to 100.5 ft bgs Terracon reports alternating layers of interbedded gray to dark gray shale, mudstone, and sandstone. These units are thin to very thinly-bedded and moderately to slightly weathered. Low angle and high angle fractures (referred to as joints on the Terracon log) were logged from 26.5 to 76.5 ft bgs. A third set of high angled, iron stained fractures were logged from 26.5 to 36.5 ft bgs. Iron staining was prevalent throughout fracturing in the core. A thin bedded gray limestone was reported from 100.5 to 115.4 ft bgs, atop gray shale interbedded with calcareous nodules from 115.4 146.7 ft bgs. Fractures in both limestone and shale units were moderately dipping and clay-filled. From 146.7 to 171.5 ft bgs the log shows a slightly to moderately weathered black, organic shale. Interbeds of slightly to highly weathered grey shale and mudstone with occasional clay seams were logged from 171.5 to 236.5 ft bgs. Black, weathered, limestone and dark shale with fossils was logged from 236.5 ft bgs to 258.1 ft bgs with a coal layer from 251.2 to 252.4 ft bgs. Gray moderately weathered shale with calcareous inclusions and laminations, interbedded with layers of calcareous cemented sandstone was logged from 258.1 ft bgs to 281.5 ft bgs. The remainder of the boring, to the total depth of 305.5 feet was logged as gray fine to medium-grained sandstone with calcareous inclusions and cement.

After the first 10 feet of coring in B2-1W recoveries remained high, ranging from 92 to 100% with most measurements at 100%. The RQDs after a depth of approximately 36.5 feet (approximately 1818 ft amsl) varied greatly over a range of values between 43 and 100%, with an overall average RQD of 84.8%.

Groundwater was not encountered in boring B2-1W and a static water level was not recorded.

2.3 Hydrogeology

2.3.1 Occurrence of Groundwater

Groundwater in the Casselman Formation is stored and moves through an interconnected network of joints, fractures, and bedding plane openings. Regional systematic joints are oriented northwest and west-northwest. Mapped fracture traces that intersect HDD S2-0080 are oriented northwest, northeast, and east-northeast. These may represent vertical zones of fracture concentration and preferred pathways for groundwater flow.

Examination of the core log for B2-1E show wet sand-sized shale fragments were encountered at 21.5 ft bgs and 16 hours after the stop of drilling, a water level was measured at 22.3 ft bgs. Low-angle/horizontal fractures were observed parallel to bedding with clay infilling throughout the core. High-angle, vertical fractures were observed within the siltstone from 34 to 42.5 ft bgs and from 47.5 to 92.5 ft bgs. These fractures represent pathways for groundwater flow.

2.3.2 Ground Elevation between HDD entry/exits

The surface elevations for the revised profiles at the eastern entry/exits are approximately 1,827 and 1,826 ft amsl for the 20-inch and 16-inch lines, respectively, and the surface elevations for the western entry/exits are 1,858 and 1,882 ft amsl, for the 20-inch and 16-inch lines, respectively. The revised 20-inch profile has a bottom elevation of 1,562 ft amsl and the bottom elevation of the revised 16-inch profile is 5 feet more shallow.

2.3.3 Well Yields and Water Levels

Published data for the Casselman Formation (McElroy, 2001) indicate that yields in residential wells range between 0 and 32 gpm.

The Pennsylvania Groundwater Information System (PaGWIS) reported four wells within a one mile of HDD S2-0080. PA Well ID 80851 and 80852 are part of a residential well cluster located approximately 3,070 feet northeast of the eastern entry/exit. Both wells were completed to 90 ft bgs and reported static water levels of 30 ft bgs. The reported well yield is 12 gpm for Well ID 80851 and 30 gpm for Well ID 80852. PA Well ID 81975 is a domestic well located approximately 4,910 feet north-northeast of the eastern entry/exit and is completed at 150 ft bgs. Static water is reported at 95 ft bgs and yield at 12 gpm. PA Well ID 80375 is a domestic well located approximately 5,260 feet southwest of the western entry/exit and is completed at 137 ft bgs. No static water level is reported for this well, but the yield is reported as 8 gpm.

Groundwater was encountered at 4.6 ft bgs (approximately 1,641 ft amsl) in test boring SB-02, installed near Station 9+00 on the revised profile for the 20-inch line. Static water was observed at 22.3 ft bgs (approximately 1,655 ft amsl) in boring B2-1E, installed at Station 7+47 on the revised profile for the 20-inch line.

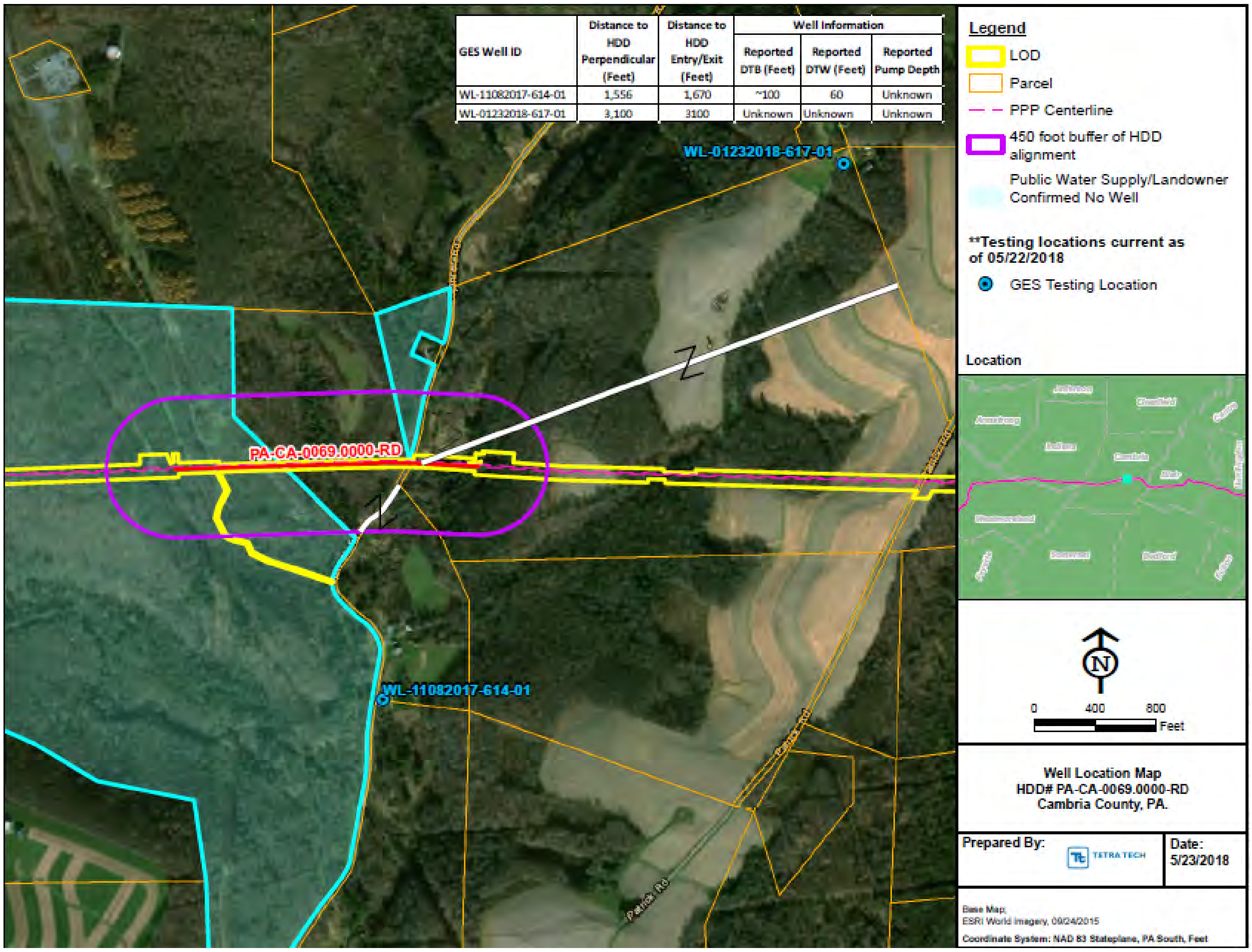
2.3.4 Water Supply Wells within 450 feet of Alignment

HDD-S2-0080 was included in the implementation of the 450-foot water supply survey program. Certified letters were sent on 10/30/2017 to three land owners who own five parcels that intersect the 450-foot survey border. Two of the owners confirmed that water wells were present on their properties and accepted SPLPs offer for pre-construction sampling. Both wells are distant from the HDD alignments. As shown on **Figure 6,** the closer of the two wells is over 1,500 feet south of the alignments.

In addition, all five property owners were offered a temporary water supply during HDD construction; however, none accepted the offer. Documentation of correspondence associated with the sampling and temporary water supply programs is provided in the Horizontal Directional Drill Analysis for HDD S2-0080.

2.4 Summary of Geophysical Studies

No geophysical studies were conducted for this reevaluation as there is no indication of karst development in the area and deep mining is present at a minimum estimated depth of approximately 685 feet below the below the flood plain for stream S-N34.



GES Well ID	Distance to HDD Perpendicular (Feet)	Distance to HDD Entry/Exit (Feet)	Well Information		
			Reported DTB (Feet)	Reported DTW (Feet)	Reported Pump Depth
WL-11082017-614-01	1,556	1,670	~100	60	Unknown
WL-01232018-617-01	3,100	3100	Unknown	Unknown	Unknown

Figure 6. 450-foot Water Supply Survey

3.0 OBSERVATIONS TO DATE

3.1 On This HDD Alignment

3.1.1 ME I

No IRs were reported along the alignment of the HDD S2-0080 drills on the list of IRs for ME I documented in the IR PPC Plan for Cambria County.

3.1.2 ME II

No drilling activities have been initiated at HDD S2-0080 as part of the ME II pipeline installation.

3.2 On Other HDD Alignments in Similar Hydrogeologic Settings

3.2.1 ME I

No IRs were reported on the list of IRs for ME I documented in the IR PPC Plan for sites underlain by Casselman Formation bedrock.

3.2.2 ME II

All of the IRs to date in Spreads 1 and 2 for the ME II pipeline have occurred while drilling through the cyclic sequences of sandstone, shale, limestone, clays seams and coal present within western Pennsylvania bedrock formations, including the Allegheny Group, Casselman Formation, Glenshaw Formation, Monongahela Group, and Waynesburg Formation. Entries and exits pass through alluvium, colluvium and soils developed on top weathered bedrock and mine spoils. In general, the IRs have been related to shallow overburden, coarse grained unconsolidated materials near the surface (such as alluvium and mine spoil), large elevation changes between entry/exits and the lowest elevation points along the profiles (sometimes creating soil plugs, elevated annular pressures and loss of fluids), and the interconnectivity of open bedrock structural features that is difficult to predict.

4.0 SUMMARY AND CONCLUSIONS OF HDD HYDROGEOLOGIC EVALUATION

4.1 HDD Site Conceptual Model

Based on the information provided in this reevaluation report, the revised drilling paths for HDD S2-0080 and HDD S2-0080-16 should encounter competent Casselman Formation bedrock throughout most of the profiles. The boreholes cross beneath two streams and one wetland complex at a minimum depth of 71 feet (below the North Branch Little Conemaugh River). The revised profiles show the HDDs deeper than the original profiles which should achieve the objective of drilling through bedrock with higher strength. However, as demonstrated on the logs for boring B2-1E and B2-1W, rock core RQDs varied widely between 25 and 100% and zones of varying strength can be expected along both drills. Fracture trace analysis indicates there is some probability that the drills will pass through zones of increased bedrock fracturing associated with four fracture traces along the eastern part of the drill and one fracture trace along the western part of the drill. Contractors should be prepared for drilling through less competent bedrock in sections as indicated by the variability of the RQD values and fracture traces.

The logs for all five geotechnical borings at HDD S2-0080 showed the overburden is predominately clay over silty sand. The log for B2-1E, drilled in August 2017, shows a thickness of mostly sandy clay from the ground surface to 34.0 feet where coring was initiated. This layer of cohesive soil will reduce IR risk upon entry or exit if the thickness of clay there is representative of the subsurface near the eastern entry/exits for the revised borings over 600 feet east of B2-1E. A thinner layer of clayey soils was seen at B2-1W (4.7 feet) covering a layer of highly weathered shale from 5.0 to 26.5 ft bgs. This indicates a slower drilling rate and lower mud pressure will be needed to prevent IRs upon entry or exit on the west end of the drills. The thickness of unconsolidated alluvial deposits (comprised of gravel, silt, and clay) under the flood plain of the River has not been determined and may be encountered in that section of the drills.

Water table elevations are anticipated to be above the elevation of the borings for a portion of the drills. The static water level in boring B2-1E, located at Station 7+47 on the revised 20-inch profile, was approximately at 1,655 ft amsl. Groundwater was not encountered in boring B2-1W. The static water level at SB-02 was at an elevation of 1,642 ft amsl and the elevation of the North Branch of the Conemaugh River is at approximately 1,645 ft amsl. If these elevations are representative of actual conditions, it is estimated that the pilot holes could be under the water table for approximately 60% of the borings, assuming the revised profiles. Given this position for the water table and elevations of the revised entry/exit points, no risk of excessive groundwater discharge or water table lowering is indicated. The recent 450-foot water supply survey indicates the closest domestic water supply well to the alignments is over 1,500 feet to the south.

The increase in profile distance and depth inherent in the revised plans represents a potential adverse increase in annular drilling fluid pressures as the pilot holes gain length, and especially when the profile turns upward at the end of the drills. As such, the revised profiles will be drilled using two intercept drills, one from each side, which greatly reduces this risk.

Three of the four mapped mine vents for the Cambria No. 33 Mine, proximal to the 20-inch and 16-inch alignments, could not be identified in the field and would affect HDD construction if encountered.

4.2 Conclusions and Recommendations

Based on the revised profiles for HDD S2-0080 and HDD S2-0080-16, the drills will be longer and reach deeper into more competent bedrock, and as such the risk of IRs is greatly reduced. The drilling plan for both the 20-inch and 16-inch drill should recognize the potential need to reduce drilling fluid pressures upon exit/entries where cohesive soil cover may be thin at the western entry/exits. Additionally, annular pressures should be closely monitored and managed while drilling under the North Branch Conemaugh River, the associated flood plain and across mapped fracture traces. The use of intercept drills is an important aspect of the revised profiles to reduce annular pressures. The drilling plan should also account for the potential to encounter one of more of the three deep mine vents that could not be located in the field.

Based on information provided by, and the expertise of, the HDD team, as well as our experience with the relevant hydrogeology and geology, GES believes that the implementation of the revised profiles and inherent intercept bores will minimize the risk of IRs and losses of circulation and minimize the likelihood of an impact to the environment. Furthermore, based on such information, expertise and experience, GES believes that implementation of the revised profiles and inherent intercept bores are practicable measures, in conjunction with absence of known water supplies within 1,500 feet of the alignments, to prevent impacts to any private water supplies. In the unlikely event of an impact to a private water supply, SPLP will implement the procedures of the IR PPC Plan.

5.0 REFERENCES

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McElroy, T. A. (1998), *Groundwater resources of Cambria County, Pennsylvania*, Pa. Geol. Surv., 4th. Ser., W67.

McElroy, T. A. (2001), *Groundwater Resources of Somerset County, Pennsylvania.* Pennsylvania Department of Environmental Resources, Office of Resource Management, Bureau of Topographic and Geologic Survey.

Nickelsen, R. P. and Hough, V. D. (1967) *Jointing in the Appalachian Plateau of Pennsylvania*, GSA Bull. v. 78, p. 609-630.

PA DEP, eMapPA (http://www.depgis.state.pa.us/emappa/).

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

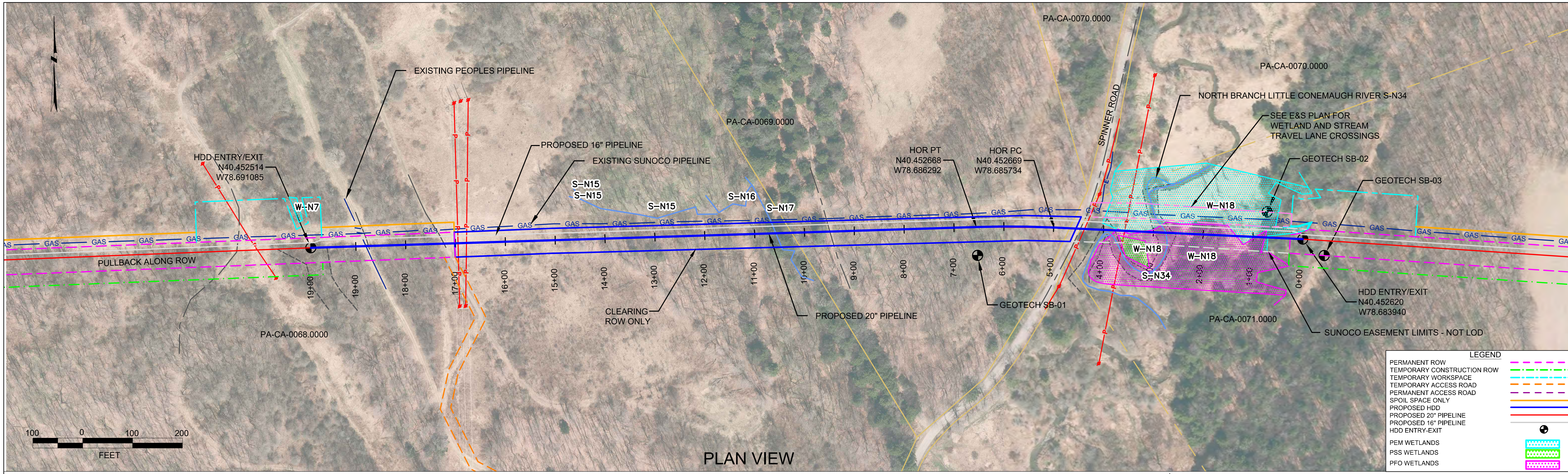
PA Mine Map Atlas (http://www.minemaps.psu.edu).

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

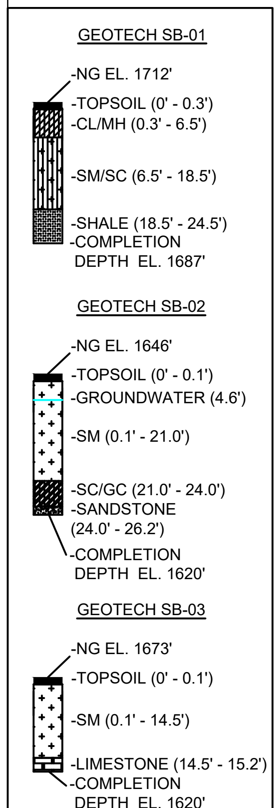
USGS (United States Geological Survey), Ebensburg, Pennsylvania, 1:24,000 topographic quadrangle map, rev. 1982

Attachment A

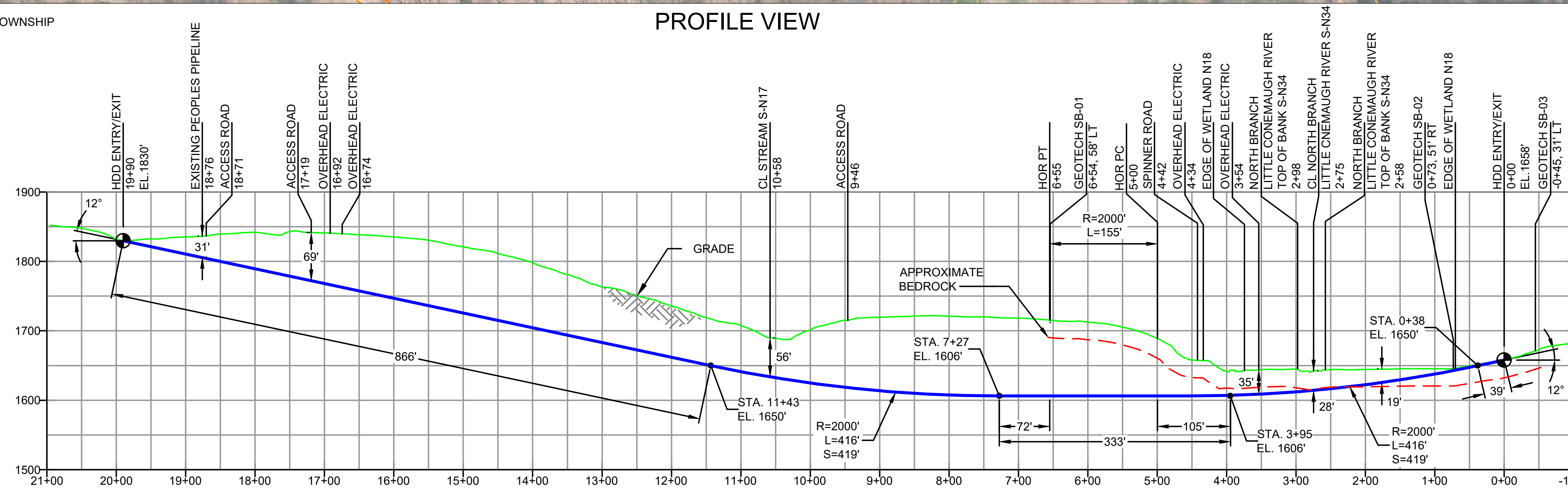
Original and Revised Plans and Profiles



CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080



NOTE: REFER TO TEST BORING LOG S2-0080 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):1990'
   HDD PIPE LENGTH (S=):2076'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		JTW	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ADDED GEOTECH INFO	MRS	09/06/15	RMB	09/06/15	AAW	09/06/15
B	ISSUED FOR BID	MRS	07/31/15	DLM	07/31/15	AAW	07/31/15
A	ISSUED FOR REVIEW	RTT	03/27/15	RMB	03/27/15	AAW	03/27/15

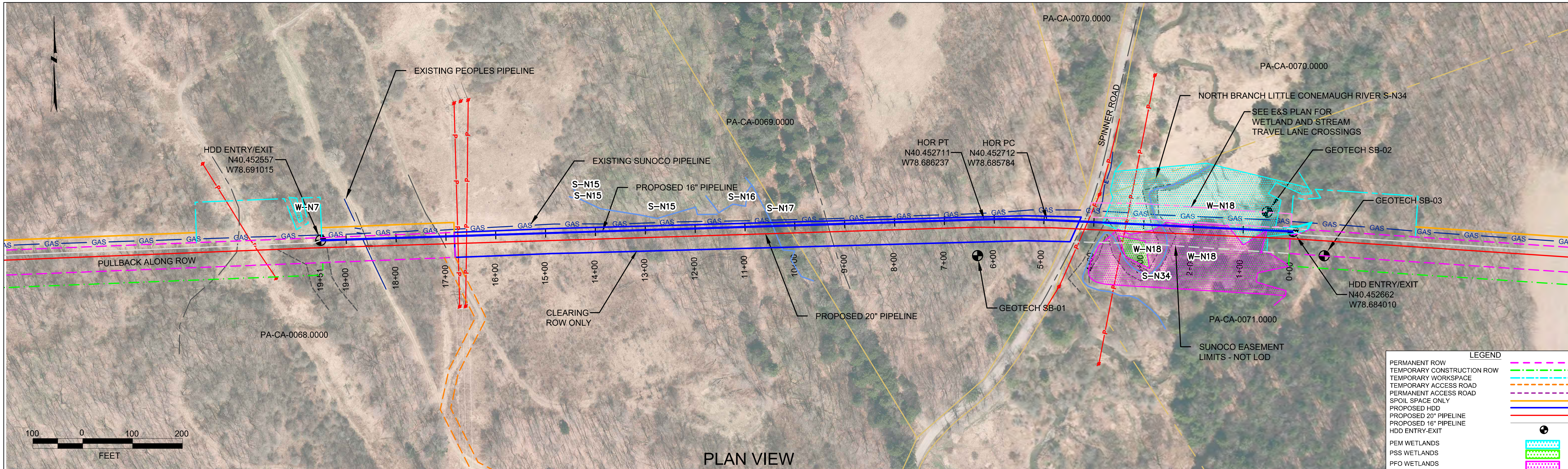
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

20-INCH HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

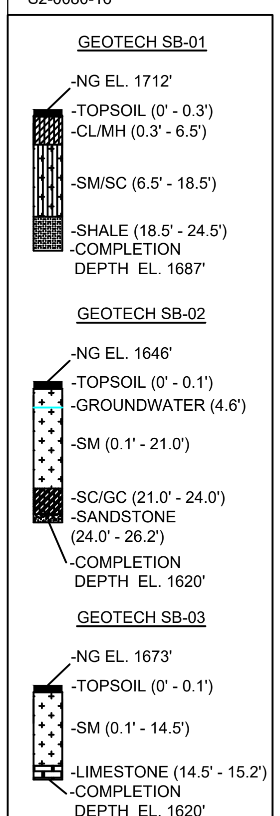
SCALE: 1"=200'
DWG. NO: PA-CA-0069.0000-RD



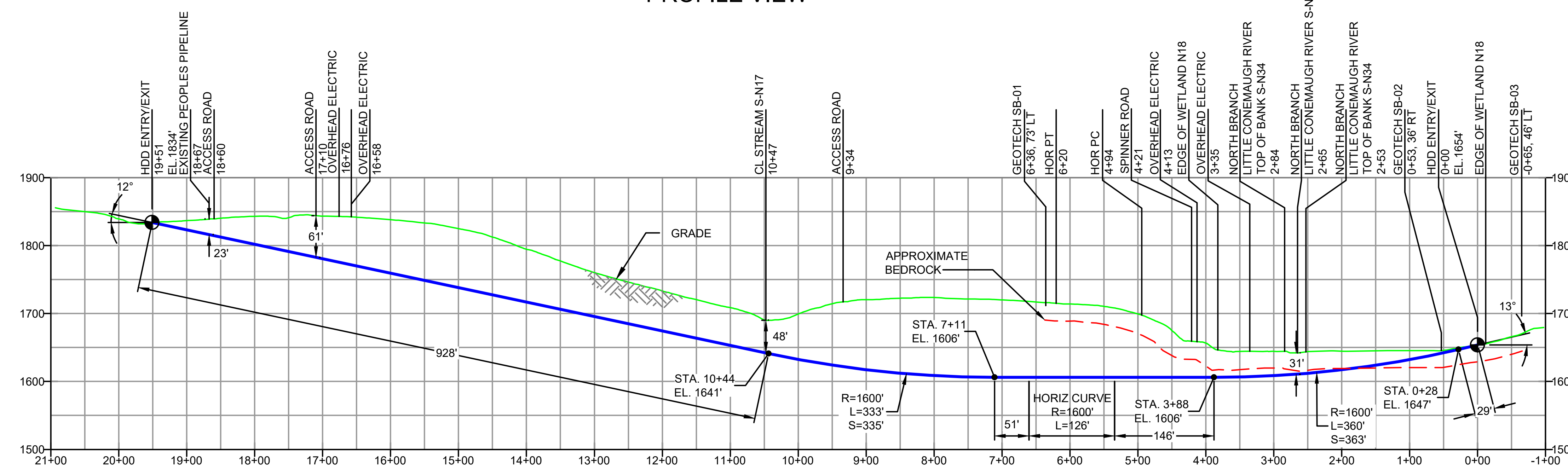
PLAN VIEW

CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080-16

PROFILE VIEW



NOTE: REFER TO TEST BORING LOG S2-0080 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 1951'
   HDD PIPE LENGTH (S=): 1978'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		JTW	03/15/16	RMB	03/15/16	AAW	03/15/16
B	ADDED GEOTECH INFO	MRS	09/06/15	RMB	09/06/15	AAW	09/06/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	03/27/15

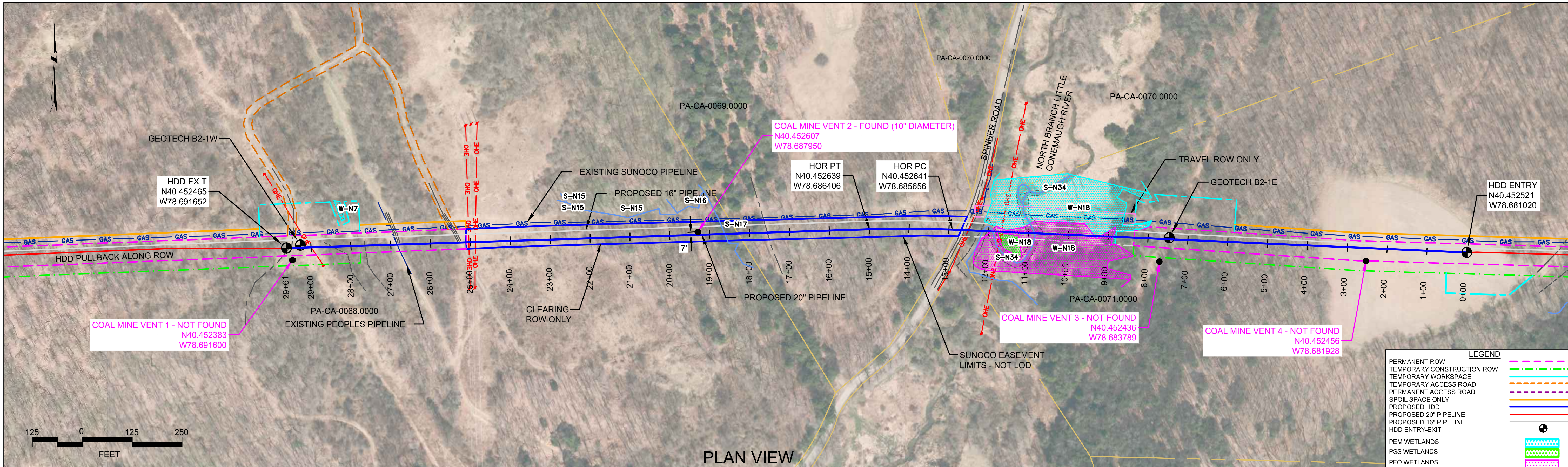
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

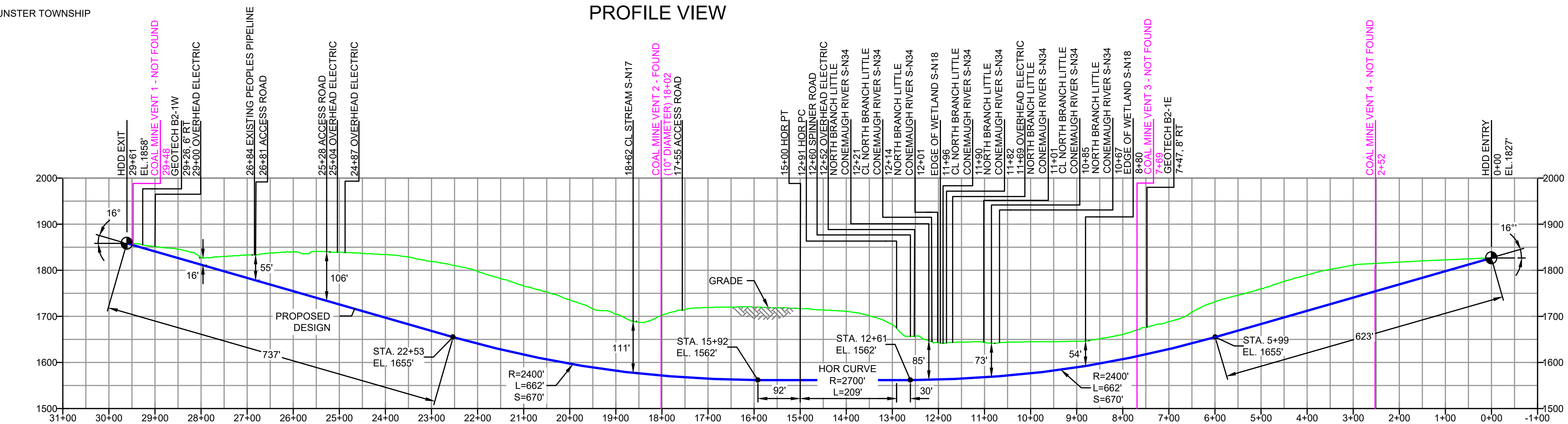
16-INCH HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' DWG. NO: PA-CA-0069.0000-RD-16



CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080

PROFILE VIEW



GEOTECH B2-1W

- NG EL. 1855'
- GRAVEL (0.0' - 0.3')
- LEAN CLAY CL (0.3' - 5.0')
- COMPLETELY WEATHERED SHALE (21.5' - 30.0')
- SHALE SANDSTONE/LIMESTONE (5.0' - 305.5')
- BORING TERMINATED EL.1549.5'

NOTE: REFER TO TEST BORING LOG B2-1W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-1E

- NG EL. 1677'
- FILL -LEAN CLAY W/ SAND (0.5' - 9.0')
- SILTY CLAY W/ SAND CL-ML (9.0' - 21.5')
- GROUNDWATER (22.3')
- LEAN CLAY W/ SAND CL (21.5' - 34.0')
- SILTSTONE/MUDSTONE (34.0' - 102.5')
- BORING TERMINATED EL.1554.5'

NOTE: REFER TO TEST BORING LOG B2-1E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2961'
   HDD PIPE LENGTH (S=):3031'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. PILOT HOLE SHALL BE COMPLETED USING THE INTERCEPT METHOD CONSISTING OF TWO PILOT HOLES DRILLING FROM BOTH SIDES OF THE DRILL.

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP7	DRILL DESIGN LENGTHENED PER CLIENTS REQUEST	MRS	04/06/18	RMB	04/06/18	CAG	04/06/18
EP6	ADDED COAL MINE VENT LOCATIONS	MRS	01/29/18	RMB	01/29/18	CAG	01/29/18
EP5	UPDATED GEOTECH BORE ELEVATION INFO PROVIDED BY DPS	MRS	11/28/17	RMB	11/28/17	CAG	11/28/17
EP4	UPDATED GEOTECH INFO PROVIDED BY DPS	MRS	11/14/17	RMB	11/14/17	CAG	11/14/17
EP3	RELOCATED HDD ENTRY / EXIT POINTS - DESIGN CHANGE BY DPS	MRS	11/07/17	RMB	11/07/17	CAG	11/07/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	09/30/16	RMB	09/30/16	AAW	09/30/16

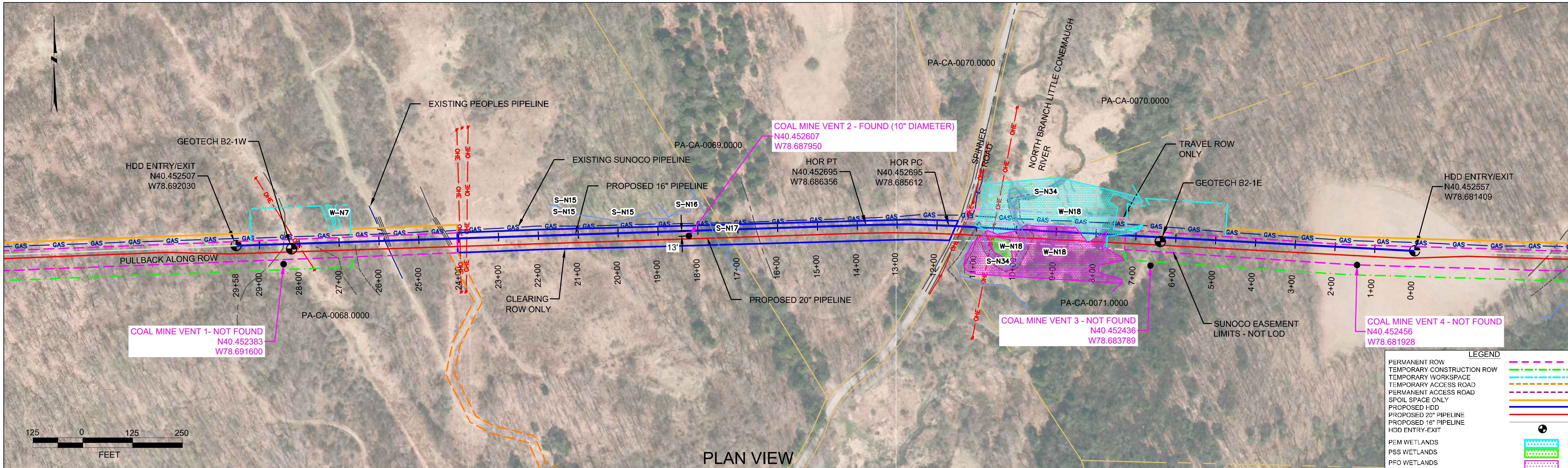
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' | DWG. NUMBER: PA-CA-0069.0000-RD



CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080-16

PROFILE VIEW

GEOTECH B2-1W

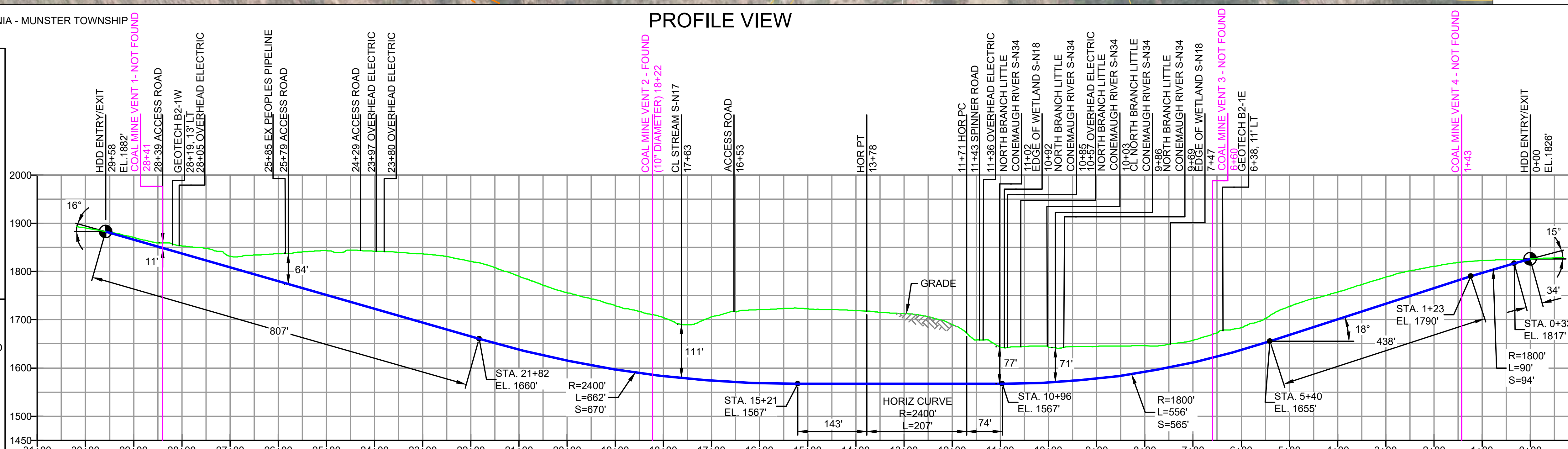
- NG EL. 1855'
- GRAVEL (0.0' - 0.3')
- LEAN CLAY CL (0.3' - 5.0')
- COMPLETELY WEATHERED SHALE (21.5' - 30.0')
- SHALE SANDSTONE/LIMESTONE (5.0' - 305.5')
- BORING TERMINATED EL.1549.5'

NOTE: REFER TO TEST BORING LOG B2-1W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-1E

- NG EL. 1677'
- FILL -LEAN CLAY W/ SAND (0.5' - 9.0')
- SILTY CLAY W/ SAND CL-ML (9.0' - 21.5')
- GROUNDWATER (22.3')
- LEAN CLAY W/ SAND CL (21.5' - 34.0')
- SILTSTONE/MUDSTONE (34.0' - 102.5')
- BORING TERMINATED EL.1554.5'

NOTE: REFER TO TEST BORING LOG B2-1E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

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2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2958'
   HDD PIPE LENGTH (S=):3032'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
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10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. PILOT HOLE SHALL BE COMPLETED USING THE INTERCEPT METHOD CONSISTING OF TWO PILOT HOLES DRILLING FROM BOTH SIDES OF THE DRILL.

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP6	ADDED COAL MINE VENT LOCATIONS	MRS	01/29/18	RMB	01/29/18	CAG	01/29/18
EP5	UPDATED GEOTECH BORE ELEVATION INFO PROVIDED BY DPS	MRS	11/28/17	RMB	11/28/17	CAG	11/28/17
EP4	UPDATED GEOTECH INFO PROVIDED BY DPS	MRS	11/14/17	RMB	11/14/17	CAG	11/14/17
EP3	RELOCATED HDD ENTRY / EXIT POINTS - DESIGN CHANGE BY DPS	MRS	11/07/17	RMB	11/07/17	CAG	11/07/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/18/16	RMB	05/18/16	AAW	05/18/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

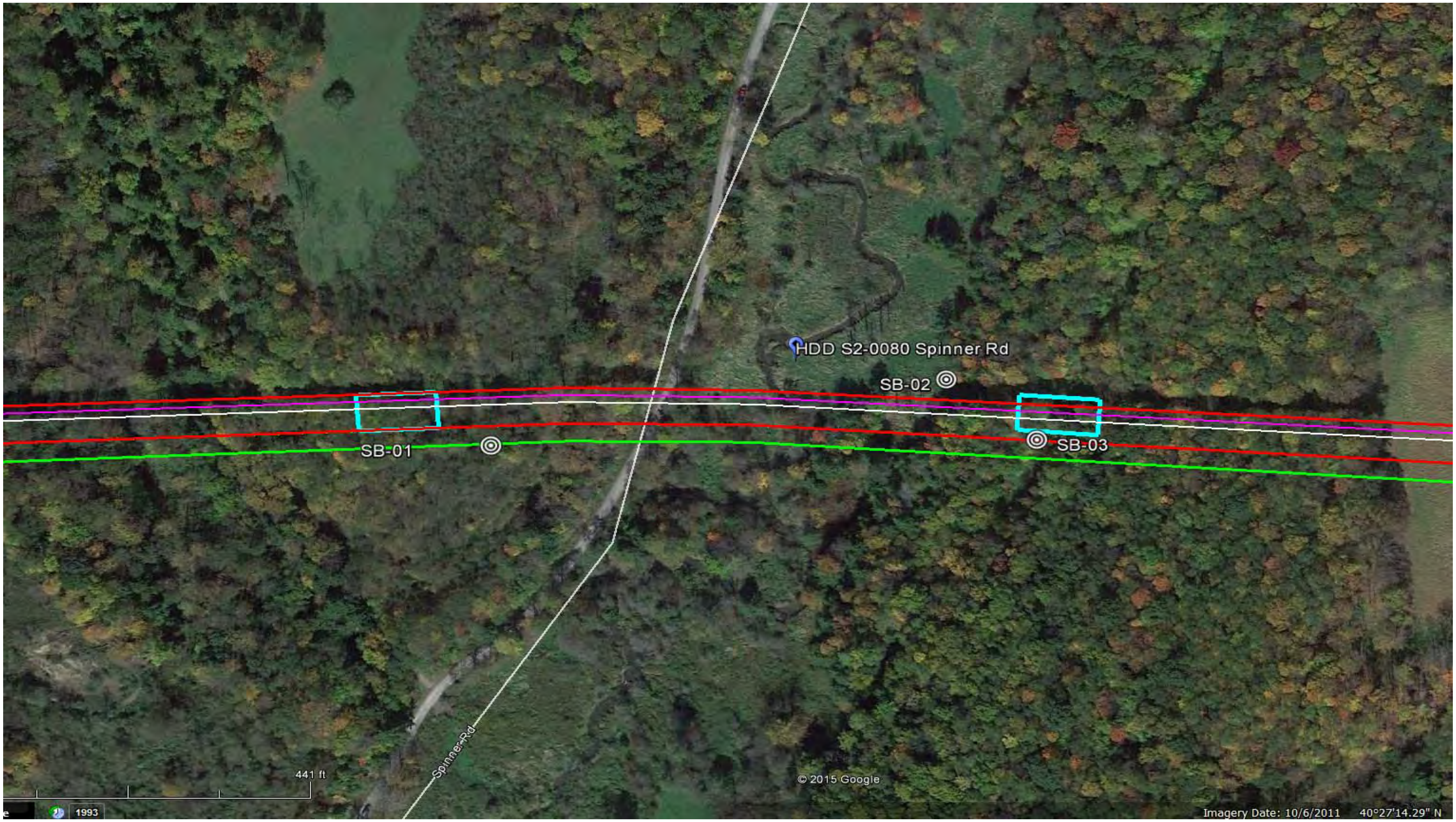
SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'
DWG. NO. PA-CA-0069.0000-RD-16

Attachment B

Geotechnical Reports



LEGEND:

Geotechnical Soil Boring (SB) Locations

TETRA TECH

GEOTECHNICAL BORING LOCATIONS
HDD S2-0080
CAMBRIA COUNTY, MUNSTER TOWNSHIP, PA
SUNOCO PENNSYLVANIA PIPELINE PROJECT

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406	
Project Location:	SPINNER ROAD, PORTAGE, PA			Page 1 of 1	
HDD No.:	S2-0080	Dates(s) Drilled: 09-20-14		Inspector:	E. WATT
Boring No.:	SB-01	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED		Total Depth (ft):	24.5

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		8	CL/ MH	DR WEATHERED TO A VARI-COLORED (BROWN, GRAY,YELLOW BR.)	4	8	10	12	**18**
				6.5			SILTY CLAY (USCS: CL/MH) WITH A LITTLE FINE SAND.					
2	8.0	9.5	6.5		14	SM/ SC	DR WEATHERED TO A YELLOWISH BROWN FINE SAND WITH SOME	5	26	50/6"		**>50**
							SILT, AND A LITTLE UNWEATHERED F-C GRAVEL (FISSILE).					
3	13.0	14.0			9		DR WEATHERED TO A VARI-COLORED FINE SAND WITH A LITTLE SILT,	2	50/6"			**>50**
							W/ A LITTLE UNWEATHERED F-C SHALE/SILTSTONE GRAVEL.					
4	18.0	18.7			7		DR WEATHERED TO A VARI-COLORED FINE SAND WITH A LITTLE SILT,	8	50/2"			**>50**
				18.5			W/ A LITTLE UNWEATHERED F-C SHALE/SILTSTONE GRAVEL.					
5	23.0	23.6	18.5	24.5	5		GRAY PARTIALLY WEATHERED SILTSTONE/SHALE.	28	50/1"			**>50**
							AUGER REFUSAL AT 24.5'.					
							CAVED AND DRY AT 18'.					

Notes/Comments:

Pocket Pentrometer Testing
S1: >4 TSF

DR: DECOMPOSED ROCK

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

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

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT			Project No.: 103IP3406	
Project Location:	SPINNER ROAD, PORTAGE, PA			Page 1 of 1	
HDD No.:	S2-0080	Dates(s) Drilled: 09-23-14		Inspector:	E. WATT
Boring No.:	SB-02	Drilling Method: SPT - ASTM D1586		Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): 4.6		Total Depth (ft):	26.2

Sample No.	Sample Depth (ft) From	Sample Depth (ft) To	Strata Depth (ft) From	Strata Depth (ft) To	Recov. (in)	Strata (USCS)	Description of Materials	6" Increment Blows *				N
			0.0	0.1			TOPSOIL (<1").					
1	3.0	5.0	0.1		16	SM	DR WEATHERED TO A MOTTLED BROWN AND GRAY FINE SAND WITH	1	6	14	16	**20**
							SOME SILT, A LITTLE UNWEATHERED FINE SANDSTONE? GRAVEL.					
2	8.0	10.0			11		DR WEATHERED TO A VARI-COLORED FINE TO MEDIUM SAND WITH A	1	9	28	40	**37**
							LITTLE SILT AND A LITLLE F-C SANDSTONE GRAVEL.					
3	13.0	14.5			12		DR WEATHERED TO A VARI-COLORED FINE TO COARSE SAND WITH A	4	28	50/6"		**>50**
							LITTLE SILT AND A LITLLE F-C SANDSTONE GRAVEL.					
4	18.0	19.0			9		DR WEATHERED TO A GRAY TO MEDIUM SAND AND	4	50/6"			**>50**
				21.0			SILT.					
5	23.0	23.2	21.0		2	SC/ GC	DR WEATHERED TO A GRAY CLAYEY FINE TO MEDIUM SAND	50/2"				**>50**
				24.0			AND UNWEATHERED SANDSTONE GRAVEL.					
6	26.0	26.2	24.0	26.2	<2		PARTIALLY WEATHERED GRAY SANDSTONE.	50/2"				**>50**
							AUGER REFUSAL AT 26.0'.					
							WET ON SPOON AT 5.5'					
							WATER LEVEL THRU AUGERS AT 4.6'.					
							CAVED AT 24'.					

Notes/Comments:

<u>Pocket Pentrometer Testing</u>

DR: DECOMPOSED ROCK

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

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

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

TEST BORING LOG

Project Name:	SUNOCO PENNSYLVANIA PIPELINE PROJECT		Project No.: 103IP3406	
Project Location:	SPINNER ROAD, PORTAGE, PA		Page 1 of 1	
HDD No.:	S2-0080	Dates(s) Drilled: 09-20-14	Inspector:	E. WATT
Boring No.:	SB-03	Drilling Method: SPT - ASTM D1586	Driller:	S. HOFFER
Drilling Contractor:	HAD DRILLING	Groundwater Depth (ft): NOT ENCOUNTERED	Total Depth (ft):	15.2

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	0.1			TOPSOIL (1").					
1	3.0	5.0	0.1		3	SM	BROWN FINE SAND WITH SOME SILT AND A LITTLE FINE	2	4	6	13	**10**
							SANDSTONE GRAVEL.					
2	8.0	10.0			20		DR WEATHERED TO A MOTTLED BROWN AND GRAY FINE SAND, WITH	4	16	32	45	**48**
							A LITTLE SILT, AND A LITTLE F-C GRAVEL.					
3	13.0	13.8			5		DR WEATHERED TO A LIGHT BROWN AND LIGHT GRAY FINE SAND,	17	50/3"			**>50**
				14.5			A LITTLE, SILT, W/ A LITTLE UNWEATHERED FINE SHALE GRAVEL.					
4	15.0	15.2	14.5		1		PARTIALLY WEATHERED ROCK (GRAY LIMESTONE AND SANDSTONE	50/2"				**>50**
				15.2			WITH QUARTZ VEINS).					
							COBBLES UP TO 6" PRESENT IN TOP 2 FEET OF BORING .					
							AUGER REFUSAL AT 15'. OFF-SET BORING 14' TO SOUTH AND					
							CONTINUOUSLY AUGERED TO REFUSAL AT 15'.					
							CAVED AND DRY AT 14'.					

Notes/Comments:

Pocket Pentrometer Testing

DR: DECOMPOSED ROCK

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

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

GEOTECHNICAL LABORATORY TESTING SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0080

HDD No.	Test Boring No.	Sample No.	Depth of Sample (ft.)		Water Content, % (ASTM D2216)	Percent Silts/Clays, % (ASTM D1140)	Atterburg Limits (ASTM D4318)			USCS Classif. (ASTM D2487)
			From	To			Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	
S2-0080	SB-01	1	3.0	5.0	21.5	86.4	45	26	19	CL/MH
		2	8.0	9.5	5.7	26.6	-	-	-	-
		3	13.0	14.0	7.7	16.9	-	-	-	-
	SB-02	1	3.0	5.0	8.9	23.9	-	-	-	-
		2	8.0	10.0	9.7	14.3	-	-	-	-
		4	18.0	19.0	14.0	46.9	-	-	-	-
		5	23.0	23.2	10.0	37.5	-	-	-	-
		6	26.0	26.2	7.2	40.6	-	-	-	-
	SB-03	1	3.0	5.0	9.2	30.6	-	-	-	-
		2	8.0	10.0	7.6	19.7	-	-	-	-
		3	13.0	13.8	2.6	19.2	-	-	-	-

Notes:

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

REGIONAL GEOLOGY SUMMARY
SUNOCO PENNSYLVANIA PIPELINE PROJECT
HDD S2-0080

HDD No.	NAME	BORING NO.	REGIONAL GEOLOGY DESCRIPTION	GENERAL TOPOGRAPHIC SETTING	BEDROCK FORMATION	GENERAL ROCK TYPE	APPROX MAX FM THICKNESS (FT)	DEPTH TO ROCK (Ft bgs) based on nearby well drilling logs	NOTES / COMMENTS
S2-0080	Spinner Rd	SB-01 SB-02 SB-03	**Casselman Formation** - Cyclic sequences of shale, siltstone, sandstone, red beds, thin, impure limestone, and thin, nonpersistent coal; red beds are associated with landslides; base is at top of Ames limestone.	Mid-slope stream valley	Casselman	Shale-siltstone, sandstone; clastic; limestone; coal	236-525	30-32	

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 6, 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 2 – Spinner Road
Commonwealth of Pennsylvania
Drawing #PA-CA-0069.000-RD
PO #20170804-10
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 Spinner Road (Drawing #PA-CA-0069.000-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 B2-1W and B2-1E, visual classification and photography of the rock core samples, and laboratory testing of representative rock samples.

Test borings, B2-1W and B2-1E were drilled between August 25 and 31, 2017 to depths of 305.5 and 102.5 feet, respectively as shown on the attached **Test Boring Location Plan**. Bedrock typically consisted of interlayered sedimentary rock comprised of shale, mudstone, sandstone, and limestone. 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. Unconfined compressive strength test results are shown on the attached reports.

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

Sincerely,
Terracon Consultants, Inc.

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

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

Attch:

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

TEST BORING LOCATION PLAN

N

APPROXIMATE BORING LOCATION

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

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

Terracon
Consulting Engineers & Scientists

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

TEST BORING LOCATION PLAN

Spinner Road HDD Cores B2-1W and B2-1E
PA-CA-0069.000-RD
Cambria County, Pennsylvania

Exhibit
A-2

EXPLORATION RESULTS

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION

Latitude: 40.452502° Longitude: -78.691539°

Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
0.3	Gravel to 3-inches	1858.5+/-								
	LEAN CLAY (CL), trace sand, trace gravel, medium stiff				X	11	3-3-4 N=7			
5.0		1854+/-	5							
	Completely weathered SHALE, brown to gray, medium dense to very dense				X	12	7-13-15 N=28			
			10		X	14	12-16-21 N=37			
			15		X	2	50/2"			
			20		X	4	100/4"			
			25							
26.5		1832.5+/-								
	Run 1, Moderately hard, gray, fine grained SHALE interbedded with mudstone, very thin bedding, primary joint set, low angle, close to very close, smooth, planar, fresh, slightly open; secondary joint set, low angle, close, planar, slightly open, iron stained; tertiary joint set, moderately close, high angle, rough, undulating, slightly open, iron stained		30		Core	60		27	3.25 3.5 3 2.25	

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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017

Boring Completed: 8/31/2017

Drill Rig: CME-850

Driller: Terracon/Peter M.

Project No.: J217P078

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 2

LOCATION

Latitude: 40.452502° Longitude: -78.691539°

Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
31.5		1827.5+/-	60			2.5	
36.5	Run 2, Similar	1822.5+/-	35		0	2.25 2.5 2.75 3.25 3.25	
41.5	Run 3, Moderately hard, gray, fine grained MUDSTONE, thin bedding, primary joint set, high angle, moderately close, slightly open to open, rough, undulating; secondary joint set, low angle, close to moderately close, slightly open, smooth, planar, fresh	1817.5+/-	60		66	2.5 2.25 2 2 2.25	
46.5	Run 4, Similar	1812.5+/-	60		50	2.25 2.25 3.25 3 2	
51.5	Run 5, Similar to 46.7 feet At 46.7 feet: Hard, slightly weathered, gray, fine grained SANDSTONE interbedded with mudstone, thin bedding, primary joint set, low angle, close, slightly open to open, rough, planar, fresh	1807.5+/-	55		66	2.5 1.5 3 2.25 2.5	
56.5	Run 6, Hard, slightly weathered, gray, fine grained SANDSTONE interbedded with mudstone, thin bedding, primary joint set, low angle, close, slightly open to open, rough, planar, fresh; secondary joint set, high angle, moderately close, slightly open, rough, undulating, iron stained At 55.5 feet: Moderately hard, slightly weathered, very fine grained MUDSTONE interbedded with shale, very thin bedding, primary joint set, low angle, moderately close, slightly open, smooth, planar, fresh; secondary joint set, high angle, moderately close, tight to slightly open, rough, fresh	1802.5+/-	60		93	2.25 2.25 1.5 1.5 2.5	
	Run 7, Similar		60		97	2.25 2.25 2 2	

Depth scale (Ft.): 35, 40, 45, 50, 55, 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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017 | Boring Completed: 8/31/2017
Drill Rig: CME-850 | Driller: Terracon/Peter M.
Project No.: J217P078

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 2

LOCATION
Latitude: 40.452502° Longitude: -78.691539°
Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
61.5	Run 7, Similar *(continued)*	1797.5+/-	60			2.25	
66.5	Run 8, Similar	1792.5+/-	60		92	1.75 1.25 1 1.25 1.5	
71.5	Run 9, Similar	1787.5+/-	60		100	1.75 1.5 1.75 1.25 1.5	
76.5	Run 10, Similar	1782.5+/-	60		100	2 2.5 2.5 2 2	
81.5	Run 11, Moderately hard, moderately weathered, dark gray SHALE interbedded with mudstone, very thin bedding, primary joint set, low angle, close, slightly open, smooth, planar, iron stained	1777.5+/-	60		85	1.3 1.5 1.5 2 1.25	
86.5	Run 12, Similar	1772.5+/-	60		43	1.75 1.75 1.5 1.25 1.5	
			60		92	2 3.25 2 3	

Depth scale (Ft.): 65, 70, 75, 80, 85, 90

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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017	Boring Completed: 8/31/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

**CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354**

SITE: Spread 2

LOCATION
Latitude: 40.452502° Longitude: -78.691539°
Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
91.5	Run 13, Moderately hard, slightly weathered, gray, fine grained SANDSTONE interbedded with mudstone, thin bedding, primary joint set, low angle, very close to close, slightly open, smooth, planar, iron stained	1767.5+/-				60			1.25	
96.5	At 90.2 feet: Moderately hard, slightly weathered, gray, fine grained MUDSTONE interbedded with shale, very thin bedding, primary joint set, low angle, close to moderately close, slightly open, smooth, planar, fresh *(continued)* Run 14, Similar	1762.5+/-	95			60		92	1.25 1.25 2 2 2.25	
101.5	Run 15, Similar to 100.5 feet At 100.5 feet: Moderately hard to hard, slightly weathered, gray LIMESTONE, thin bedding, primary joint set, moderately dipping, close to moderately close, tight, rough, planar, clay-filled	1757.5+/-	100			60		93	1.25 1.5 1.25 2.25 1.75	
106.5	Run 16, Similar	1752.5+/-	105			60		100	1.25 1.25 1.5 2 2.25	
111.5	Run 17, Similar	1747.5+/-	110			60		65	1.75 2.25 1.75 2 2	
116.5	Run 18, Similar to 115.4 feet At 115.4 feet: Moderately hard, slightly weathered, gray SHALE interbedded with calcareous nodules, very thin bedding, primary joint set, moderately dipping, close to moderately close, tight, rough, planar, clay-filled	1742.5+/-	115			60		87	2 2 2 1.75 2.25	
	Run 19, Similar		120			60		83	1.5 2.225 2.25 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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017	Boring Completed: 8/31/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 2

LOCATION
Latitude: 40.452502° Longitude: -78.691539°
Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
121.5	Run 19, Similar *(continued)*	1737.5+/-				60			2.25	
126.5	Run 20, Similar	1732.5+/-	125			60		72	1.25 3 2 2.25 2	
131.5	Run 21, Similar	1727.5+/-	130			60		98	1.75 1.5 2 1.75 2.25	
136.5	Run 22, Similar	1722.5+/-	135			60		91	1.75 1.25 1.75 3.25 1.75	
141.5	Run 23, Similar	1717.5+/-	140			60		94	1.75 1.75 1.75 2.25 2.5	
146.5	Run 24, Similar	1712.5+/-	145			60		90	2 2.5 2.5 2.5 2.5	
	Run 25, Similar to 146.7 feet At 146.7 feet: Hard to moderately hard, slightly to moderately weathered, black, organic SHALE		150			60		90	2 2.5 2.5 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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
Not encountered

201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017	Boring Completed: 8/31/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION

Latitude: 40.452502° Longitude: -78.691539°

Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
151.5		1707.5+/-				60			2	
156.5	Run 26, Similar	1702.5+/-	155			60		92	2 2.5 2.5 2 2.5	
161.5	Run 27, Similar	1697.5+/-	160			60		78	2.5 2.5 2.5 2 2.5	
166.5	Run 28, Similar	1692.5+/-	165			60		95	2.5 1.5 1.5 2 1	
171.5	Run 29, Similar	1687.5+/-	170			60		94	1.5 1.5 2 2 3	
176.5	Run 30, Similar to 175.5 feet At 175.5 feet: Moderately hard, moderately to highly weathered, gray SHALE, with gray calcareous clay seams and calcareous nodules (possibly weathered limestone)	1682.5+/-	175			60		86	1.5 1.5 2.5 3 2	
	Run 31, Similar		180			60		72	2 2.5 2.5 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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017	Boring Completed: 8/31/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION
Latitude: 40.452502° Longitude: -78.691539°
Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DESCRIPTION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
181.5	1677.5+/-	Run 31, Similar *(continued)*				60			2	
186.5	1672.5+/-	Run 32, Similar	185			60		56	2.5 2.5 3 2.5 1.5	
191.5	1667.5+/-	Run 33, Moderately hard to hard, moderately to slightly weathered, gray MUDSTONE with moderately to slightly weathered shale layers	190			60		80	2 2 1.5 1.5 2	
196.5	1662.5+/-	Run 34, Similar to 195.1 feet At 195.1 feet: Medium to moderately hard, slightly to moderately weathered, dark gray SHALE with interbedded mudstone	195			60		85	2.5 1.5 1.5 1.5 1.5	
201.5	1657.5+/-	Run 35, Similar	200			60		83	3 2 2 1.5 2.5	
206.5	1652.5+/-	Run 36, Similar	205			60		96	3 2.5 2 2.5 1.5	
		Run 37, Similar to 206.8 feet At 206.8 feet: Moderately hard to hard, slightly to moderately weathered, dark gray SHALE, with occasional clay layers (possibly weathered shale layers)	210			60		82	3 2 2 2	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017	Boring Completed: 8/31/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 2

LOCATION

Latitude: 40.452502° Longitude: -78.691539°

Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH / Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
211.5	1647.5+/-				60			2.5	
Run 38, Similar 216.5	1642.5+/-	215			60		90	3.5 2 2 2 1.5	
Run 39, Similar 221.5	1637.5+/-	220			60		76	3.5 2.5 2 2 2	
Run 40, Similar 226.5	1632.5+/-	225			60		94	3.5 2.5 2 2 2.5	
Run 41, Similar 231.5	1627.5+/-	230			60		89	3 2.5 2.5 2.5 2	
Run 42, Similar 236.5	1622.5+/-	235			60		98	2 2 2.5 2 2	
Run 43, Moderately hard to hard, slightly to highly weathered, black LIMESTONE, contains fossils		240			60		86	2 2 2.5 2.5	

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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017
Boring Completed: 8/31/2017
Drill Rig: CME-850
Driller: Terracon/Peter M.
Project No.: J217P078

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION
Latitude: 40.452502° Longitude: -78.691539°

Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
241.5	Run 43, Moderately hard to hard, slightly to highly weathered, black LIMESTONE, contains fossils *(continued)*	1617.5+/-	60			1.5	
246.5	Run 44, Similar	1612.5+/-	60		84	1.5 2.5 2 3.5 3	
251.5	Run 45, Similar to 248.8 feet At 248.8 feet: Moderately hard to hard, slightly weathered, black SHALE, contains fossils	1607.5+/-	60		74	3 2.5 3.5 3 2	
256.5	Run 46, Similar to 252.7 feet Coal layer from 251.2 to 252.4 feet At 252.7 feet: Moderately hard, slightly to moderately weathered, gray LIMESTONE, with highly weathered limestone layers	1602.5+/-	60		58	1.5 2 4.5 3 3	
261.5	Run 47, Similar to 258.1 feet At 258.1 feet: Moderately hard to hard, moderately weathered, gray SHALE, with calcareous inclusions and laminations	1597.5+/-	60		85	5 4.5 3 3.5 3	
266.5	Run 48, Similar	1592.5+/-	60		95	2.5 3.5 2.5 2.5 3	
	Run 49, Similar		60		84	3 4 3 3	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017	Boring Completed: 8/31/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 2

LOCATION

Latitude: 40.452502° Longitude: -78.691539°

Approximate Surface Elev: 1859 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
Run 49, Similar *(continued)*								3	
271.5	1587.5+/-				60				
Run 50, Similar At 272.7 feet: Occasional layers of a moderately hard sandstone, with possible calcareous cement, gray		275			60		88	3.5 5.5 3 2.5 3	
276.5	1582.5+/-								
Run 51, Similar		280			60		76	4 4 2 1.5 2	
281.5	1577.5+/-								
Run 52, Similar to 282.5 feet At 282.5 feet: Hard to very hard, slightly weathered, gray, fine to medium grained SANDSTONE, with calcareous inclusions and some calcareous cement		285			60		74	3.5 3 3.5 3.5 2.5	
286.5	1572.5+/-								
Run 53, Similar		290			59		93	2.5 2 3 2.5 1.5	
291.5	1567.5+/-								
Run 54, Similar		295			60		95	2 2 1.5 1.5 2	
296.5	1562.5+/-								
Run 55, Similar		300			60		100	2 2 1.5 3.5	

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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017	Boring Completed: 8/31/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1W Spinner Road West

PROJECT: Mariner East Pipeline Borings

SITE: Spread 2

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

LOCATION

Latitude: 40.452502° Longitude: -78.691539°

Approximate Surface Elev: 1859 (Ft.) +/-

GRAPHIC LOG	DEPTH / DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	Run 55, Similar *(continued)*					60			2.5	
	301.5	1557.5+/-								
	Run 56, Similar					48		100	2.5 2.5 2.5 2.5	
	305.5	1553.5+/-	305							

Boring Terminated at 305.5 Feet

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not encountered

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/28/2017	Boring Completed: 8/31/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1E Spinner Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354

SITE: Spread 2

LOCATION

Latitude: 40.452616° Longitude: -78.683712°

Approximate Surface Elev: 1657 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	FILL - LEAN CLAY WITH SAND, light brown to brown, medium stiff to stiff		0		X	6	3-4-3 N=7			
			5		X	7	5-4-7 N=11			
9.0	**SILTY CLAY WITH SAND (CL-ML)**, orange to black, stiff	1648+/-								
			10		X	15	1-3-6 N=9			
	Similar, light gray to brown, hard		15		X	9	51-50/3"			
			20		X	9	35-50/3"			
21.5	**LEAN CLAY WITH SAND (CL)**, and gravel, gray, hard	1635.5+/-								
			22.3	▽						
	Shale fragments (sand size), black at 25 to 26.5 feet		25		X	16	28-17-29 N=46			
	Natural gas odor from 26 to 28 feet									
			30							

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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:
NR = Not recorded

WATER LEVEL OBSERVATIONS

▽ *22.3' after 16 hrs*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/25/2017	Boring Completed: 8/27/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1E Spinner Road East

PROJECT: Mariner East Pipeline Borings

SITE: Spread 2

**CLIENT: Directional Project Support Incorporated
Magnolia, TX 77354**

LOCATION
Latitude: 40.452616° Longitude: -78.683712°

Approximate Surface Elev: 1657 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	LEAN CLAY WITH SAND (CL), and gravel, gray, hard *(continued)*					3	50/3"			
34.0	Roller bit and casing advanced to 34 feet, begin rock core	1623+/-								
37.5	Run 1, Moderately hard, slightly weathered, fine-grained to argillaceous MUDSTONE, thin bedding, primary joint set, low angle to horizontal, very close to moderately close spacing, slightly undulating, open, discolored to decomposed with clay in-filling; secondary joint set, high angle to vertical, close to moderately close spacing, undulating, open discolored, slightly calcareous	1619.5+/-	35			41		NR	2 2 2 2.5	
42.5	Run 2, Similar, primary joints, close to wide spacing; secondary joints, wide spacing	1614.5+/-	40			60		80	NR	
47.5	Run 3, Similar, gray to gray-green by 43 feet Soft to medium hard, highly fractured from 45.8 to 46.3 feet	1609.5+/-	45			60		67	NR	
52.5	Run 4, Medium to moderately hard, moderately weathered, gray-green to dark gray MUDSTONE, primary joint set, horizontal to low angle, close to moderately close spacing, planar to undulating, decomposed, open; secondary joint set, high angle to vertical, moderately close to wide spacing, undulating Decomposed, highly weathered zones at 48.4 to 49 feet, 49.7 to 50 feet, 50.6 to 51.6 feet, and 52.1 to 52.5 feet	1604.5+/-	50			60		25	NR	
57.5	Run 5, Similar, fresh, primary joint set, moderately close spacing At 54.6 feet: Similar to above, fine to medium-grained	1599.5+/-	55			60		80	2 2.5 2.5 2.5 2.5	
	Run 6, Similar, medium-grained, primary joint set, moderately close spacing, discolored to fresh, open to tight; secondary joint set, widely spaced, discolored		60			60			2.5 2.5	

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

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:
NR = Not recorded

WATER LEVEL OBSERVATIONS
22.3' after 16 hrs

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/25/2017	Boring Completed: 8/27/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1E Spinner Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 2

LOCATION

Latitude: 40.452616° Longitude: -78.683712°

Approximate Surface Elev: 1657 (Ft.) +/-

GRAPHIC LOG	DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	62.5	Run 6, Similar, medium-grained, primary joint set, moderately close spacing, discolored to fresh, open to tight; secondary joint set, widely spaced, discolored *(continued)*	1594.5+/-				60		90	2.5 2.5 2.5	
	67.5	Run 7, Similar, occasional relict (fossil) mudcracks	1589.5+/-	65			60		92	2.5 2.5 2.5 2.5 2.5	
	72.5	Run 8, Similar	1584.5+/-	70			60		80	2.5 2.5 2 2 2.5	
	77.5	Run 9, Similar to 74.3 feet At 74.3 feet: Moderately hard, dark gray to black, argillaceous MUDSTONE with interbedded shale, very thin bedding, primary joint set, horizontal to low angle, close to moderately close spacing, smooth, planar, slightly decomposed with clay in-filling to fresh, open to tight; secondary joint set, moderately dipping to vertical, moderately close to wide spacing, occasional pyrite nodules	1579.5+/-	75			60		88	2 2.5 2.5 2.5 2.5	
	82.5	Run 10, Similar	1574.5+/-	80			60		88	2.5 2.5 2.5 2.5 2.5	
	87.5	Run 11, Similar	1569.5+/-	85			60		85	3 2.5 2.5 3 3	
		Run 12, Similar, primary joint set, close spacing, moderately weathered, partially friable from 89.4 to 92.5 feet		90			59			2.5 3	

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:
NR = Not recorded

WATER LEVEL OBSERVATIONS

22.3' after 16 hrs

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/25/2017	Boring Completed: 8/27/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

BORING LOG NO. B2-1E Spinner Road East

PROJECT: Mariner East Pipeline Borings

CLIENT: Directional Project Support Incorporated Magnolia, TX 77354

SITE: Spread 2

LOCATION

Latitude: 40.452616° Longitude: -78.683712°

Approximate Surface Elev: 1657 (Ft.) +/-

GRAPHIC LOG	DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	RQD (%)	Core rate (min/ft)	Penetrometer Test (tsf)
	92.5	Run 12, Similar, primary joint set, close spacing, moderately weathered, partially friable from 89.4 to 92.5 feet *(continued)*	1564.5+/-				59		38	3 3 3.5	
	97.5	Run 13, Similar, except green-gray to dark gray MUDSTONE, slightly to moderately weathered, primary joints decomposed and friable	1559.5+/-	95			58		60	3 3 3 3 3	
	102.5	Run 14, Similar	1554.5+/-	100			59		44	3 3 3 3 3	

Boring Terminated at 102.5 Feet

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

Hammer Type: Automatic

Advancement Method:
Mud rotary with wireline

Abandonment Method:
Grouted to surface

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:
NR = Not recorded

WATER LEVEL OBSERVATIONS

▽ *22.3' after 16 hrs*

Terracon
201 Hammer Mill Rd
Rocky Hill, CT

Boring Started: 8/25/2017	Boring Completed: 8/27/2017
Drill Rig: CME-850	Driller: Terracon/Peter M.
Project No.: J217P078	

Attachment C

Detailed Mine Map Report, Bethenergy No.33-B Seam Mine

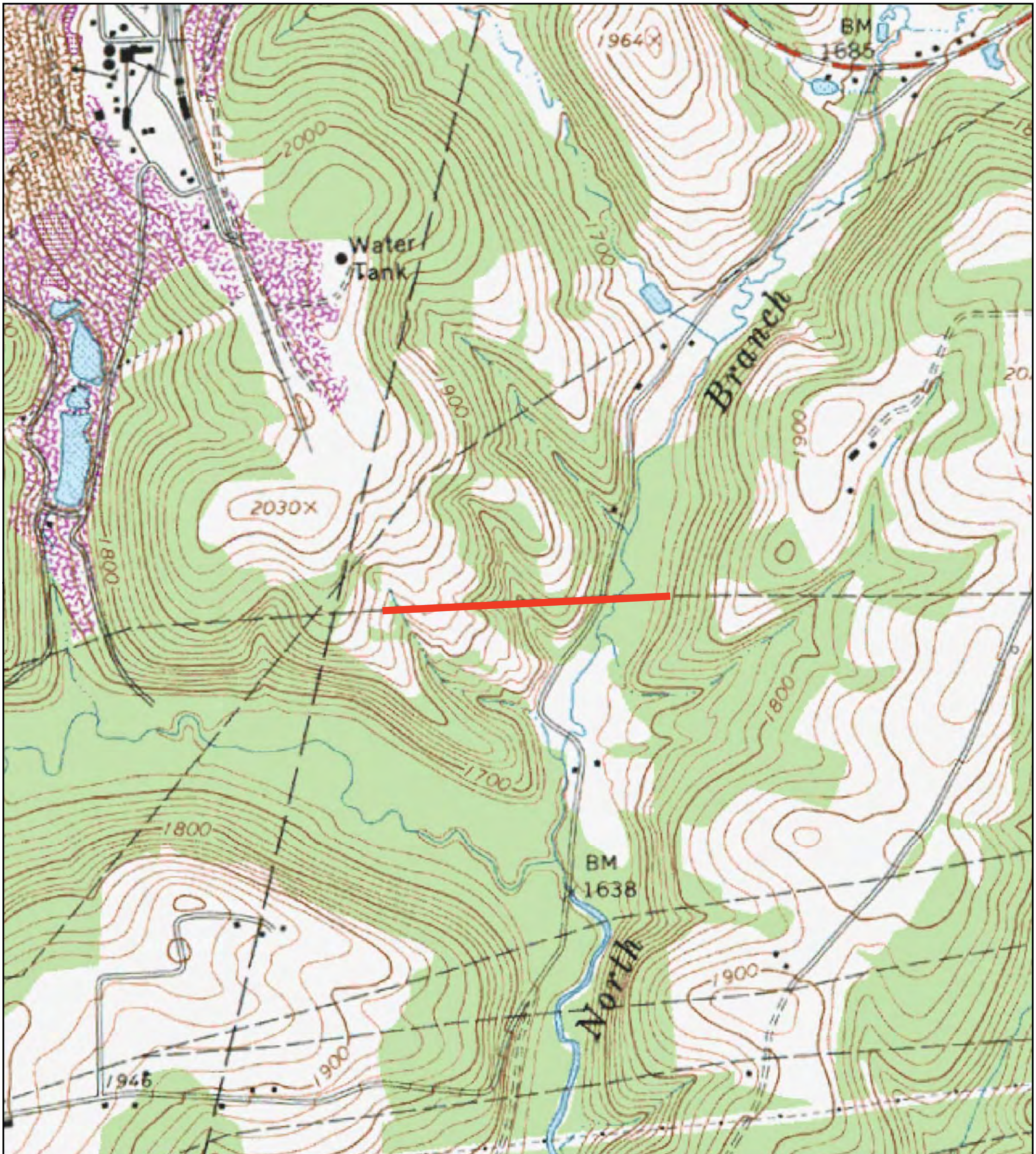
pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

This map was prepared using information considered to be the best historic data available. The Department cannot verify the accuracy or completeness of this information or alignment of images.

Scale: 1 inch = 400 feet

Aerial Map

Imagery Source:
PAMAP Program, PA DCNR



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DEPARTMENT OF ENVIRONMENTAL PROTECTION

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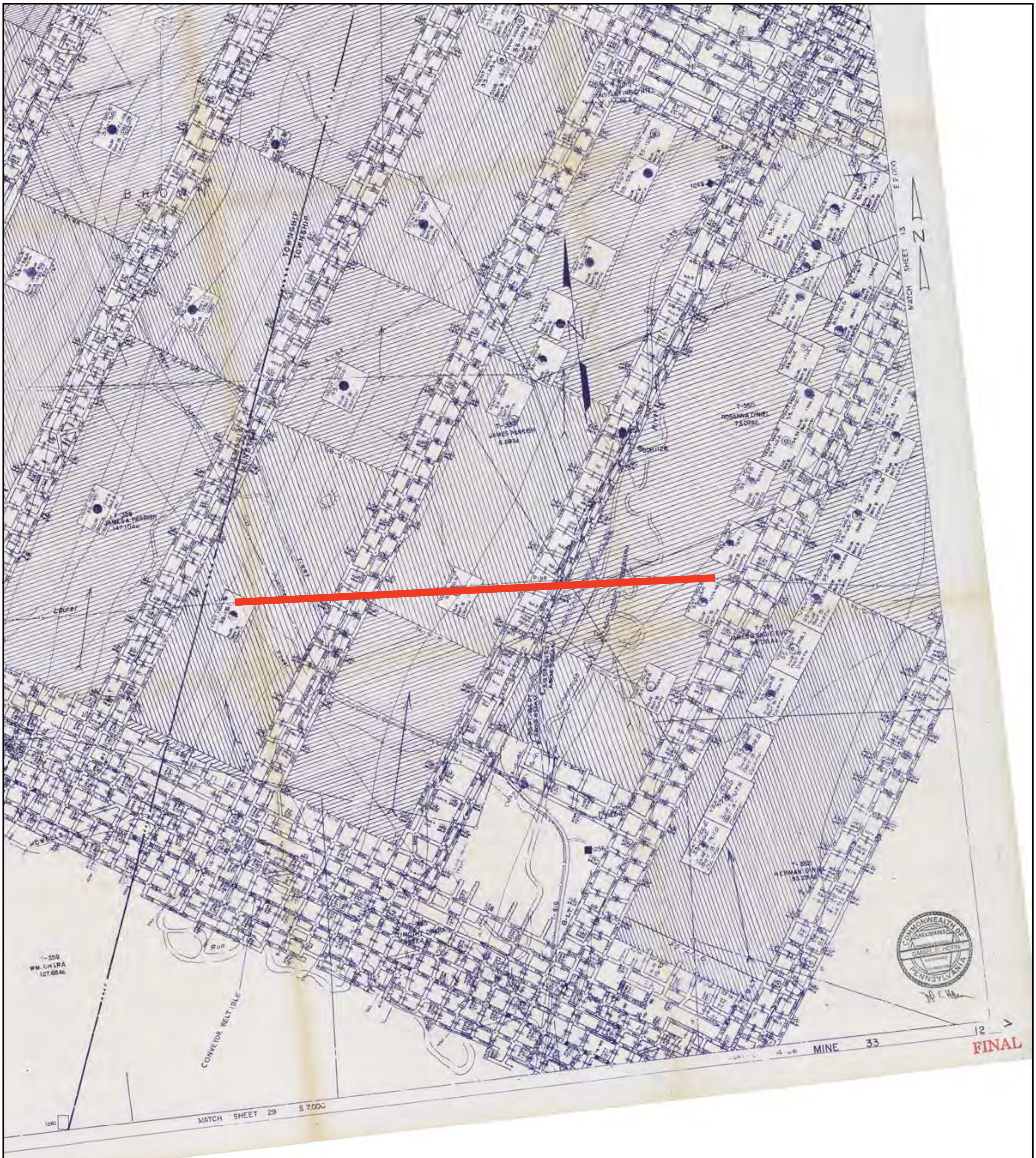
Scale: 1 inch = 1,000 feet

N

USGS Topographic Map

USGS 7.5' Ebensburg, PA Quadrangle



pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

This map was prepared using information considered to be the best historic data available. The Department cannot verify the accuracy or completeness of this information or alignment of images.

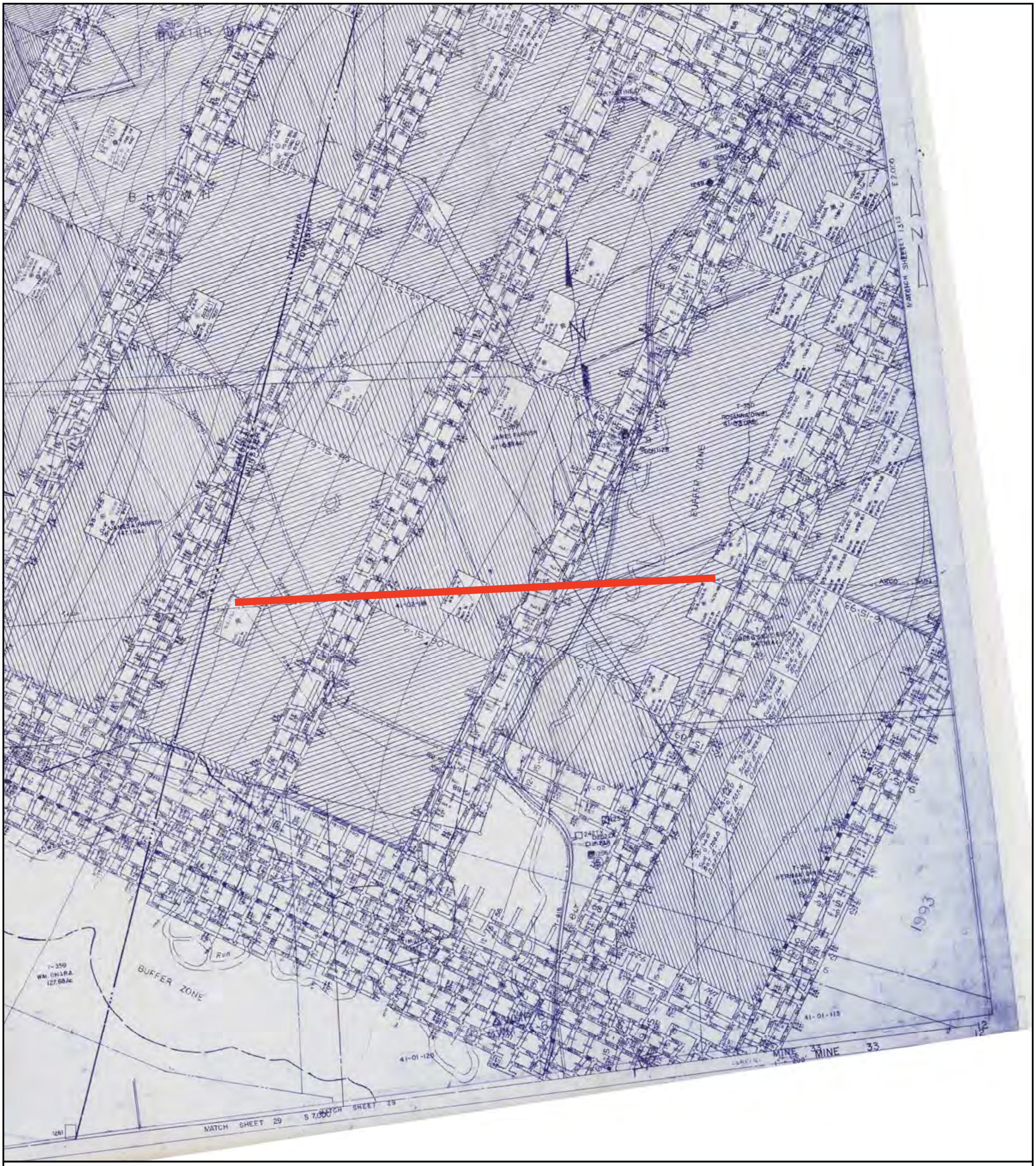
Scale: 1 inch = 600 feet

N

Detailed Mine Map

Mine 33 - B Seam Mine
Bethenergy Mines, Inc.

Lower Kittanning Coal Seam



pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

This map was prepared using information considered to be the best historic data available. The Department cannot verify the accuracy or completeness of this information or alignment of images.

Scale: 1 inch = 600 feet

N

Detailed Mine Map

Mine 33 - B Seam Mine
Bethenergy Mines, Inc.

Lower Kittanning Coal Seam

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Scale: 1 inch = 400 feet

N

Detailed Mine Map

Mine 33 - B Seam Mine
Bethenergy Mines, Inc.

Lower Kittanning Coal Seam

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

This map was prepared using information considered to be the best historic data available. The Department cannot verify the accuracy or completeness of this information or alignment of images.

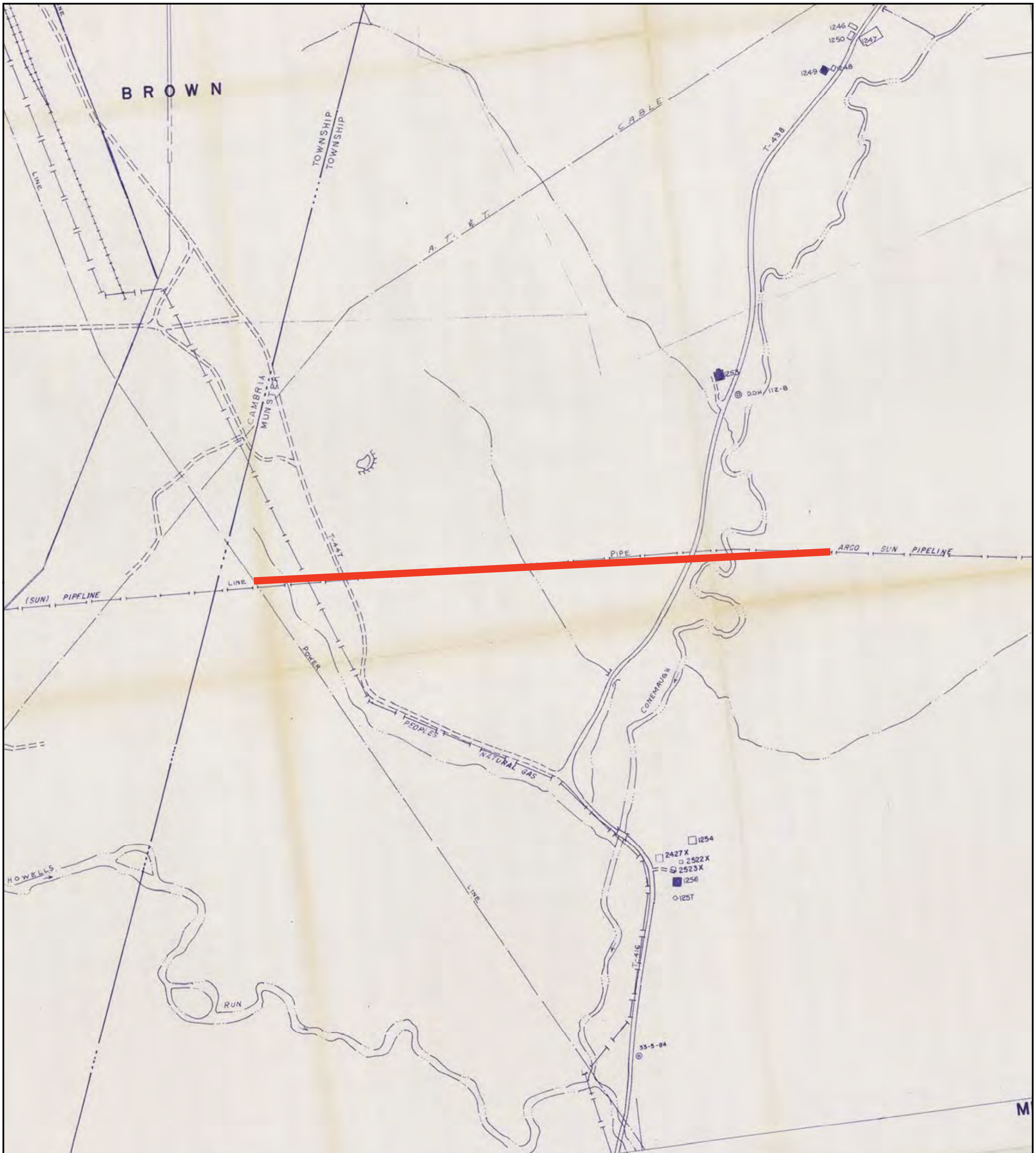
Scale: 1 inch = 800 feet

N

Detailed Mine Map

Mine 33 - C Prime Mine
Bethenergy Mines, Inc.

Upper Kittanning Coal Seam



This map was prepared using information considered to be the best historic data available. The Department cannot verify the accuracy or completeness of this information or alignment of images.

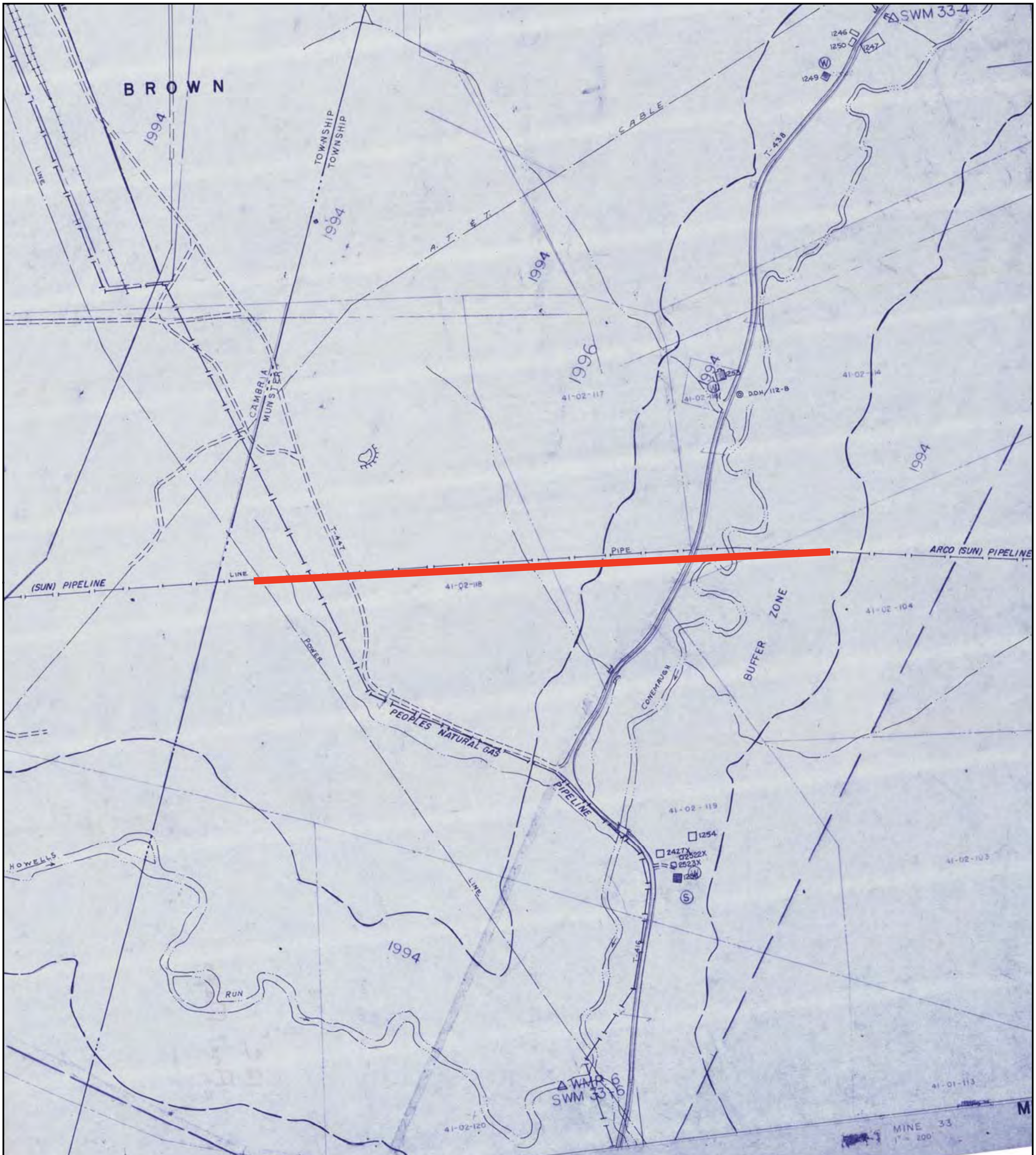
Scale: 1 inch = 500 feet

N

Detailed Mine Map

Mine 33 - C Prime Mine
Bethenergy Mines, Inc.

Upper Kittanning Coal Seam



![pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION]

This map was prepared using information considered to be the best historic data available. The Department cannot verify the accuracy or completeness of this information or alignment of images.

Scale: 1 inch = 500 feet

N

Detailed Mine Map

Mine 33 - C Prime Mine
Bethenergy Mines, Inc.

Upper Kittanning Coal Seam

SPINNER ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E11-352
PA-CA-0069.0000-RD
(SPLP HDD No. S2-0080)

ATTACHMENT 2

COAL MINE SUBSIDENCE AND STRESS ANALYSIS

SUBSIDENCE POTENTIAL REVIEW
SPINNER ROAD
HORIZONTAL DIRECTIONAL DRILLED PIPELINE PROJECT
MUNSTER TOWNSHIP, CAMBRIA COUNTY, PA
May 2018

PRESENTED FOR

Sunoco Logistics, L.P.
525 Fritztown Road
Sinking Spring, PA

PRESENTED BY

Tetra Tech
661 Andersen Drive
Foster Plaza 7
Pittsburgh, PA 15220

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FIGURES

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INTRODUCTION

Tetra Tech, Inc. (Tetra Tech) was retained by Sunoco Logistics L.P. (Sunoco) to review the mining activity and subsidence potential of the abandoned coal mines below the two planned Spinner Road horizontal directional drilled pipelines (HDDPs) located in Munster Township, Cambria County, Pennsylvania. Our report follows.

BACKGROUND

Mine subsidence is defined by Pennsylvania Department of Environmental Protection (PADEP) as "movement of the ground surface as a result of readjustments of the overburden due to collapse or failure of underground mine workings." Overburden is the soil and rock lying between the coal and the surface. When subsidence occurs at or near the location of an overlying structure, damage to the structure may occur. The potential impacts to surface structures are "generally classified as cosmetic, functional, or structural. Cosmetic damage refers to slight problems where only the physical appearance of the structure is affected, such as cracking in plaster or drywall. Functional damage refers to situations where the structure's use has been impacted, such as jammed doors or windows. A more significant impact on structural integrity is classified as structural damage. This includes situations where entire foundations require replacement due to severe cracking of supporting walls and footings." (PADEP, 2017). When a new structure is designed over areas where potential mine subsidence could result in structural damage, structural engineers can mitigate the damage concerns by improving the structural integrity of the structure or isolating the structure from the subsidence. When structural improvement or isolation is not possible or is cost prohibitive, the hazards posed by mine subsidence can be mitigated by grouting the remnant mined entries (filling voids with concrete like material to prevent settling) to reduce the potential for subsidence.

The most effective mitigation method is to relocate the structure over areas where the coal has not been mined; however, in Pennsylvania mining regions, this is not always a possibility. When a structure is located over abandoned mine workings, predicting the probability and timing of future subsidence is not a clearly defined science. The probability of future subsidence depends on the remaining stability of the mine pillars, the columns of coal left in place to support the overlying overburden. The timing of any future failure of the pillars would depend on knowing the exact failure strength, the geometry of the mine pillars and the reduction in the strength of the mine pillars over time. Thus, there is no specific way to know exactly when pillar failure and subsequently subsidence will occur. Mining maps are prepared by active mining companies when the mine was operating to indicate where mining occurred and the type of mining conducted. Maps of abandoned mines are used by mining engineers to verify the mine layout and to estimate the size of remaining voids and pillars. These maps, especially older maps, often lack complete details of the mining and are sometimes inaccurate. Incomplete or inaccurate knowledge of mine configuration can introduce additional errors into any future subsidence prediction.

Most abandoned mine subsidence impacts to structures that result in structural damage have occurred in areas of limited overburden, such as where the mine depth is less than 100 feet. Although the subsidence damage classifications above refer to surface impacts, similar classifications might be applicable for impacts to underground pipelines located below the ground surface. As an example, areas of minor ground movement after a pipeline has been installed within a horizontal drilled borehole may cause movement of the pipeline (similar to cosmetic or functional damage to a surface structure) but may not cause structural damage such as a break in the pipeline resulting in a loss of fluids or gas. Areas of potential structural damage should be avoided or mitigated.

The Bethlehem Mines Corporation's Cambria Division operated the Cambria Slope Mine #33 underground mine in Munster Township, Cambria County from the 1960's into the mid-1990's. The Lower Kittanning seam was mined using the longwall mining method directly below the HDDP from 1989 to 1993. The depth of the coal from surface is about 900 feet at Station 0.0 (the beginning of the HDDP) and about 850 feet at Station 29+57 (the end of the HDDP).

Three entry (gate-roads) were driven using mechanized continuous mining machine parallel to each other so that a 600 foot wide coal pillar remained between them. This coal pillar was 11,500 feet long. The large coal pillar was systematically removed with a mechanical coal cutting machine that excavated a section of the coal along the 600 foot side of the pillar. The machine went back and forth along the pillar systematically shearing up to 30 inches (horizontally) of coal each pass. A chain conveyor moved the coal to one side of the longwall pillar where it was transferred to a continuous belt conveyor within the gate-roads for transport outside the mine. To keep the miners safe, a row of hydraulic roof supports (chocks or shields) was used to support about a 10 foot wide section of the overlying roof from the face of the coal pillar. As the mining progressed through the pillar, the roof supports were advanced. As the roof supports advanced, the mine's roof collapsed behind them. By allowing the roof to collapse, the weight of the strata on the roof supports and coal pillars was reduced. When the strata collapsed into the remaining void, surface subsidence would occur. Most subsidence would occur almost immediately, and most ground movements would be completed within a few weeks.

The gate-road pillars remained after mining. The mine plan included three entries in each gate-road. Pillar sizes in the gate-roads varied. The eastern most gate-road pillars included two 75 feet wide by 80 feet long pillars. The next gate-road pillar set included one 100 foot wide pillar and one 25 foot wide pillar. The third gate-road included two 60 foot wide pillars. The small (25 foot wide) pillars were designed to fail soon after the longwall passed by (a yield pillar in mining terms). These pillars probably failed soon after mining and thus the subsidence due to yield pillar failure has probably already occurred. The large pillars 75 foot or 100 foot wide would have been designed to provide long term support. The 60 foot wide pillars would not provide as much long term support as the larger pillars, and may have been marginally sized at the time of mining.

TYPES OF MINE SUBSIDENCE

Mine subsidence occurs in one of two physical forms, a trough or a sinkhole. A trough is a shallow, often broad, dish-shaped depression that develops when the overburden sags downward into a mine opening in response to roof collapse, the crushing of mine pillars, or the punching (pushing) of pillars into the mine floor. There can also be areas of surface heave around the edges of the subsidence troughs. Trough subsidence typically occurs in areas of deeper overburden, typically more than 100 feet deep. The depth and extent of the trough are closely related to the depth, dimensions and thickness of the extracted coal, and the physical properties of the overburden.

A sinkhole is a depression in the ground surface that occurs due to localized collapse of the overburden directly into a mine opening (a room or entry). This is often called "chimney" type subsidence. Boundaries between the ground surface and the vertical walls of the sinkhole are often abrupt, and because sinkhole diameter generally increases with depth, the sinkhole in profile may initially resemble an open bottle with the top at the ground surface. Erosion of soil at the sinkhole's periphery may increase the diameter near the ground surface to create an hourglass profile. Sinkhole subsidence typically occurs in areas of shallow overburden, primarily 100 feet or less. Sinkhole-prone areas are the primary locations where subsidence causes severe structural damage to buildings on the surface. Sinkhole subsidence in an area of single-seam mining is usually limited to areas where the total thickness of the rock layers above the coal is no more than 6 to 10 times the thickness of the coal mined in the area. The soil thickness overlying the rock is not included in this estimate. (Kendorski, 2006).

CATEGORIES OF MINE SUBSIDENCE POTENTIAL

Mining-induced subsidence is caused when a seam of coal is extracted and overlying rock layers cave into the voids left by mining such that there is movement on the ground surface. The probability of subsidence is greater in areas where a high percentage of coal is removed. In an analysis of underground mines, subsidence potential can be classified into the following three general categories:

Category 1 – Subsidence probably occurred during or soon after mining.

Category 2 – Well supported areas where subsidence is unlikely.

Category 3 – Areas where subsidence may occur in the future if it has not already occurred.

Longwall mining, the method of mining used in the project area, is a method of mining where full recovery (generally over 95 percent recovery) of the coal seam was practiced. The roof of the mine is allowed to cave in a predictable controlled manner immediately following coal extraction. This controlled caving process systematically relieves built-up stresses caused by the cantilever action of the mine roof thereby reducing the risk of catastrophic strata failure where men are working. The limits and extents of the subsidence are relatively predictable where longwall mining is employed because subsidence normally occurs soon after mining. Category 1 refers to areas where nearly full extraction of the coal occurred as a result of longwall mining and there is very low probability of extensive future subsidence, although subsidence can occur at the edges of these areas due to failure of adjacent, highly stressed, supporting pillars. The pillars in the gate-roads (the development entries on the sides of each longwall pillar) remain in place.

Category 2 refers to areas where the mine configuration and pillars are adequately designed to provide permanent support to the ground surface. The amount of coal removed in these areas is generally low to moderate. These areas, although mined, generally remain stable over the long term and would include the gate-road areas that had relatively large pillars with high factors of safety. Areas of mines delineated as Category 2 would have a relatively low probability of future subsidence.

Category 3 refers to areas underlain by room and pillar mines with a high percentage of coal removed and where retreat mining was not performed. In Category 3 areas, it is uncertain whether subsidence occurred and whether there remains a likelihood of subsidence in the future. In these areas, entries were driven through the coal, and the pillar sizes were smaller than what would generally be required to provide permanent long-term support. In other words, the pillars were designed with a low factor of safety (caused by the high extraction ratio), and there would be an elevated risk of pillar, roof, or floor failure. If subsidence already occurred, the possibility of future subsidence is very unlikely. However, if subsidence has not previously occurred, the possibility of future subsidence remains high. Of the three categories, Category 3 would have the highest probability for future subsidence. The gate-road areas with the smaller pillars were classified in this category but if these pillars had failed as planned shortly after the longwall face passed them then these areas probably could be reclassified as Category 1.

In mining subsidence terms, the extent of the potential area impacted by subsidence can be defined using a specific angle from the coal seam to the ground surface that could be affected if roof or pillar failure occurred at the mine level. The potential subsidence affected area can be directly overhead but could also be offset a certain horizontal distance from the roof failure location. The angle, termed the “angle-of-draw,” can vary depending on the overburden rock type (Peng, 1978). PADEP accepts 20° as the angle-of-draw for the flat-lying coal seams in the bituminous coal region; however, up to 35° angle-of-draws have been found in numerous subsidence publications. In an effort to provide conservative analysis to protect both HDDPs, both angle-of-draws will be used in this report. The angle-of-draw can also be projected downward from a surface structure or a pipeline in the ground to determine what area within a mine could, if pillar or roof failure occurred, cause subsidence that may impact the surface or pipeline.

Tetra Tech reviewed the mine maps and the location and elevation of the two HDDPs. Figure 1 depicts the areas where potential roof failure at mine level could impact the strata at the level of both planned HDDPs. Both angle-of-draws (20° and 35°) were shown on Figure 1. The area shown was created by using an angle-of-draw from the lowest HDDP’s bottom elevation to the top of the coal seam. Based on a conversation with former Bethlehem Mines employees the mining height in the longwall panels was 54 inches. Some entries in the mains and gate roads were mined to a height of six feet to accommodate the movements of the longwall mining equipment between panels. A 15 foot horizontal zone on each side of the HDDPs (50 feet total) was also included. Figure 2 depicts each category of potential mine subsidence. A total of 46.9 acres lies within the 20° angle-of-draw influence area, while 100.1 acres lie within a 35° angle-of-draw influence area. A summary of subsidence category areas is shown in Table 1.

Table 1: Summary of Categories of Subsidence Potential within Angle-of-Draw

Subsidence Category	Subsidence Potential	20° Angle-of-Draw (Acres)	35° Angle-of-Draw (Acres)
1	Subsidence probably occurred during or soon after mining	39.1	82.8
2	Support area where subsidence is unlikely	4.1	8.4
3	Area where subsidence may occur in the future if it has not already occurred	3.7	8.9
Total		**46.9**	**100.1**

When roof or pillar failure occurs, strata above the mined area will collapse and/or sag downward to fill the voids left in the mine. Mining research has classified these areas as different zones based on the degree of fracturing expected. These zones depend on the width and height of the extraction, the overburden rock types, and the vertical height above the mine. A caved zone occurs from the roof of the mined coal and typically extends upwards for 6 to 10 times the mining thickness (Kendorski, 2006), and outward laterally within the angle-of-draw. In the case of the Cambria Slope Mine #33 where the longwall mining thickness was 54 inches, this zone would be from 27 to 45 feet above the top of coal. Rock in this zone would have extensive fracturing and sizable voids.

Above the caved zone a fracture zone occurs and extends for 24 to 30 times the mining thickness. In this zone, a lot of fractures would be present but the rock strata would remain as a single unit without extensive dislocated rock or voids present. At the Cambria Slope Mine #33, this zone would extend from 27 to 45 feet to 108 to 135 feet above the top of mining.

The next zone would extend from the top of the fractured zone to about 60 times the mining thickness. This zone is termed the dilated zone. This zone would have small temporary fractures that would heal over time. The rock again would remain as a single unit. At the Cambria Slope Mine #33, this dilation zone would extend from 108 to 135 feet up to 270 feet above the top of the coal.

The zone above that is termed the constrained or bending zone where no fracturing would occur. In this case, the minimum distance between the HDDPs and the coal seam is 450 feet vertically. Both HDDPs would be in this zone.

Table 2: Zones of Strata Fracturing During Subsidence

Zone	Extent Above Coal Seam (ft.) (x mining height)	Impact to Strata	Voids Created
Constrained	>60	No Fractures	None
Dilation	Up to 60	Small Fractures	Micro
Fracture	Up to 30	Fractured	Minimal
Caved	Up to 10	Fractured	Sizable
Mined Coal Seam			

Determining induced strains from subsidence during active mining has become a relatively accurate prediction, especially for longwall mines. There are numerous computer program models that were developed by mining agencies and universities that use variations in the rock type within the overlying strata, mining thickness, and mine geometry at coal seam level to predict ground movements at the surface during active full-recovery mining. These models not only predict the extent and amount of subsidence but can predict tilts and strains occurring at ground level. They can also be used to predict maximum strains when subsidence occurs. Abandoned mines are less predictable as to the time when subsidence would occur as well as the extent of subsidence. Mine subsidence from abandoned mines are less uniform or predictable than that of active mines. However, the use of models for active mining can be adapted to estimate subsidence and stress if pillar failure occurs sometime in the future at abandoned mine sites.

FINDINGS

The mine maps were reviewed by experienced mining engineers. The mining shown on the maps covering the area under the planned pipeline occurred about 30 years ago. The maps were found to be very detailed regarding the mining type and location of mining. The maps were georeferenced by PADEP. In our opinion, the mine maps are a reliable indication of what was mined. We have reviewed several of the different maps available on the Pennsylvania Mine Map Atlas website. They all indicated the same depiction of the mine workings under the planned pipeline area.

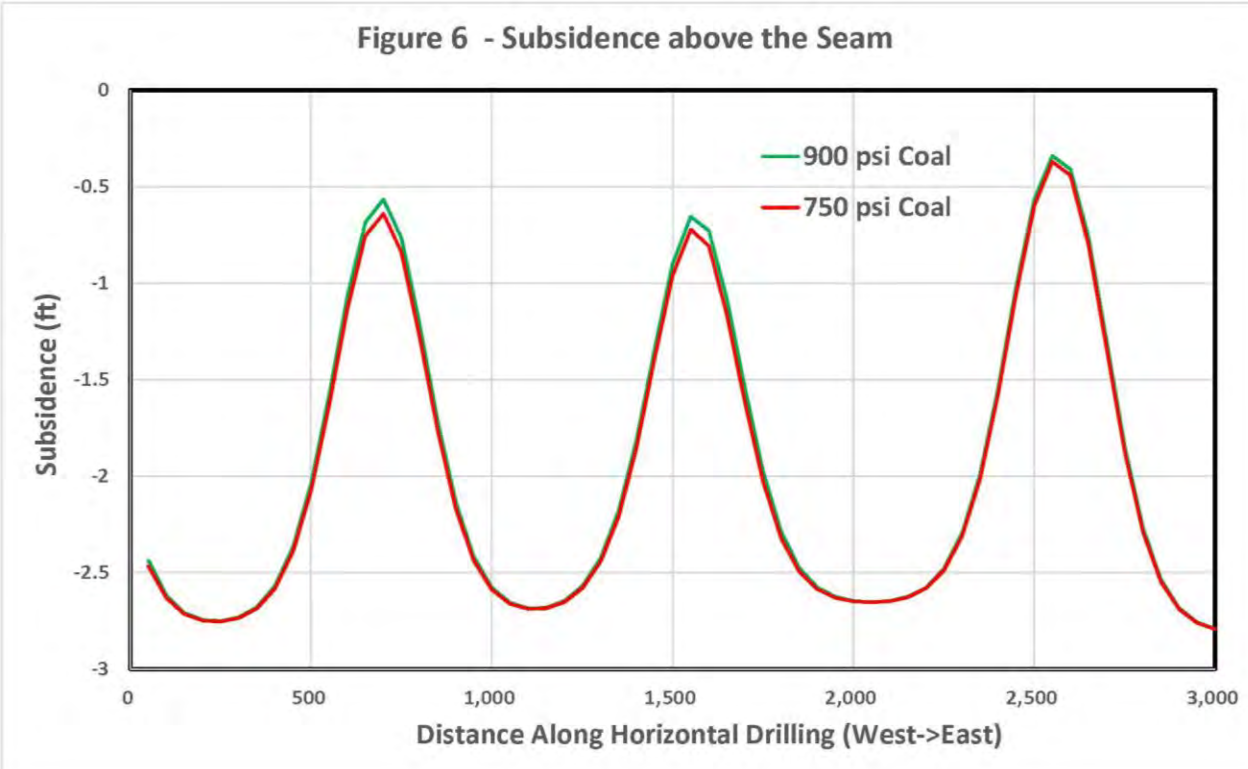
The HDDPs start on the eastern most location at about 900 feet above the coal. The descending borings will be approximately 585 feet above the coal when they level off about 1000 feet horizontally from its start. The borings would then be fairly level for another 500 feet to a location where it will be approximately 600 feet above the coal. From there the borings will ascend upward until it reaches the surface about 2,960 feet from its start. At the surface exit location, the boring would be about 850 feet above the coal. It should be noted that the two HDDPs are approximately 20 feet horizontally from each other and can also be up to 20 feet vertically from each other. Due to the historic longwall mining, most of the area that the HDDPs cross over is Subsidence Category 1 (subsidence probably occurred during or soon after mining). The three gate-road areas located between the longwall panels are categorized either as Subsidence Category 2 (support area where subsidence is unlikely) or Subsidence Category 3 (area where subsidence may have occurred or may occur in the future) depending on the size of pillar used. The larger pillars (80 foot or 100 foot wide) were included a Subsidence Category 2 while the smaller pillars (60 foot wide) were included as Subsidence Category 3. In our opinion, the small (25 foot wide) pillars were designed as "yield" pillars and were expected to fail shortly after the longwall passed them. In that case, subsidence due to their failure would have already occurred. Thus, the area where these small pillars were located was included as Subsidence Category 1.

Figures 3 and 4 depict the planned HDDP profiles. Since the coal level was deeper than Figures 3 and 4 could show, Figure 5 was prepared to show the top of each fracture zone. To be conservative, the top of each fracture zone was selected as the maximum value based on the Kendorski's research (Kendorski, 2006). The two HDDPs are exclusively within the constrained zone and do not cross through the dilated or the fractured zones.

The PADEP is responsible for maintaining an inventory of all abandoned mine related incidents in Pennsylvania. This includes mine subsidence incidents above closed mines such as Mine #33. It is our understanding that their recording of these incidents began shortly after 1977. To our knowledge there have been no subsidence incidents reported to PADEP since 1977 anywhere near the planned HDDP.

When the earth subsides, the curvature of the strata can produce a horizontal strain within the strata. Some of this strain can be transferred to a rigid pipeline that is placed within the strata. Strain is defined as the amount of deformation in the direction of applied force divided by the initial length of the material. This results in a unitless number such as inches per inch. Strain can be induced by compression, tension, pipe bending, pipe placed in tension or shear. Using historical subsidence data from primarily known conditions during longwall mining, models have been developed to predict the strains at ground surface. These models, although not a perfect translation, can be adapted to estimate strains within the relatively undisturbed rock strata at the elevations where the HDDP would be placed. To estimate the strains that may be seen at the pipeline level, Tetra Tech engaged Dr. Keith Heasley and Dr. Andrew Schissler, mining engineers that have experience using subsidence models to predict the possible strains. Dr. Heasley is a professor of Mining Engineering at West Virginia University. Dr. Schissler is associated with the Colorado School of Mines and a part-time employee of Tetra Tech. Dr. Heasley's report can be found in Appendix A.

Modeling of the Cambria Slope Mine #33 was conducted using a base coal strength of 900 psi to simulate the strength of the coal at the time of mining. Subsequently a coal strength of 750 psi was modeled to simulate the coal strength after the mine pillars degrade over time. The predicted subsidence associated with both coal strength along the pipeline alignment is shown in Figure 6. The 900 psi coal subsidence plot indicates anticipated ground subsidence directly after mining. The 750 psi plot predicts the subsidence along the pipeline which may occur as the mine conditions degrade over time. The degraded mine subsidence may have already occurred, may occur at some time in the future, or may never reach this level. Predicting the exact condition of the mine at this time, or at any precise time in the future is not possible.



LaModel was chosen as the mining induced stress analysis program to evaluate strain on the pipeline. This is a full-featured displacement-discontinuity program that is primarily designed to calculate the seam stress and displacement in an underground mine. The software uses boundary-elements for calculating the stresses and displacements in coal mines or other thin, tabular seams or veins. It can be used to investigate and optimize pillar sizes and layout in relation to pillar stress and multi-seam mining stress. This program can also reasonably calculate surface subsidence. A medium distance of 700 feet above the mine was chosen for detailed analysis of the mine subsidence in this case. In the LaModel program, the overburden is modeled as a continuum. Therefore, the program shows the subsidence directly over the mined areas, and also within the angle-of-draw. The magnitude of subsidence naturally decreases as the distance from the mine increases and the subsidence spreads, but the program does not model any dilation of the overburden.

The two HDDPs lie above four longwall panels that were mined between 1989 and 1993. A fourth longwall panel lies to the west of the HDDP but within the 35° angle-of-draw. The longwall panels are separated by gate-roads, three entry developments sections. The model estimated that the surface above the longwall panels subsided up to 2.75 feet following mining. Additional subsidence due to the longwall mined areas is unlikely. The mine lies between 700 and 900 feet below the ground surface and about 585 feet below the HDDP at its deepest point.

In U.S. coal mining practice, longwall panels are delineated by mining entries around all four sides - leaving a large pillar. In the case of the Cambria Slope Mine #33, longwall panels at the HDDP location were 600 feet wide and 11,500 feet long. To develop the longwall panels, three entry gate-roads, two pillars wide, are mined. These “gate-road” entries were critical infrastructure for the longwall mining process. The gate-roads provided ventilation, power, water, a route for coal transportation, and safe access for miners to the longwall mining area and its associated equipment.

As the longwall mining progressed, the roof would collapse immediately after mining. However, the gate-road pillars were not mined. These pillars were left unmined to support the overlying strata so that the miners could fully remove the next longwall panel without high stress directly on the panel being mined. The roof collapsed during longwall mining occurring up to the edge of these pillars, causing large stresses on the gateroad pillars.

Due to their need to provide strata support for next panel to be mined, most gate-road pillars are now developed at a size that would also provide long term stability. CONSOL Energy has been longwall mining in the Pittsburgh coal seam in southwestern Pennsylvania since the early 1970’s. They currently operate three large longwall mines (currently with 5 longwalls operating) with somewhat similar conditions as Mine #33 (~6-foot mining height and 600 to 1000 feet of overburden). The first of these mines began operating in 1982. Gate-road pillars used at these mines are one 110 to 145-foot wide pillar and one 45 to 65-foot wide pillar. The wider pillar is 265 feet long and the thinner pillar is 125 feet long. According to Mr. James Goroncy (former Chief Engineer of these operations) there has not been any reported surface subsidence above abandoned gate-roads over the past 35 years.

Dr. Tony Iannacchione, head of the University of Pittsburgh mining group, has been the lead reviewer of the PADEP subsidence regulatory program for the last 15 years (submitting three 5-years reviews). He reviews the regulatory compliance for mine subsidence for PADEP. He reported to our team that there has only been one incident where there was a problem with subsidence over a longwall mining section gate-road pillars. This subsidence occurred soon after mining at the Gateway Mine in Washington County, PA and was believed to be associated with failed gate-road pillars due to the inadequate sizes of the pillars. This incident occurred about the time that improved pillar design methods were being developed. This incident may have had similar conditions as the Mine #33 site in the western gate-roads below the Spinner Road HDDP.

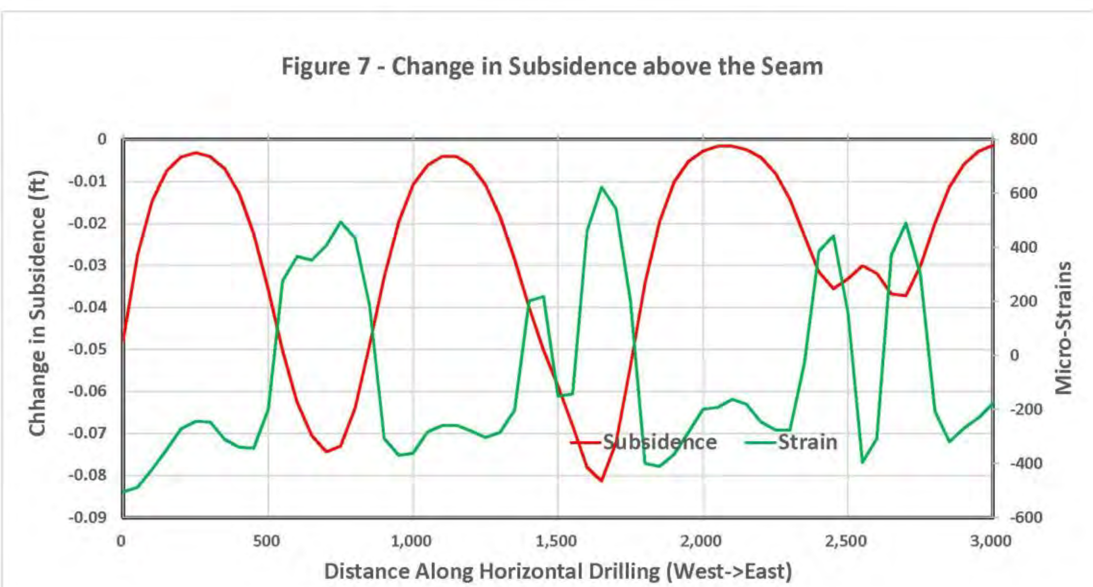
At Mine #33, mining occurred from west to east. Longwall mining had been a recent innovation to the industry and engineering design of pillars-in gate-roads was in its infancy and was being actively researched by mining companies and government agencies. In our review of the mining sequence, it appears that the mine operator was trying different pillar sizes in an attempt to determine which pillar size was adequate for the conditions present at this location. They started with two 60-foot wide pillars in the western gate-roads. The next mined gate-road included one 100-foot wide pillar and one 25-foot wide pillar. The easternmost gate-road included two 80-foot wide pillars. In discussion with Mr. Larry Neff, formerly Head Field Engineer at Bethlehem Mines when these sections were being mined, he reported that this section had very poor roof conditions during development and several roof failures occurred. The larger pillars alleviated this condition. The longwall removed 54 inches of coal with a shear. When the longwall first began Mine 33 personnel surveyed the subsidence and about 2.5 feet of subsidence was found to occur in the center of each panel. Since their subsidence pattern was found to be very consistent, they eliminated surveying the subsidence over each panel prior to mining the panels below the HDDP. Mr. Neff is still working at the facility (now owned by Arcelor Mittal) and there have been no incidents of surface subsidence above any abandoned gate-roads at this mine, of which he is aware.

Mr. Neff also reported that there was no known damage to the existing pipeline (that was installed in the 1930’s) during or after longwall mining in the HDDP area. He did report that the only pipeline damage due to mining (to his knowledge) occurred when a second overlying coal seam was longwall mined beneath a pipeline owned by People’s Natural Gas Company in the Roaring Run area (located WSW of the HDDP site). At that location two seams were longwall mined and the mining that occurred was much shallower than at the Spinner Road HDDP site. Following an initial incident in that area the pipeline company uncovered and cribbed the pipeline during mining of each subsequent longwall panel.

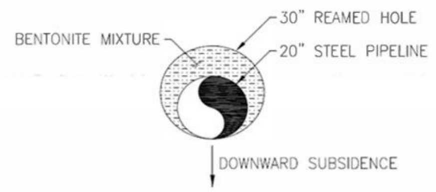
The Analysis of Longwall Pillar Stability (ALPS) software program was developed and first introduced by the U.S. Bureau of Mines (now a part of NIOSH) around 1990. This program is generally accepted by the mining industry for use in estimating the load bearing capacity of longwall pillar systems. A discussion of an ALPS analysis for the pillar sizes in the three gate-road sections beneath the planned HDDP was completed by Dr. Schissler and included in Appendix B of this report. The westernmost gate-road pillars were shown by the ALPS analysis to be undersized for gate-road use at both coal strengths. The other two gate-roads were shown by the ALPS analysis to be adequately sized when the coal was at full strength but not adequately sized when the pillar strength is reduced. Using the original strength of coal (900 psi), the smaller sized pillars (25-foot wide) probably failed right after the longwall was mined and thus subsidence has already occurred over them. With the smaller pillars already having failed, the model was run by reducing the strength of the pillars as they would degrade over time.

The estimated maximum subsidence that the pipeline may experience in the future is the difference between the subsidence estimated using the original strength (900 psi) of coal and the subsidence estimated using a degraded strength (750 psi) of coal. The differential in subsidence between the two coal strengths is plotted in Figure 7, along with the associated strains. There are three areas of potential increased subsidence. These three areas are located above the three gate-roads. The largest increased subsidence would be estimated to be about 0.074 feet (0.89 inches) - above the western most gate-road (centered at Station 700). The second area of increased subsidence occurs above Station 1650 - above the center gate-road. The estimated additional subsidence in this area is estimated to be about 0.081 feet (0.97 inches). The third area of increased subsidence occurs above Station 2700 - above the eastern gate-road. The estimated additional subsidence in this area is estimated to be about 0.037 feet (0.44 inches).

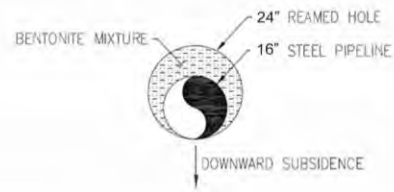
The maximum strain values range from -0.0005 to = +0.0006 strain (compression is positive), and fluctuate continuously along the pipeline length, but being highest above the gate-roads. Figure 7 includes both the change in subsidence and the strain along the HDDP location. The level of strain that the pipeline may experience is a function of the ground movement and a function of how tightly the pipeline is coupled to the ground movement. If the pipeline can slide within the horizontal drilling distance, then areas of tensile or compressive strain can be reasonably canceled by adjacent areas of the opposite strain.



The modeled strains are in the strata at the location of the pipeline alignment. The bored excavation for both HDDPs will be larger than the pipe to be installed. As illustrated on Figure 8, the strain in the strata encompassing the hole, is not directly correlated to the strain imparted to the pipeline. The overbore (larger diameter of the hole compared to the pipe) leaves room for potential movement of the pipe within the strata. Transmission of the strain from the strata to the pipe associated with this project is being reviewed by pipeline engineers.



HDDP 20”



HDDP 16”

Figure 8 – Borehole and Pipeline Cross Section

RECOMMENDATIONS

Based on the findings presented above, Tetra Tech recommends the following actions:

- Provide the estimated maximum subsidence and strain within the strata to pipeline engineers for their use to assure that the pipeline stresses are within appropriate pipeline design standards, including adequate factor of safety.
- Consider mitigating the subsidence strain by grouting the underlying abandoned coal mine if the pipeline stresses exceed appropriate pipeline design standards.

CLOSURE

The subsidence modeling calculates the stress and ground movement throughout the strata, from the coal seam to the surface. Numerical subsidence models have been calibrated both at the mine level (for optimizing pillar design) and at the surface (for subsidence prediction). Obviously, these are the locations where there is relatively simple access for performing the broad area measurements needed for the calibration of the model. Obtaining calibration measurements from within the solid rock mass between the mine and the surface is not very effective, since only limited locations can be practically measured versus wide area measurements in the mine or on the surface. In addition, underground subsidence has been observed in multi-seam mines and every indication is that the strain field is continuous throughout the overburden. Further, the numerical method used for simulating the rock strata is consistent with the physical laws of superposition and interpolation. Therefore, it is entirely reasonable and standard engineering practice to calculate/interpolate the subsidence at the location of the pipeline which is between the calibrated mine and surface locations. The model calculations are based on average subsidence parameters which may certainly have some variable for each individual site. Also, predicting subsidence from pillar failure and incomplete caving is different than the complete caving subsidence used to develop the subsidence parameters.

In areas where the pipeline is to be located greater than 50 feet below the ground surface, the drill will be over-bored to a diameter larger than the pipeline. This will decrease the frictional drag between the earth and the pipeline, and maintaining this low-friction environment over the life of the pipeline would help decouple the pipeline from any ground movements and subsidence-induced strains.

This report was prepared to assist Sunoco in the evaluation of the subject project. The scope of this report is limited to the specific project, location, and time described herein. The report presents Tetra Tech's understanding of site conditions as discernible from information provided by others and obtained by Tetra Tech. Maps in this report are included only to aid the reader and should not be considered surveys. If additional data concerning this site become available, Tetra Tech should be informed so that we may examine the information and, if necessary, modify this report accordingly.

Respectfully submitted,

Thomas A. Gray, P.E.
Mining Engineer

Farley Wood, P.E.
Mining Engineer

Andrew Schissler, PhD, P.E.
Mining Engineer

Keith Heasley. PhD, P.E.

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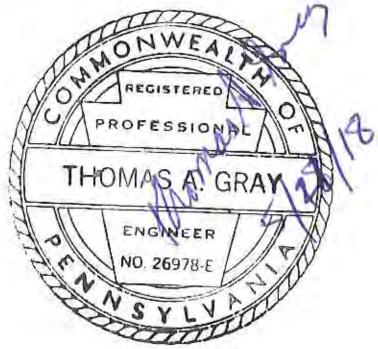
CERTIFICATION

SUBSIDENCE POTENTIAL REVIEW
SPINNER ROAD
HORIZONTAL DIRECTIONAL DRILLED PIPELINE PROJECT

By affixing my seal to this document I am confirming that the project conditions were reviewed and that accepted engineering practices were used to arrive at the reported results. Subsidence engineering is not an exact science and professional judgement was used to assess the many variables that exist, and is subject to those limitations that may be included in the Subsidence Report and information provided by third parties.



Thomas Gray, P.E.

License No. 26978-E

Date 5/21/18

The term certify as used herein is defined as follows: An engineer's certification of condition is a declaration of professional judgement. It does not constitute a warranty or guarantee, either expressed or implied.

TETRA TECH ROONEY

Date: 5/21/2018

To: Mathew Gordon
Project Manager
Sunoco Logistics, L.P.
525 Fritztown Road
Sinking Spring, PA

Subject: **Subsidence Potential Review Spinner Road Horizontal Directional Drilled Pipeline Project – Munster Township, Cambria County, PA**
Mariner East II TTR Project: 204-3110 1.1 PPP1

Mr. Gordon,

Tetra Tech Rooney has reviewed the above referenced subsidence report in addition to a Finite Element Analysis (FEA) model and we have confirmed that if the predicted subsidence does in fact occur in the future, the resulting stresses within the pipeline will still be in compliance with ASME B31.4.

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
ALAN DEAN SHAUERS
ENGINEER
PE077947

Sincerely,

Dean Shauers, P.E.
Tetra Tech Rooney

Attachments:

Geotechnical Report: Subsidence Potential Review Spinner Road Horizontally Directional Drilled Pipeline – Munster Township, Cambria County, PA

CC: Larry Gremminger, CWB, Environmental Project Consultant
Thomas A. Gray, P.E., Energy and Natural Resources Manager, Tetra Tech, Inc.

FIGURES

LEGEND

LIMIT OF POTENTIAL INFLUENCE AREA ON PIPELINE

REFERENCE: BETHENERGY'S MINE 33 MAP – OBTAINED FROM PA DEP – UNDATED

REVISIONS			
NO.	BY	DATE	REMARKS

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T: (412) 921-7090 | F: (412) 921-4040

SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

PENNSYLVANIA PIPELINE PROJECT

PROJECT LOCATION WITH ANGLE OF DRAW

CAMBRIA COUNTY
SPINNER ROAD
MINE AREA

DATE:	2/20/18
PROJECT NO.:	
DESIGNED BY:	TG
DRAWN BY:	JSM
CHECKED BY:	TG

FIGURE 1

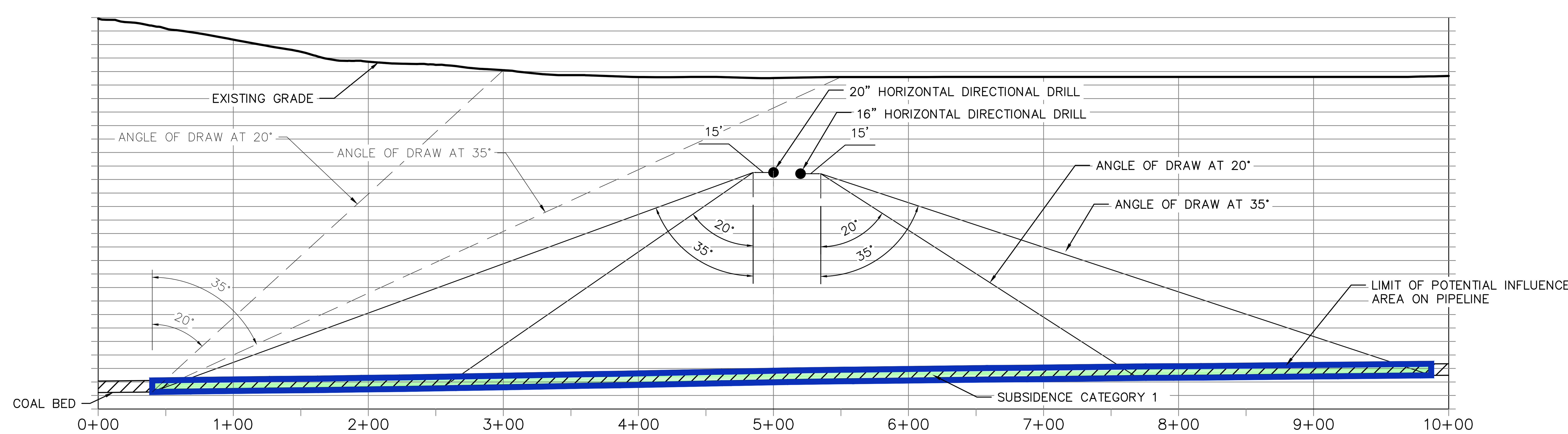
LEGEND

LIMIT OF POTENTIAL INFLUENCE AREA ON PIPELINE	(blue line)
SUBSIDENCE CATEGORY 1	(green)
SUBSIDENCE CATEGORY 2	(yellow)
SUBSIDENCE CATEGORY 3	(orange)

CATEGORIES OF MINE SUBSIDENCE POTENTIAL

CATEGORY 1: SUBSIDENCE PROBABLY OCCURRED DURING OR SOON AFTER MINING.
CATEGORY 2: SUPPORT AREA WHERE SUBSIDENCE UNLIKELY.
CATEGORY 3: AREAS WHERE SUBSIDENCE MAY HAVE OCCURRED OR MAY OCCUR IN THE FUTURE.

REFERENCE: BETHENERGY'S MINE 33 MAP – OBTAINED FROM PA DEP – UNDATED



A–A'
NOT TO SCALE

0 150 300
SCALE IN FEET

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REVISIONS

NO.	BY	DATE	REMARKS

SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

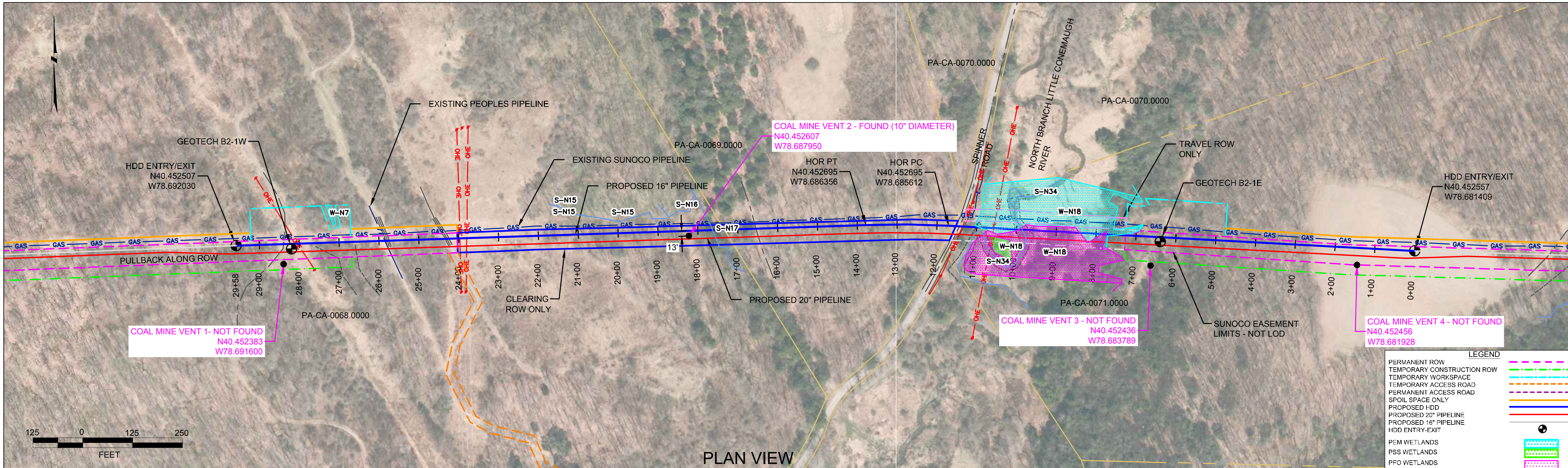
PENNSYLVANIA PIPELINE PROJECT

PROJECT LOCATION WITH SUBSIDENCE CATEGORIES

CAMBRIA COUNTY
SPINNER ROAD
MINE AREA

DATE:	2/20/18
PROJECT NO.:	
DESIGNED BY:	TG
DRAWN BY:	JSM
CHECKED BY:	TG

FIGURE 2



PLAN VIEW

CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080-16

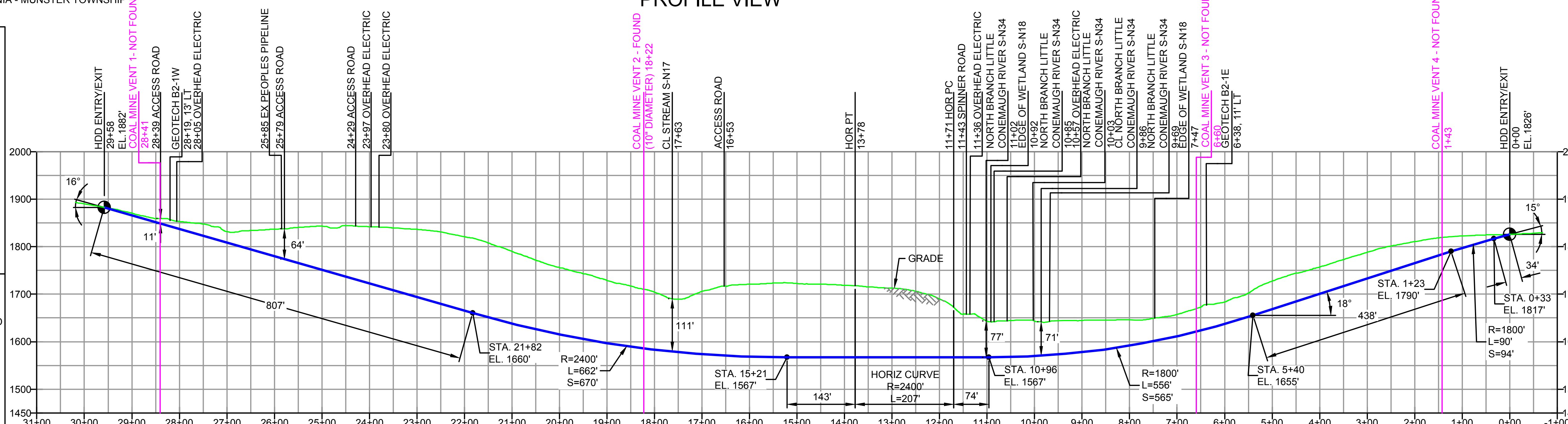
PROFILE VIEW

GEOTECH B2-1W
- NG EL. 1855'
- GRAVEL (0.0' - 0.3')
- LEAN CLAY CL (0.3' - 5.0')
- COMPLETELY WEATHERED SHALE (21.5' - 30.0')
- SHALE SANDSTONE/LIMESTONE (5.0' - 305.5')
- BORING TERMINATED EL.1549.5'

NOTE: REFER TO TEST BORING LOG B2-1W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-1E
- NG EL. 1677'
- FILL -LEAN CLAY W/ SAND (0.5' - 9.0')
- SILTY CLAY W/ SAND CL-ML (9.0' - 21.5')
- GROUNDWATER (22.3')
- LEAN CLAY W/ SAND CL (21.5' - 34.0')
- SILTSTONE/MUDSTONE (34.0' - 102.5')
- BORING TERMINATED EL.1554.5'

NOTE: REFER TO TEST BORING LOG B2-1E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2958'
   HDD PIPE LENGTH (S=):3032'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. PILOT HOLE SHALL BE COMPLETED USING THE INTERCEPT METHOD CONSISTING OF TWO PILOT HOLES DRILLING FROM BOTH SIDES OF THE DRILL.

Figure 3. HDDP-Plan and Profile-16"

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP6	ADDED COAL MINE VENT LOCATIONS	MRS	01/29/18	RMB	01/29/18	CAG	01/29/18
EP5	UPDATED GEOTECH BORE ELEVATION INFO PROVIDED BY DPS	MRS	11/28/17	RMB	11/28/17	CAG	11/28/17
EP4	UPDATED GEOTECH INFO PROVIDED BY DPS	MRS	11/14/17	RMB	11/14/17	CAG	11/14/17
EP3	RELOCATED HDD ENTRY / EXIT POINTS - DESIGN CHANGE BY DPS	MRS	11/07/17	RMB	11/07/17	CAG	11/07/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/18/16	RMB	05/18/16	AAW	05/18/16

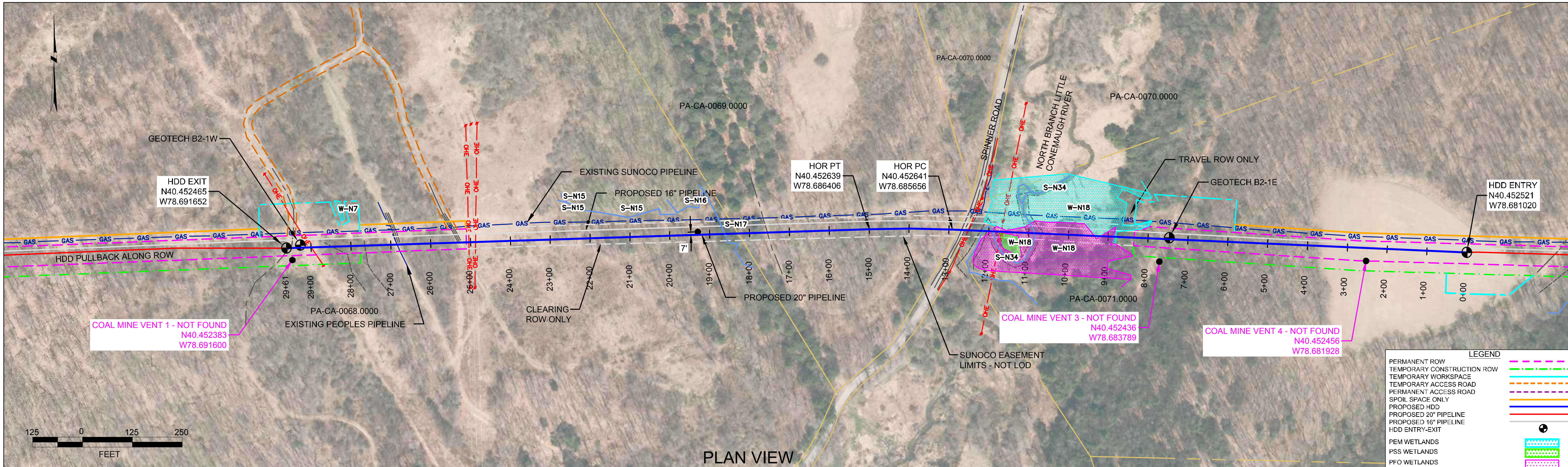
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' | DWG. NO. PA-CA-0069.0000-RD-16



CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080

GEOTECH B2-1W

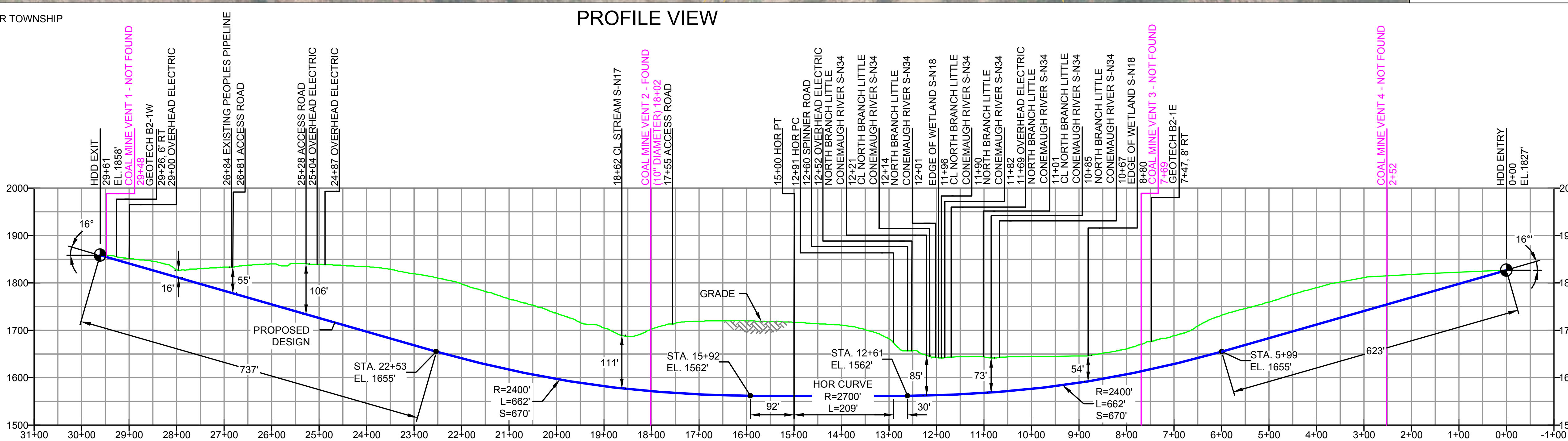
- NG EL. 1855'
- GRAVEL (0.0' - 0.3')
- LEAN CLAY CL (0.3' - 5.0')
- COMPLETELY WEATHERED SHALE (21.5' - 30.0')
- SHALE SANDSTONE/LIMESTONE (5.0' - 305.5')
- BORING TERMINATED EL.1549.5'

NOTE: REFER TO TEST BORING LOG B2-1W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-1E

- NG EL. 1677'
- FILL -LEAN CLAY W/ SAND (0.5' - 9.0')
- SILTY CLAY W/ SAND CL-ML (9.0' - 21.5')
- GROUNDWATER (22.3')
- LEAN CLAY W/ SAND CL (21.5' - 34.0')
- SILTSTONE/MUDSTONE (34.0' - 102.5')
- BORING TERMINATED EL.1554.5'

NOTE: REFER TO TEST BORING LOG B2-1E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2961'
   HDD PIPE LENGTH (S=):3031'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
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12. PILOT HOLE SHALL BE COMPLETED USING THE INTERCEPT METHOD CONSISTING OF TWO PILOT HOLES DRILLING FROM BOTH SIDES OF THE DRILL.

Figure 4. HDDP-Plan and Profile-20"

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP7	DRILL DESIGN LENGTHENED PER CLIENTS REQUEST	MRS	04/06/18	RMB	04/06/18	CAG	04/06/18
EP6	ADDED COAL MINE VENT LOCATIONS	MRS	01/29/18	RMB	01/29/18	CAG	01/29/18
EP5	UPDATED GEOTECH BORE ELEVATION INFO PROVIDED BY DPS	MRS	11/28/17	RMB	11/28/17	CAG	11/28/17
EP4	UPDATED GEOTECH INFO PROVIDED BY DPS	MRS	11/14/17	RMB	11/14/17	CAG	11/14/17
EP3	RELOCATED HDD ENTRY / EXIT POINTS - DESIGN CHANGE BY DPS	MRS	11/07/17	RMB	11/07/17	CAG	11/07/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	09/30/16	RMB	09/30/16	AAW	09/30/16

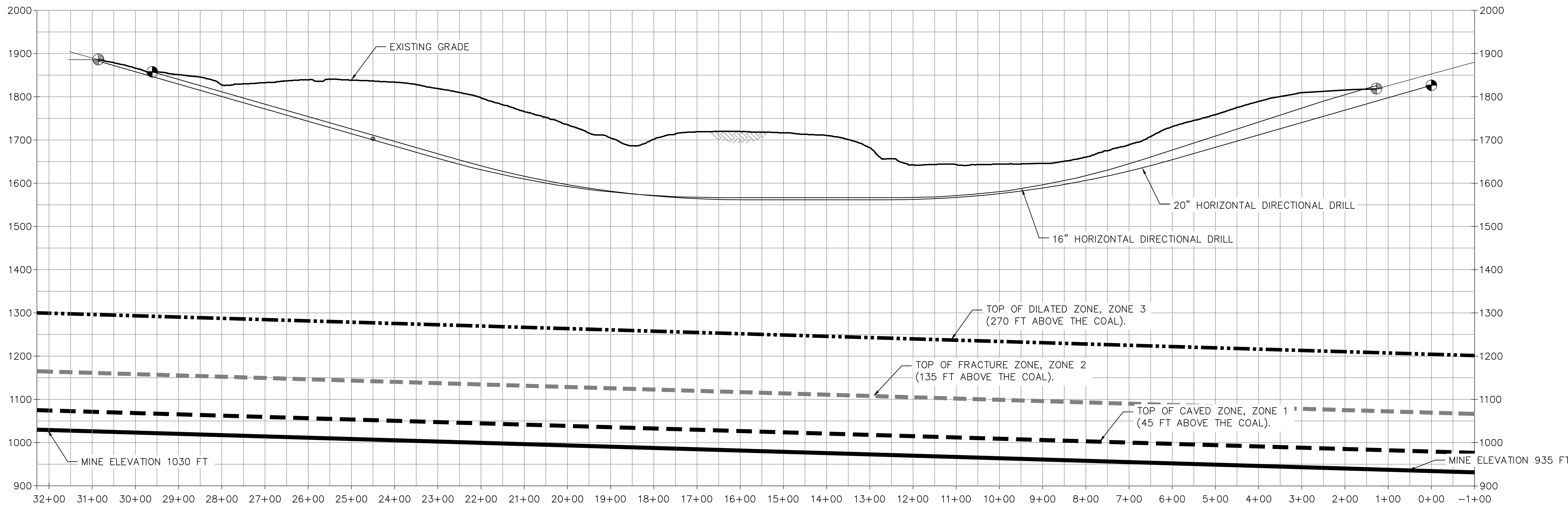
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'
DWG. NUMBER: PA-CA-0069.0000-RD



0 120 240
SCALE IN FEET

TETRA TECH

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PITTSBURGH, PA 15220
T: (412) 921-7090 | F: (412) 921-4040

REVISIONS			
NO.	BY	DATE	REMARKS

SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

PENNSYLVANIA PIPELINE PROJECT

FRACTURE ZONE CROSS SECTION

CAMBRIA COUNTY
SPINNER ROAD
MINE AREA

DATE:	2/20/18
PROJECT NO.:	
DESIGNED BY:	TG
DRAWN BY:	JSM
CHECKED BY:	TG

FIGURE 5

R:_Marcellus Shale Projects\Sunoco\5958 – Penn Pipeline Project\5 – Cambria\HDD Mining Review\Figures\PA-CA-HDD-FG006.dwg PIT JOY.SCABILLONI 5/21/2018 12:18:39 PM

APPENDIX A

Dr. Heasley Subsidence Report

LAMODEL ANALYSIS OF SUBSIDENCE POTENTIAL
SPINNER ROAD
HORIZONTAL DIRECTIONAL DRILLED PIPELINE PROJECT
MUNSTER TOWNSHIP, CAMBRIA COUNTY, PA
May, 2018

PRESENTED FOR

Sunoco Logistics, L.P.
525 Fritztown Road
Sinking Spring, PA

PRESENTED BY

Tetra Tech
661 Anderson Drive
Foster Plaza 7
Pittsburgh, PA 15220

TETRA TECH

TABLE OF CONTENTS

FIGURES

INTRODUCTION

The Sunoco Logistic L.P. is planning to horizontally directional drill (HDD) a pipeline under Spinner Road in the strata over the abandoned Cambria Slope Mine #33 in Munster Township, Cambria County, PA. The HDD section under the Spinner Road will be about 2.957 ft long and 500-900 ft above the mine level. The objective of this investigation is to utilize the LaModel boundary-element program to analyze the future subsidence potential over the abandoned Mines, and in particular, to determine any potential subsidence and associated strains that may occur along the proposed pipeline alignment.

MINING BACKGROUND

The Bethlehem Mines Corporation's Cambria Division operated the underground Cambria Slope Mine #33 in Munster Township, Cambria County from the 1960's into the mid-1990's. The Lower Kittanning seam was mined using the longwall mining method directly below the HDDP from 1989 to 1993. The depth of the coal from surface is about 900 ft at Station 0.0 (the beginning of the HDDP) and about 850 ft at Station 29+61 (the end of the HDDP). The mine gets as little as 650 ft deep under the North Branch Little Conemagh River valley and Spinner Road, which follows the valley.

The mining method employed at the Cambria Slope Mine #33 was longwall mining. Three entry gate-roads were driven using mechanized continuous mining machine parallel to each other so that a 600-700 ft wide 11,500 ft long coal pillar remained between them. The large coal pillar was systematically removed with a mechanical coal cutting machine (called a "shearer") that excavated a section of the coal along the 600 ft width of the pillar. The machine went back and forth along the pillar systematically "shearing" up to 30 inches (horizontally) of coal each pass. A chain conveyor moved the coal to one side of the longwall pillar where it was transferred to a continuous belt conveyor within the gate-roads for transport outside the mine. To keep the miners safe, a row of hydraulic roof supports (chocks or shields) was used to support about a 10-16 ft wide section of the overlying roof from the face of the coal pillar. As the mining progressed through the pillar, the roof supports were advanced. As the roof supports advanced, the mine's roof collapsed behind them. By allowing the roof to collapse, the weight of the strata on the roof supports, longwall face and gateroad coal pillars was reduced. When the strata collapsed into the remaining void, surface subsidence would occur. Most subsidence would occur almost immediately, and most ground movements would be completed within a few weeks.

The gate-road pillars remained after mining. The mine plan included three entries in each gate-road. Pillar sizes in the gate-roads varied. The eastern most gate-road pillars included two 80 ft wide by 80 ft long pillars. The next gate-road pillar set included one 100 ft wide pillar and one 25 ft wide pillar. The third gate-road included two 60 ft wide pillars. The small (25 ft wide) pillars in the middle gateroad were designed to fail (a yield pillar in mining terms) soon after the longwall passed. These pillars probably failed soon after mining and thus the subsidence due to yield pillar failure has probably already occurred. The large pillars 80 ft or 100 ft wide would have been designed to provide long term support. The 60 ft wide pillars would not provide as much long term support as the larger pillars, and may have been marginally sized at the time of mining.

THE LAMODEL PROGRAM

The LaModel program is used to model the stresses and displacements on thin tabular deposits such as coal seams. It uses the displacement-discontinuity (DD) variation of the boundary-element method, and because of this formulation, it is able to analyze large areas of single or multiple-seam coal mines (Heasley, 1998). LaModel is unique among boundary element codes because the overburden material includes laminations which give the model a very realistic flexibility for stratified sedimentary geologies and multiple-seam mines. Using LaModel, the total vertical stresses and displacements in the coal seam are calculated, and optionally, the surface subsidence, or subsidence anywhere in the overburden, can be calculated. Amongst subsidence prediction programs, LaModel has the unique ability of be able to model the highly variable subsidence associated with time-dependent, pillar failure.

Since LaModel's original introduction in 1996, it has continually been upgraded and modernized as operating systems and programming languages have changed. The present program is written in Microsoft Visual C++ and runs in the windows operating system. It can be used to calculate convergence, vertical stress, overburden stress, element safety factors, pillar safety factors, intra-seam subsidence, etc. on single and multiple seams with complex geometries and variable topography. Presently, the program can analyze a 2000 x 2000 grid with 6 different material models and 52 different individual in-seam materials. It uses a forms-based system for inputting model parameters and a graphical interface for creating the mine grid. Also, it includes a utility referred to as a "Wizard" for automatically calculating coal pillars with a Mark-Bienawski pillar strength and another utility to assist with the development of "standard" gob properties. Recently, the LaModel program was interfaced with AutoCAD to allow mine plans and overburden contours to be automatically imported into the corresponding seam and overburden grids. Also, the output from LaModel can be downloaded into AutoCAD and overlain on the mine map for enhanced analysis and graphical display. Within the last couple of years, new algorithms have been added to the program to help optimize subsidence calculations (Yang, 2016).

LAMODEL MATERIAL PROPERTY INPUT

Mine Grid: The LaModel simulation of the Cambria Slope Mine #33 encompassed a fairly large area of the abandoned mine (see the "Mine Grid" area in Figure 1) in order to keep any edge effects from the boundary conditions from affecting the area of interest around the pipeline alignment. This model area was 4,400 ft wide and 5,000 ft high. A relatively small element size of 5 ft was used to best model the given entries and pillars. This smaller element size also facilitates using a thin lamination thickness for the overburden to optimize the subsidence angle-or-draw. With the 5 ft element width, the final grid size was 880 X 1000 elements. Based on the mine map, the boundaries of the model were simulated with rigid boundary conditions on the north, east and south, and symmetric boundary conditions on the west. The actual mine grid was automatically generated from a digitized version of the Cambria Slope Mine #33. Subsequent, seismic interpretation did not require any adjustment to the mine model the was digitized from the mine map.

Overburden Grid: For inputting the overburden information in order to accurately simulate the overburden stress on the seam, an overburden grid was developed that was 800 ft wider than the mine grid on all four sides. Therefore, the final overburden grid was 6000 ft wide by 6600 ft high and used 25 ft wide elements on a 240 X 264 element grid. The values for the overburden grid were then automatically generated from the AutoCAD topographic lines as shown in Figure 1. The result of the overburden grid generation process is the calculated overburden stress on the coal seam as plotted in Figure 2. In the plotted overburden stress, the lower stress areas under the north-south running North Branch Little Conemagh River valley (and Spinner Road which follows the valley) in the center of the grid can be seen along with the significantly higher stress areas under the ridges to the west and east. In particular, the variable stress under the pipeline can be seen as it: starts on a hill top in the east, travels under the broad Little Conemaugh valley, and then exits toward a ridge top in the west.

Overburden, Gob and Coal Properties: The material properties for the Cambria Slope Mine #33 model were generated using the LaModel subsidence optimization routines (Yang, 2016) to provide a subsidence factor (56%) and angle-of-draw consistent with the Pittsburgh Seam overburden and consistent with the 700 ft wide, 700 ft deep extraction panels that underlie the pipeline alignment. This resulted in an average rock modulus of 3,000,000 psi and lamination thickness of 10.5 ft. for the overburden, and a final gob modulus of 29,118 psi for the strain-hardening gob model. For the initial model, intended to simulate the coal strength at the time of mining, a NIOSH recommended coal strength of 900 psi as implemented in the Mark-Bieniawski pillar strength formula by the LaModel coal wizard was used. To simulate the maximum potential subsidence that might occur over time after initial mining (assumedly due to coal, roof or floor degradation by oxidation, spalling, moisture, etc.), a 17% reduced coal strength (750 psi) was implemented into a separate “degraded mine” model.

POST-MINING MODEL RESULTS

Seam Convergence: Initially, the model with the 900 psi coal strength intended to simulate the mine conditions immediately after mining was run and analyzed in order to gain an understanding of the post-mining conditions. The first model output to be examined was the seam convergence as shown in Figure 3. In this output, the overburden convergence over the 600 and 700 ft wide longwall gobs is clearly visible. In particular, the panels adjacent to the pipeline show 2.4 to 3.0 ft of convergence.

Pillar Safety Factors: Next, the safety factors of the remaining coal pillars were examined, as shown in Figure 4. (Note: the scale of this safety factor plot was set to give details on the pillars with safety factors less than 2.5). This Figure shows that the pillars located in the main line entries are very stable. Also, the larger gateroad pillars on the two eastern gateroads under the HDD have safety factors greater than 1.5. However, the western gateroad under the HDD has smaller pillars with marginal safety factors below 1.00. This western gateroad may be prone to failure and subsidence at some time after mining.

Subsidence: The next output from the post-mining model to be examined was the subsidence at the pipeline location (see Figure 5). This subsidence is directly correlated to the seam convergence shown in Figure 3. Similar to the convergence, the increase in surface subsidence due to wider and/or deeper panels is evident in Figure 5. Here the original predicted subsidence under the pipeline location can be seen. Generally, the HDD starts (0+00) in the center of a subsidence trough (to the east) then crosses over three gateroads and ends in the center of another subsidence trough to the west (29+61).

The pipeline in the HDD sections ranges from 850-900 ft above the seam, at the entry and exit hillside locations, to 500 ft above the seam under the floor of the North Branch Little Conemagh River valley. In LaModel, an average distance above the seam of 700 ft was used to calculate the subsidence values which are applied to the HDD pipeline. In the LaModel program, the overburden is modeled as a continuum. Therefore, the program does show the subsidence horizontally expand, within the angle-of-draw, and the magnitude decrease as the distance from the mine increases, but the program does not model any vertical dilation of the overburden, which minimizes the change in subsidence with depth.

To examine the details of the previous subsidence along the pipeline alignment, the subsidence above the seam has been interpolated from the output shown in Figure 6 directly to the pipeline coordinates, as shown in Figure 6. In this plot, the subsidence under the pipeline as it crosses over the various gob and supporting gateroad pillar areas is clearly visible.

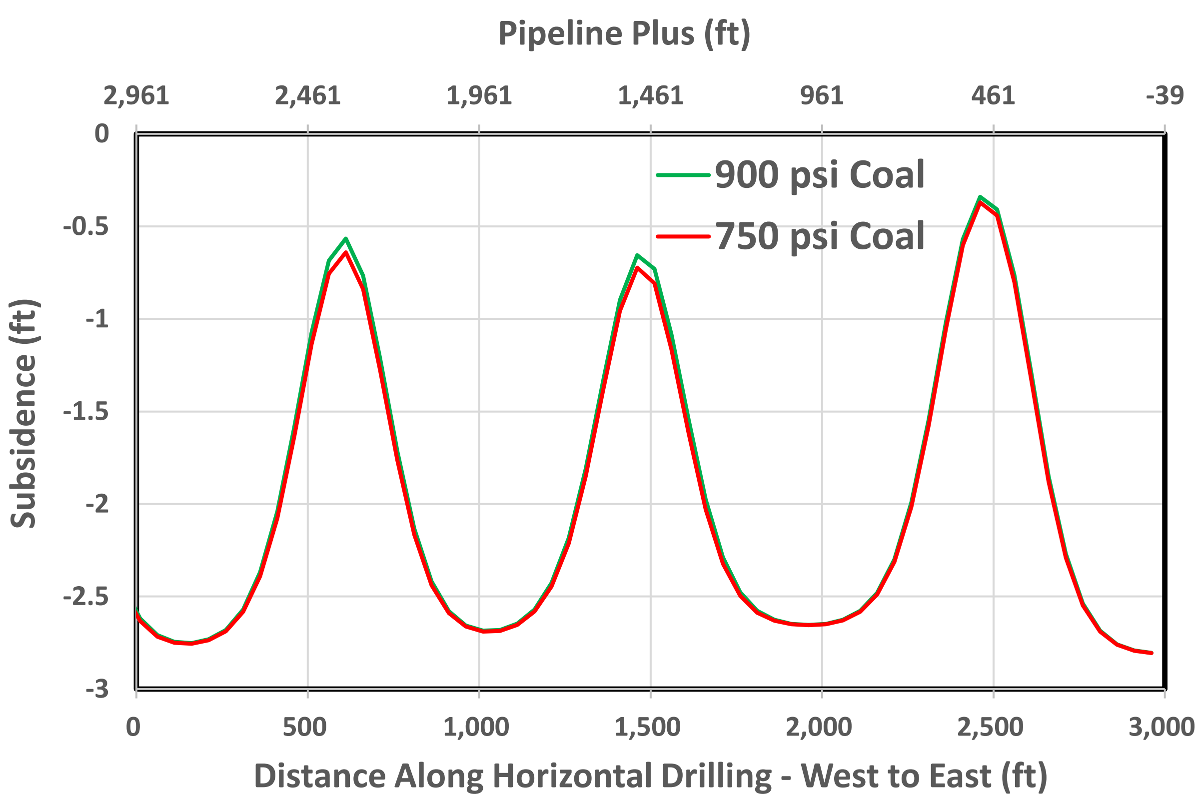

Figure 6. Subsidence prediction along the pipeline alignment at different coal strengths.

DEGRADED MINE MODEL RESULTS

As previously stated, the model with 900 psi coal strength (as shown in Figures 3, 4, and 5) was intended to simulate the mine conditions immediately after mining. The subsidence shown in Figure 5 and the 900 psi coal line in Figure 6 has assumedly already occurred immediately after mining. To simulate the maximum potential subsidence that might occur over time due to degradation of the coal, roof and/or floor by oxidation, spalling, moisture, etc., a model with a coal strength of 750 psi (a 17% strength reduction) was run, analyzed and compared with the post-mining 900 psi model.

Pillar Safety Factors: The first output to be closely examined from the degraded mine model was pillar safety factors as shown in Figure 7. This Figure shows that the pillars located in the main line entries are still very stable. Also, the larger gateroad pillars on the eastern gateroad under the HDD still have safety factors that range from 1.25 to 1.75. However, with the degraded coal strength, the safety factors for the pillars in the center gateroad under the HDD have dropped to just below 1.0. Also, the western gateroad under the HDD, which had marginal safety factors below 1.00 for the 900 psi coal strength, now shows pillar safety factors that range from 0.50 to 0.75.

Additional Subsidence: As the marginally sized pillars in some areas of the gateroads fail, they cause convergence directly over the pillar. Also, the pillar failure puts additional loading and associate convergence on the adjacent gob areas. The ground reaction to the pillar failures then results in additional overburden subsidence as shown in Figures 8 and 9. With a reduction in coal strength to 750 psi, the areas of greatest increased subsidence are the areas in the gateroads where the pillar safety factors have changed from above 1.0 to below 1.0. However, the gateroad pillars are fairly large and the extraction ratio in the gateroads is fairly low, so even when the gateroad pillars fail, they still carry considerable load and the associated subsidence is greatly minimized. Under the pipeline, the additional subsidence is only in the range of 0.05 to 0.10 ft (see Figures 8 and 9). The pipeline is adjacent to a couple of areas over the gateroads that subside an additional 0.20 ft, but this is till minor. In fact, the greatest increased subsidence in the entire degraded coal model is only 0.5 ft (see Figures 8), which is still very manageable.

Strains: The strains associated with the predicted post-mining subsidence are also shown in Figure 9. The maximum strain values at the HDD location range from 0.0004 to 0.006, or 0.04% to 0.06%, and fluctuate continuously along the pipeline length.

The level of strain that the pipeline may experience is both a function of the ground movement and also a function of how tightly the pipeline is coupled to the ground movement. If the pipe is tight within the horizontal borehole due to the drilling mud confining the pipe or collapse of the borehole, then it may be assumed that the pipe will experience the full ground strain as shown in Figure 9. If the pipeline is simply lying in the open horizontal borehole and can easily slide, then areas of tension or compression in the ground can be reasonably canceled by sliding of the pipe between adjacent areas of the opposite strain.

The degraded mine subsidence predicted in this model may have already occurred, may occur at some time in the future, or may never reach this level. Predicting the actual condition of the mine at this time, and at any given time in the future, is difficult.

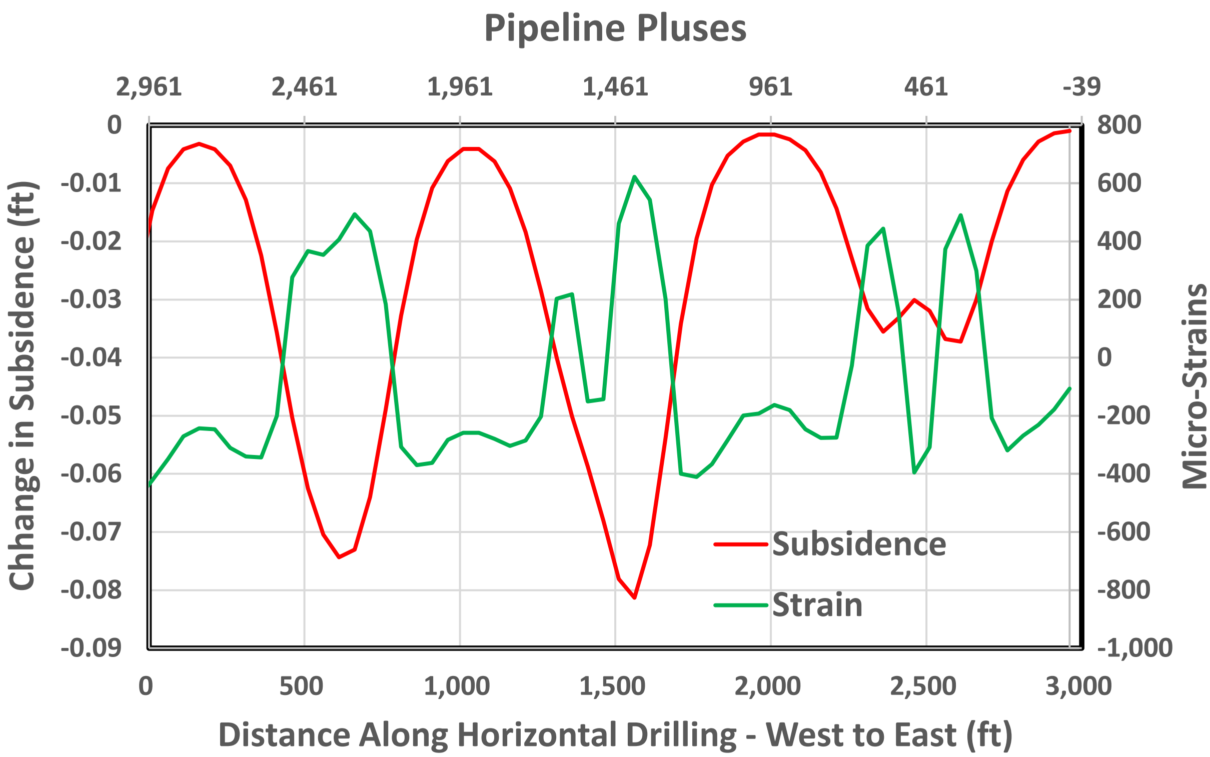

Figure 9. Predicted worst case subsidence and associated strains (tension is negative).

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Heasley, K. A. (1998) Numerical Modeling of Coal Mines with a Laminated Displacement-Discontinuity Code, Ph.D. dissertation, Colorado School of Mines, 187 pp.

Kendorski, F. S. (2006) Effect of Full-Extraction Underground Mining on Ground and Surface Waters a 25-Year Retrospective, 25th International Conference on Ground Control Mining, Morgantown WV 2006

The Pennsylvania State University (2014) Pennsylvania Mine Map Atlas, http://www.minemaps.psu.edu/

Yang, J. (2016) Calibrating LaModel for Subsidence, M.S. thesis, West Virginia University, 93 pp.

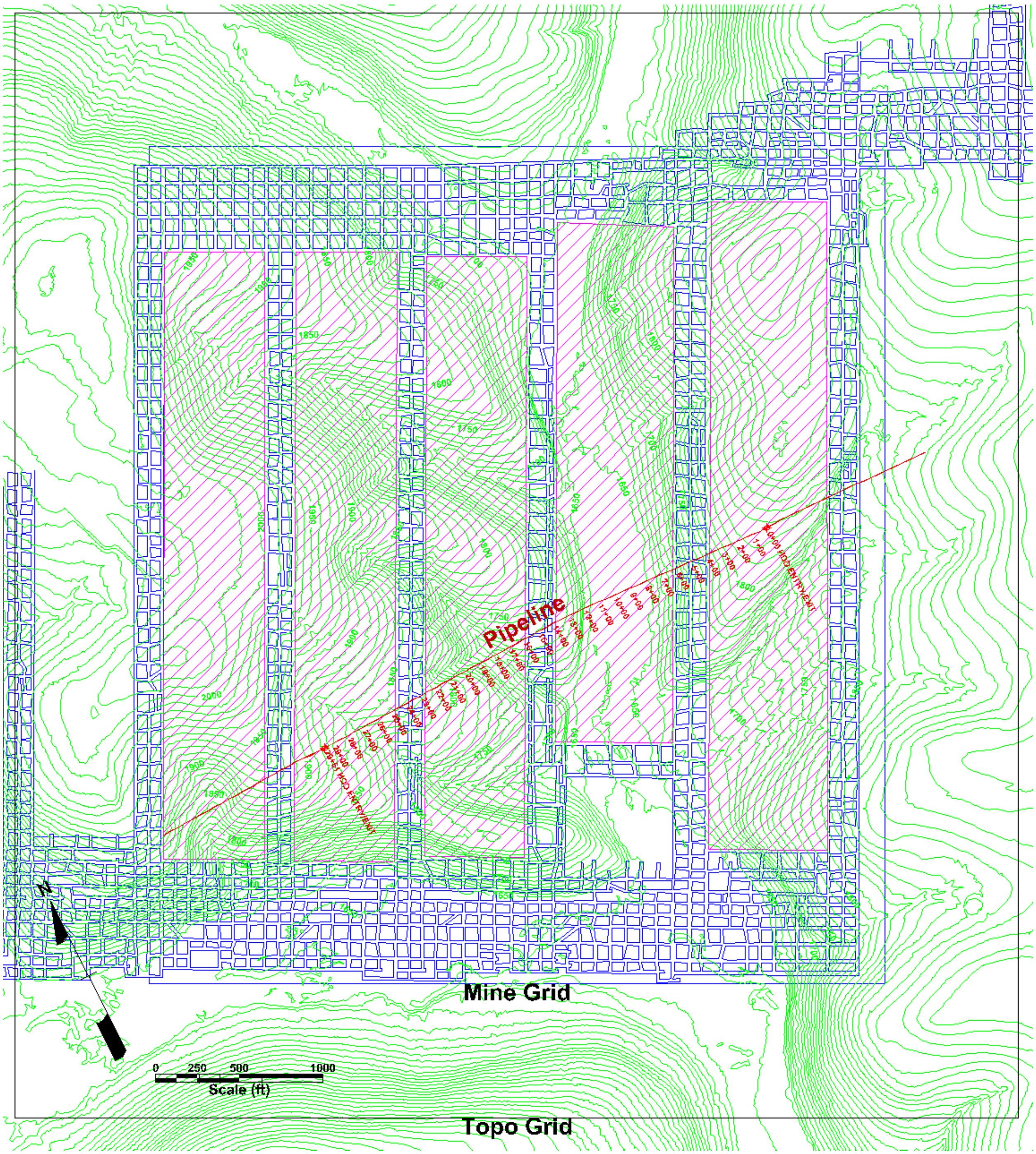

Figure 1. Map of mine and overlying pipeline

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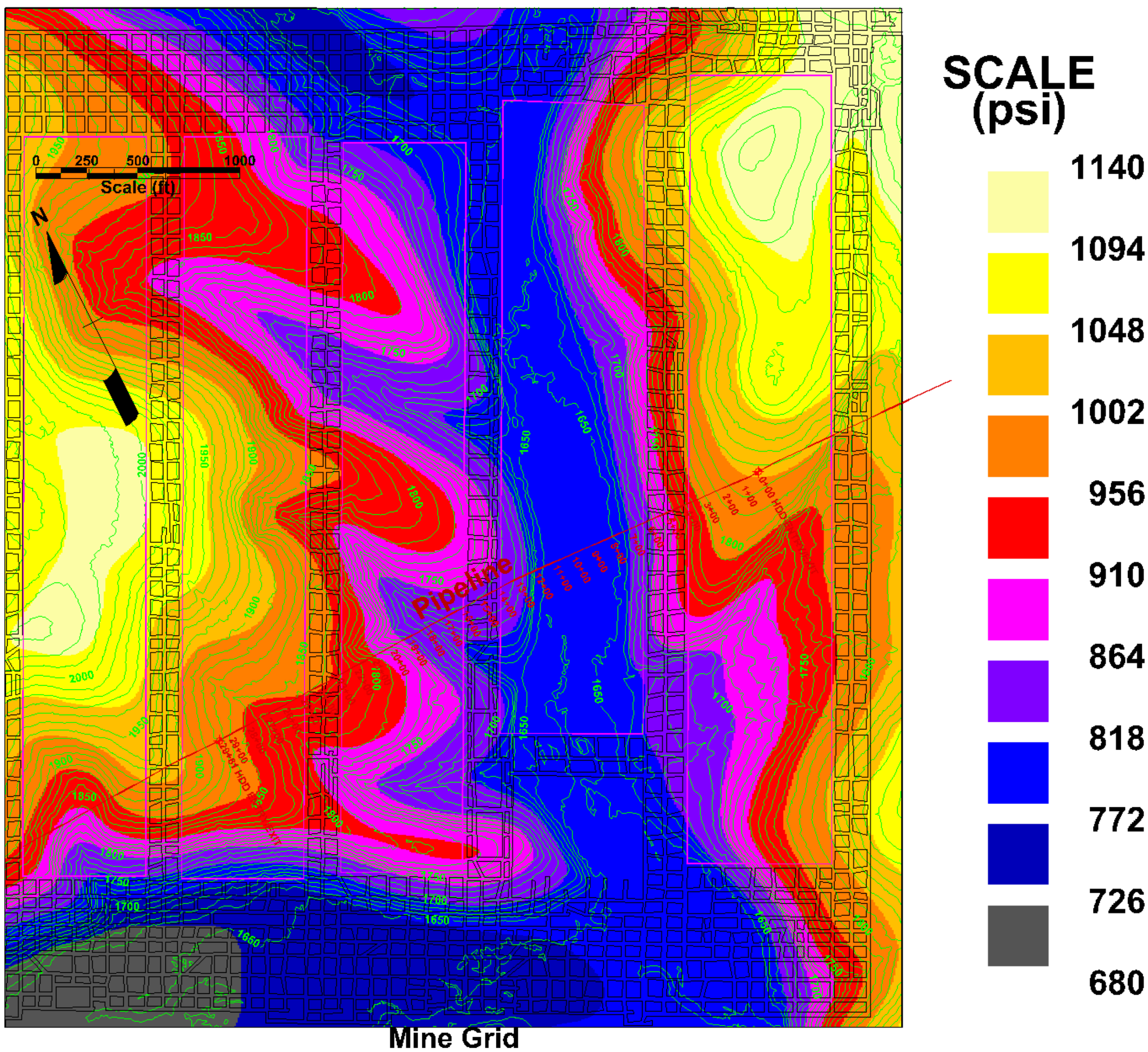

Figure 2. Overburden stress on the seam.

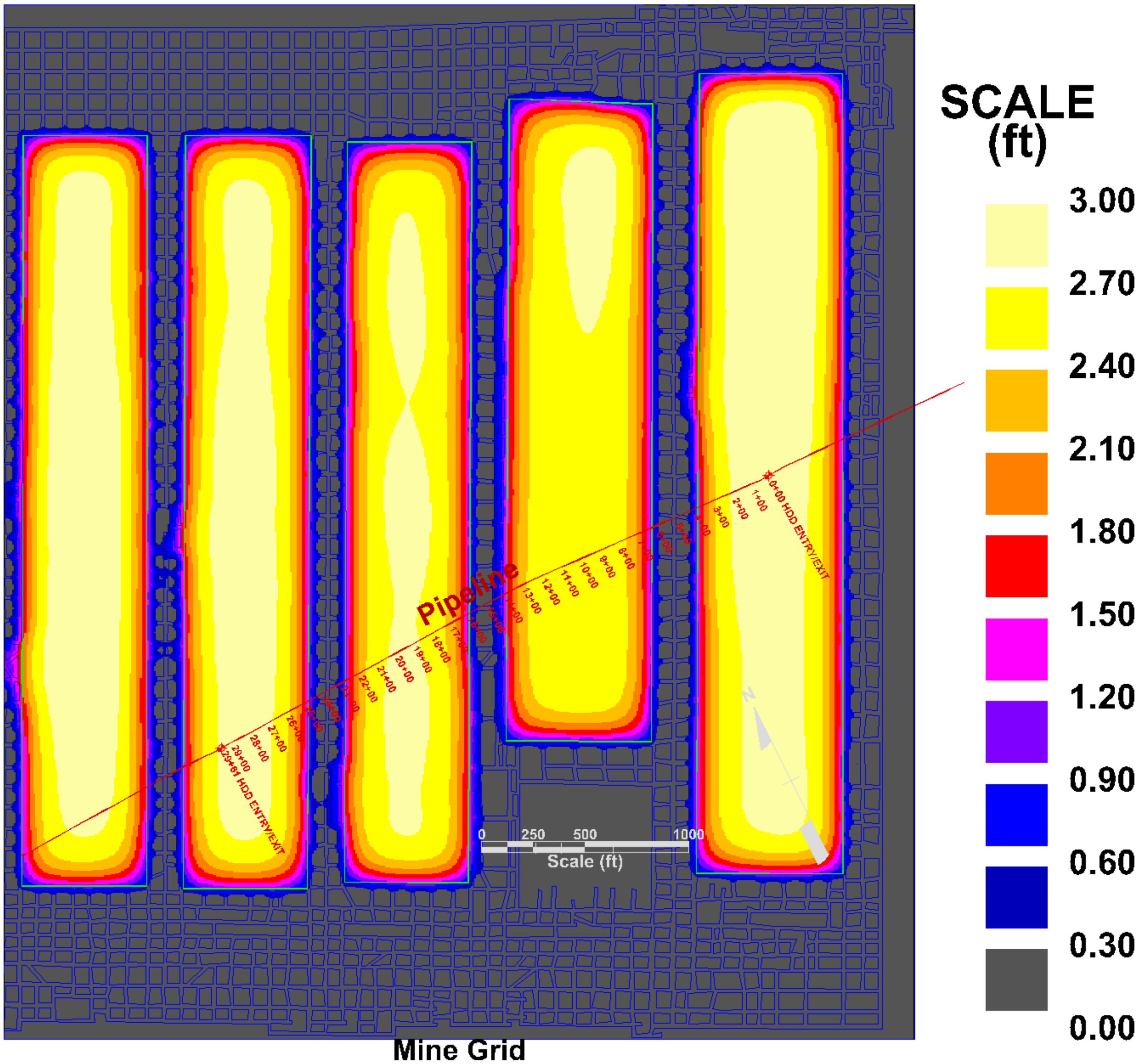

Figure 3. Seam convergence with 900 psi coal strength.

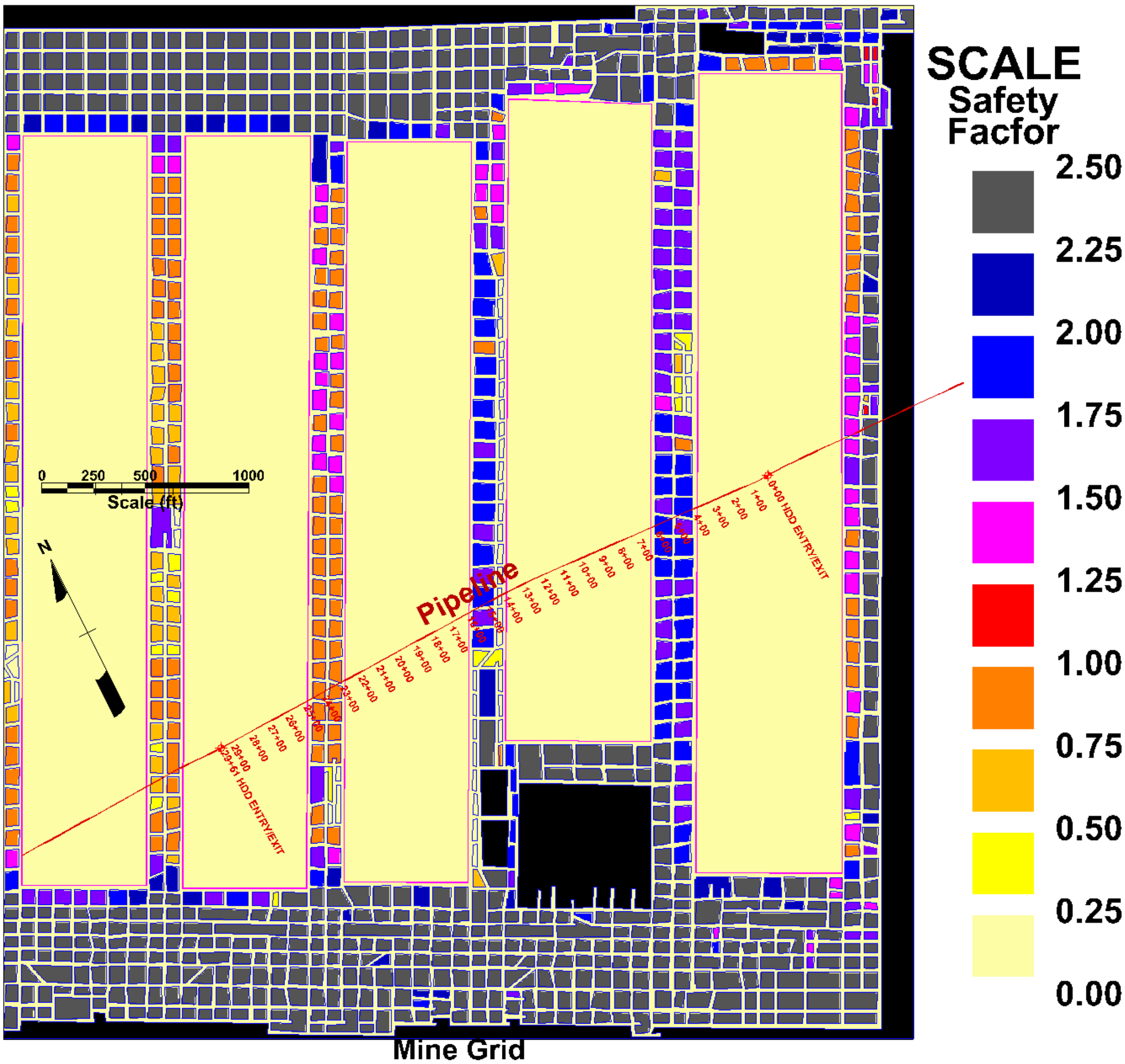

Figure 4. Pillar safety factors with 900 psi coal strength.

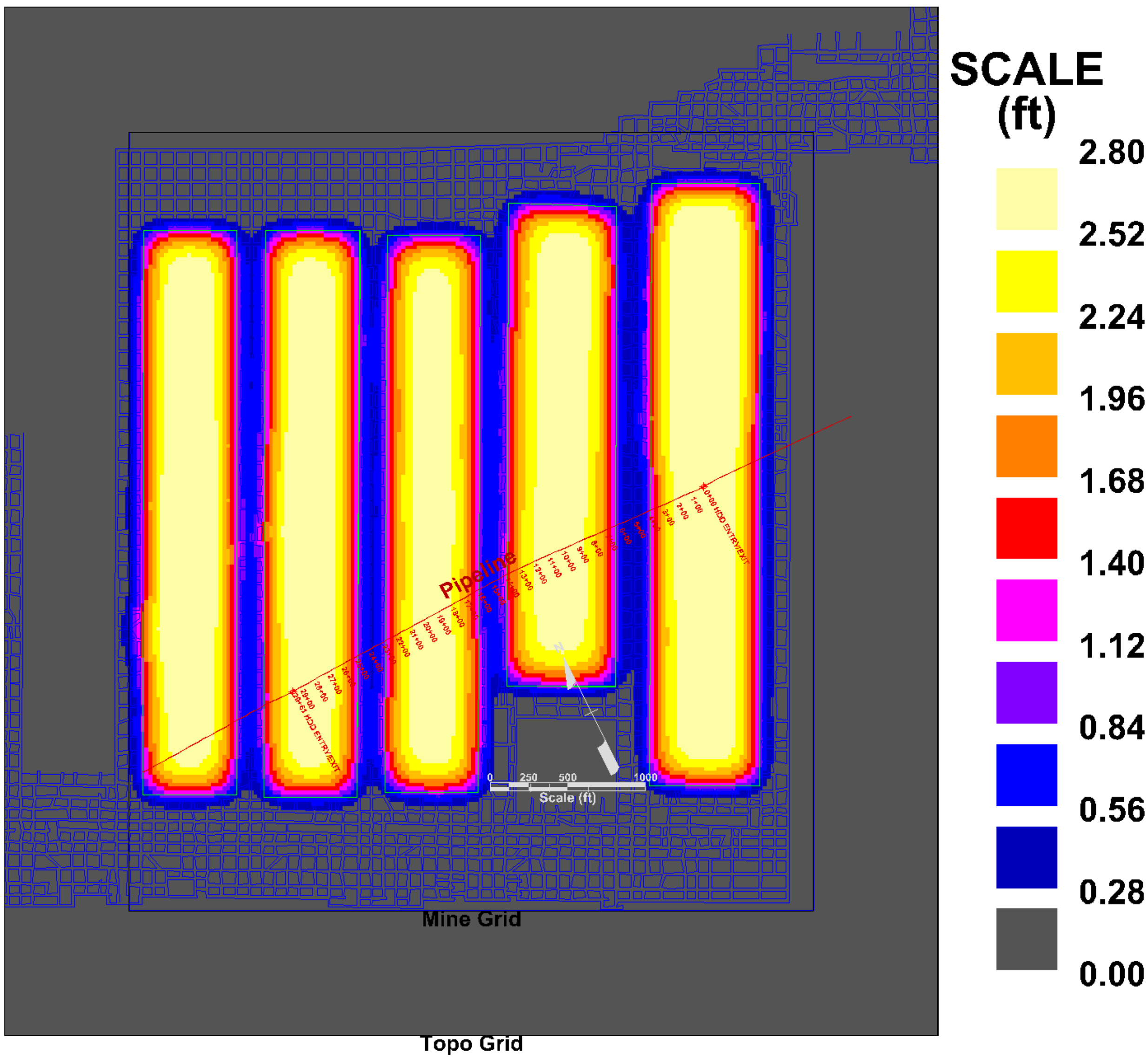

Figure 5. Subsidence at the pipeline for 900 psi coal strength.

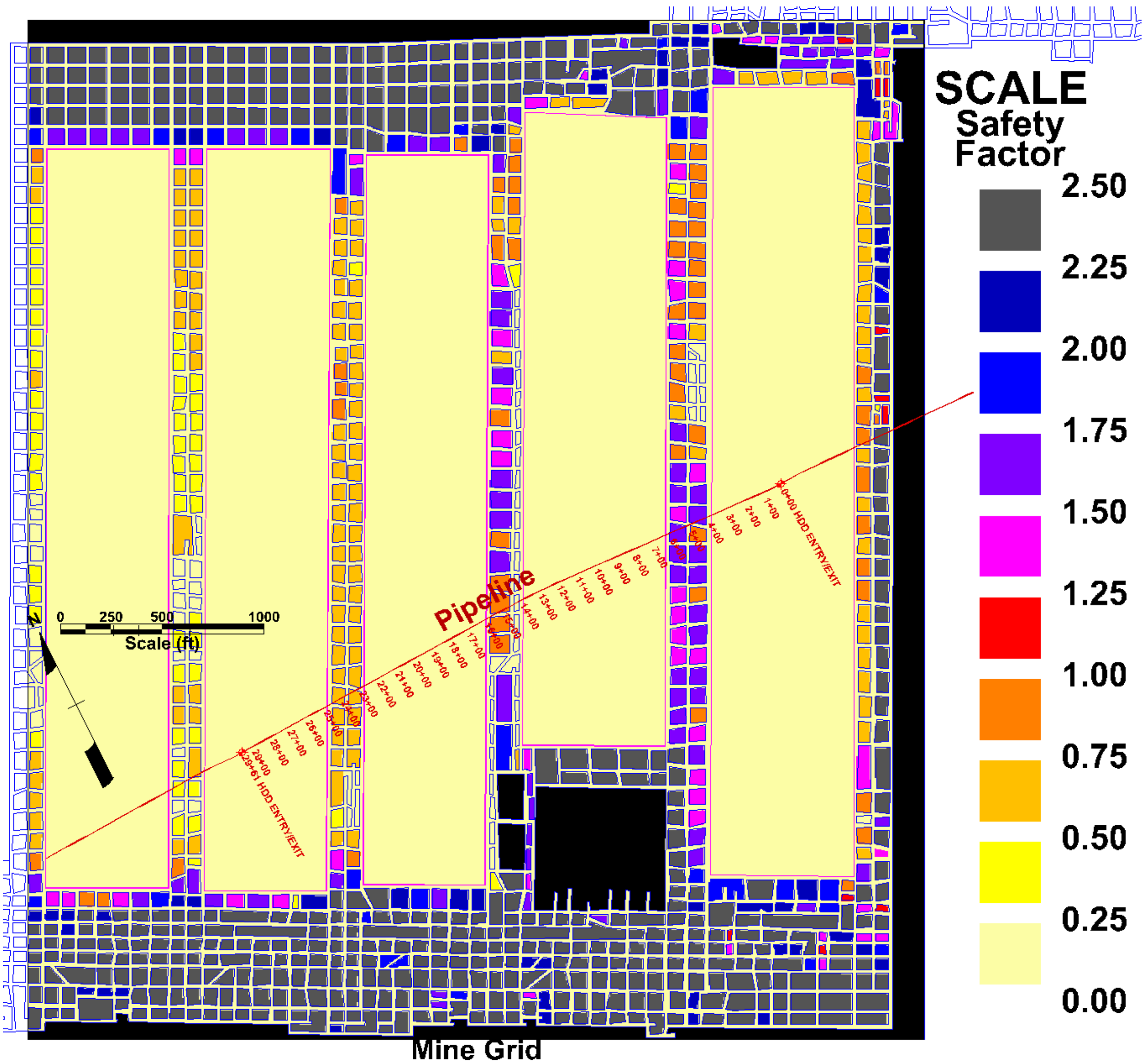

Figure 7. Pillar safety factor with 750 psi coal strength.

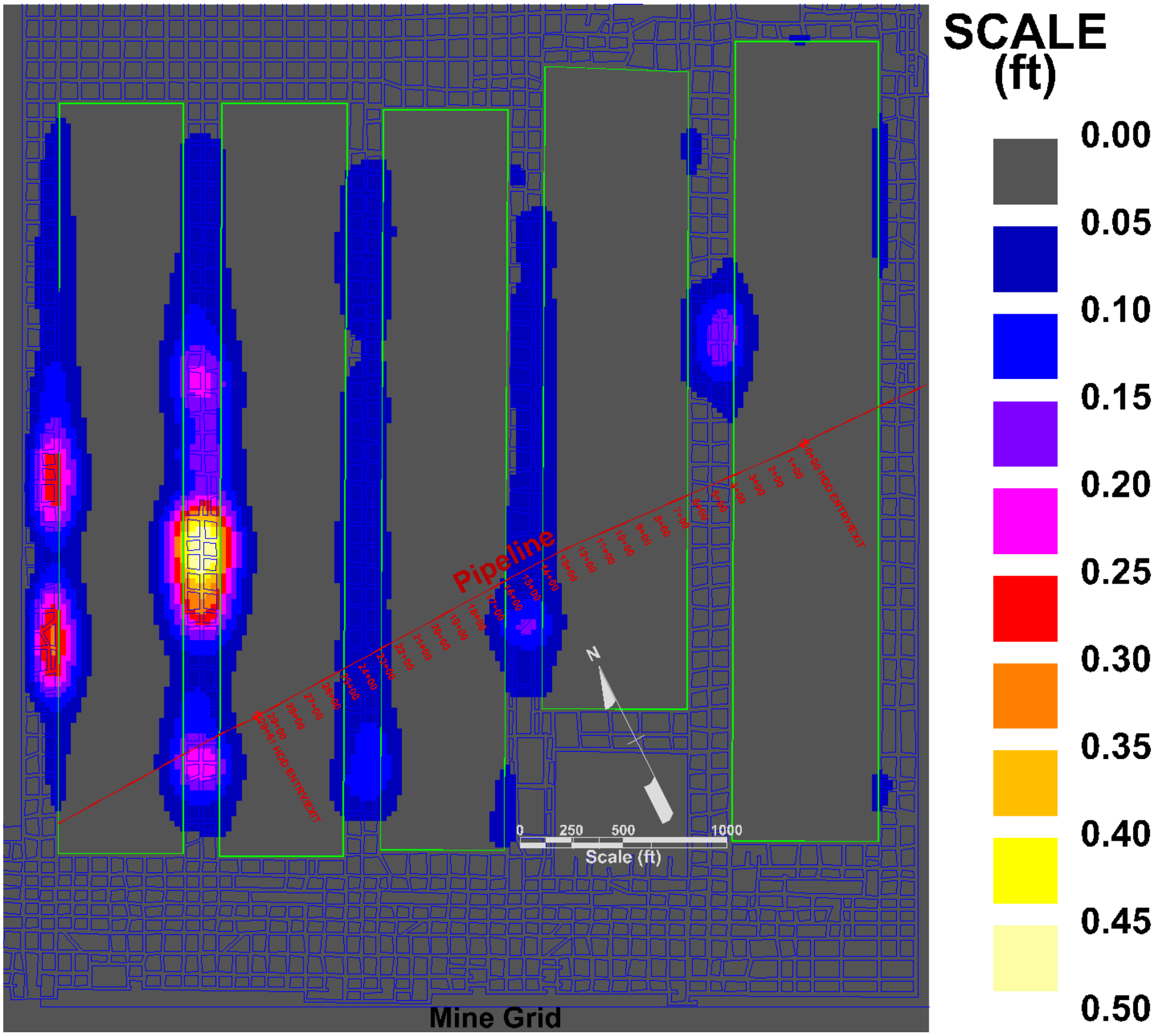

Figure 8. Increase in subsidence going from 900 psi coal to 750 psi coal.

APPENDIX B

Dr. Schissler ALPS Pillar Evaluation

Spinner Site Pillar Analysis

The Spinner Road Pipeline is projected to be installed over a longwall coal mine with underground works mined 1988 to 1992. The pipeline traverses 4 longwall panels that are mined out and three sets of entries, called gateroads, that used to access the longwall face as it extracts the coal. The ground stability between the pipeline and the coal mine works below are dependent on two conditions: 1) that coal mine settlement, called mine subsidence, has ceased or is within pipeline design criteria, is finished, and 2) remaining pillars in the coal mine are not prone to post-mining failure which could cause settlement.

Surface subsidence has been measured to begin when the longwall face is 1.0 X the seam depth behind the surface point of interest. Subsidence reaches approximately 7% of its final value when the face is directly under the interest point. Subsidence achieves 97% of its ultimate value when the longwall is 1.2 times the seam depth. Further subsidence from 97% to 100% of final value is time dependent caused by the rate of gob compaction. Gob is the term for the broken rock that caves into the mine void (Peng 1992). Using the British Coal Board empirical method of predicting maximum surface subsidence for the Spinner site given a panel width of 600 ft and the shallowest depth to the coal seam of 747 ft yields maximum subsidence in the center of the longwall panels of 2.9 ft. If 3% of the subsidence remains, that would equal 3% of 2.9 ft or 0.09 ft (1.1 inches). The British Coal Board (1995) offers a nomogram that when the Spinner Road site is applied yields a time of approximately 1 year for final subsidence to be achieved for a single panel. Spinner Road is a multiple panel site and sufficient time has elapsed for final subsidence to occur. (Other studies performed in the US have yield subsidence taking up to 5 years to finalize, still within the idle time for the Spinner site.

The risk of post-mining pillar failure was analyzed using the Revised ALPS (Analysis of Longwall Pillar Stability) method. ALPS first promulgated in 1990 and revised several times has received wide following due to its accuracy and reliability for use in mine design. The Spinner site intercepts 3 gateroads (Figure 1). ALPS was applied to assess the strength of the pillar against the load demanded.

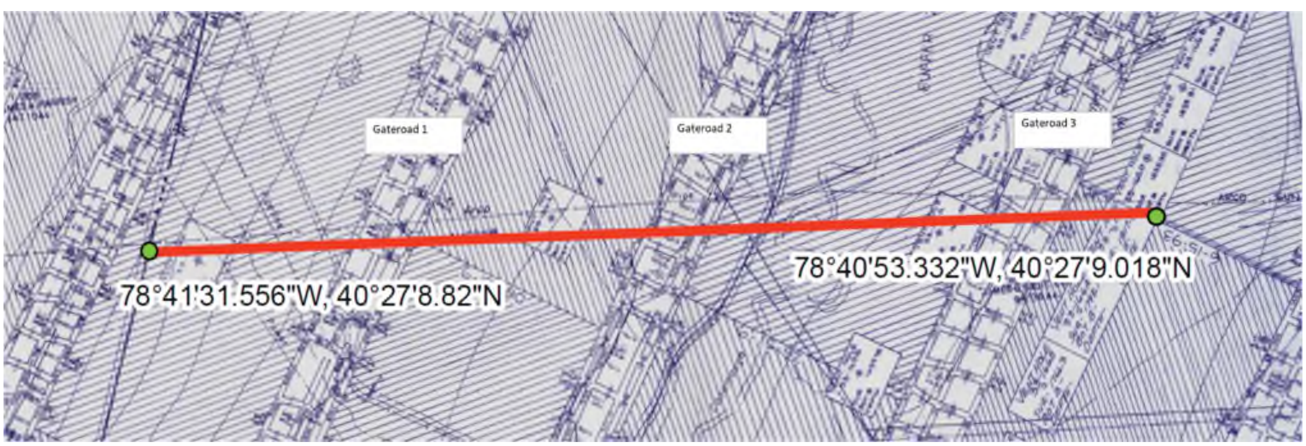

Figure 1. Spinner site pipeline traversing over 3 gateroads.

Pillar strength in mass is a direct result of the coal strength by specimen. The subject has been studied exhaustively, and it has been concluded that coal seams in Appalachia have a strength of 900 psi. Deterioration caused by in-mine water and oxidation can weaken the coal to 750 psi. These two parameters were analyzed in the ALPS method to estimate pillar coal strength. The load demanded on the pillars increases episodically coinciding with the stage of mining. The input and results in applying ALPS is shown in Table 1. Note pillar dimensions used are center to center.

Inputs	Gateroad 1 900 psi case	Gateroad 1 750 psi case	Gateroad 2 900 psi case	Gateroad 2 750 psi case	Gateroad 3 900 psi case	Gateroad 3 750 psi case
Depth of cover, ft	884	884	747	747	755	755
Mining height, ft	4.5	4.5	4.5	4.5	4.5	4.5
Entry width, ft	19	19	19	19	19	19
Pillar width #1, #2, center to center, ft	80,80	80,80	120,40	120,40	95,95	95,95
Crosscut spacing, center to center, ft	100	100	100	100	100	100
Panel width, ft	600	600	600	600	700	700
Coal strength, psi	900	750	900	750	900	750
Stability Factors (strength / load)						
Development Loading: tributary area loading	3.42	2.85	4.59	3.82	4.14	3.95
Headgate Loading: development load + 1 front abutment	2.31	1.92	3.22	2.68	3.45	2.87
Bleeder Loading: development load + 1 side abutment	1.74	1.45	2.48	2.06	2.71	2.26
Tailgate Loading: development + 1 side + 2nd front abutment	1.23	1.03	1.82	1.51	2.07	1.72
Isolated Loading: development load + 2 side abutments	1.11	0.92	1.64	1.37	1.88	1.57

The target for minimum pillar stability factor is 1.3 or greater. This is a parameter validated by back analyzing actual mine cases histories. In all 900 psi-strength cases, the gateroad pillar systems have adequate stability factors except for Gateroad system 1 where the two highest load demand cases show 1.11 and a 0.92 stability factor. The 750 psi cases show more instability than 900 psi coal strength. Gateroad 1 and its associated longwall panel were mined before gateroads 2 and 3. As the mine may have changed design to increase pillar strength. The ALPS method shows increasing strength chronologically coinciding with the changed pillar geometry for the 3 gateroads. Gateroad 2 contains a 2-pillar combination called a stiff yield pillar whereas Gateroads 1 and 3 have two stiff pillars. A yield pillar in mining is design to fail which de-stresses the active face. The total load demanded on the 2-pillar system in Gateroad 2 is approximately 48.9 million lbs. per ft of length along the pillar system. The yield pillar in and of itself has a strength of 4.2 million lbs. per ft of length. Given these conditions, the yield pillar has failed as designed during mining. Based on observed coal conditions at outcrops that have been exposed to air over time, and known effects of water weakening shale and clay rock, the coal strength in the Spinner Road site has probably decreased in strength since mining.

<u>References</u>

Mehnert, Brenda B. and Dan J. Van Rosendaal, Robert A. Bauer. “Long-term Subsidence Monitoring Over a Longwall Coal Mine in Southern Illinois.” In proceedings of 3rd Subsidence Workshop due to Underground Mining.

Mining Department, National Coal board. Subsidence Engineers’ Handbook. National Coal Board, London, 1975.

NIOSH. Analysis of Longwall Pillar Stability. NIOSH, Pittsburgh, August 2013 last revision.

Peng, Syd S. Surface Subsidence Engineering. Society for Mining, Metallurgy, and Exploration Inc., Centennial CO, 1992.

Schissler, Andrew, and S. Badr, M.D.G. Salamon, and U. Ozbay. “Yield Pillar Design at Depth Based on Review of Case Histories.” Society for Mining, Metallurgy, and Exploration Inc., Preprint 03-110, 2003 SME Annual Meeting.

SPINNER ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E11-352
PA-CA-0069.0000-RD
(SPLP HDD No. S2-0080)

ATTACHMENT 3

LANDOWNER COMMUNICATIONS

SUNOCO PIPELINE
An ENERGY TRANSFER Partnership

P. O. Box 2218
Altoona, PA 16602

October 30, 2017

BY CERTIFIED AND FIRST CLASS MAIL
[redacted]

Re: Mariner East 2 – Pennsylvania Pipeline Project
Horizontal Directional Drilling Construction Notification
and Private Water Supply/Well Sampling Offer

To whom it may concern:

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Thank you for your cooperation.

Mark McConnell

Mark McConnell
Land Project Manager
Representing Sunoco Pipeline L.P.
Office: (814) 204-0450

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SUNOCO PIPELINE
An ENERGY TRANSFER Partnership

P. O. Box 2218
Altoona, PA 16602

October 30, 2017

BY CERTIFIED AND FIRST CLASS MAIL

[redacted]

Re: Mariner East 2 – Pennsylvania Pipeline Project
Horizontal Directional Drilling Construction Notification
and Private Water Supply/Well Sampling Offer

Dear [redacted]:

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Thank you for your cooperation.

Mark McConnell
Land Project Manager
Representing Sunoco Pipeline L.P.
Office: (814) 204-0450

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An ENERGY TRANSFER Partnership

P. O. Box 2218
Altoona, PA 16602

October 30, 2017

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P. O. Box 2218
Altoona, PA 16602

October 30, 2017

BY CERTIFIED AND FIRST CLASS MAIL

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1. Article Addressed to:

2. Article Number *(Transfer from service label)*

COMPLETE THIS SECTION ON DELIVERY

A. Signature: *(☐ Addressee or ☐ Agent)*

X

B. Received By: *(Printed Name)*

C. Date of Delivery

D. Is delivery address different from item 1? ☐ Yes
If YES, enter delivery address below: ☐ No

3. Service Type

PS Form 3811 Facsimile, July 2015 (SDC 3930)

Domestic Return Receipt

CERTIFIED MAIL

VOID

B
Certified Mail
WITH Physical Return Receipt Service
(Uses Return Receipt Card)
Instructions
1. Apply address label above to the back of this card.
2. Apply this card to the TOP EDGE of the mailpiece.
3. Peel the Certified Mail label above and fold it over your envelope, just above the postage so that it covers the existing Certified Mail marking.

Covered by and/or for use with U.S. Patents 6,244,763; 6,868,406; 7,216,110; 7,236,956; 7,236,970; 7,490,065; 7,567,940; 7,613,639; 7,743,043; 7,882,094; 8,027,926; 8,027,927; 8,027,935; 8,041,644; 8,046,823; 8,103,647; 8,195,579; 8,301,572; 8,392,391; 8,498,943 and 8,843,464.

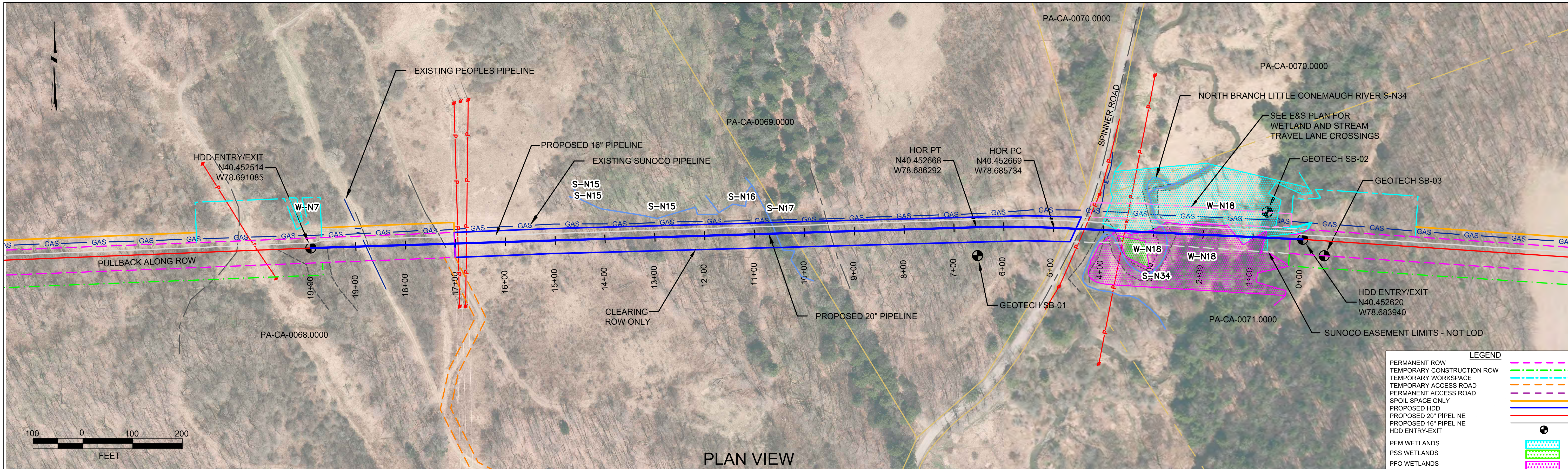
stamps.com

★1-UP Laser Form★
★USA CMF - 134 04/17★

SPINNER ROAD CROSSING
PADEP SECTION 105 PERMIT NO.: E11-352
PA-CA-0069.0000-RD
(SPLP HDD No. S2-0080)

ATTACHMENT 4

ORIGINAL AND REVISED HORIZONTAL DIRECTIONAL DRILL PLAN AND PROFILES



PLAN VIEW

CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080

PROFILE VIEW

GEOTECH SB-01

- NG EL. 1712'
- TOPSOIL (0' - 0.3')
- CL/MH (0.3' - 6.5')
- SM/SC (6.5' - 18.5')
- SHALE (18.5' - 24.5')
- COMPLETION DEPTH EL. 1687'

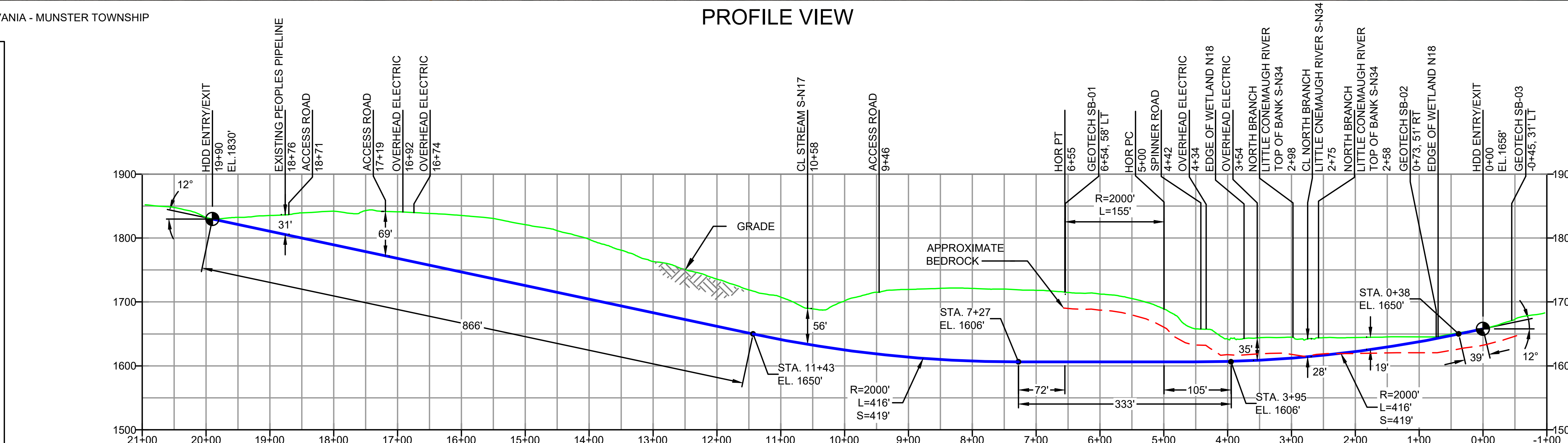
GEOTECH SB-02

- NG EL. 1646'
- TOPSOIL (0' - 0.1')
- GROUNDWATER (4.6')
- SM (0.1' - 21.0')
- SC/GC (21.0' - 24.0')
- SANDSTONE (24.0' - 26.2')
- COMPLETION DEPTH EL. 1620'

GEOTECH SB-03

- NG EL. 1673'
- TOPSOIL (0' - 0.1')
- SM (0.1' - 14.5')
- LIMESTONE (14.5' - 15.2')
- COMPLETION DEPTH EL. 1620'

NOTE: REFER TO TEST BORING LOG S2-0080 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):1990'
   HDD PIPE LENGTH (S=):2076'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 1. Original 20-Inch HDD Plan and Profile

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	09/30/16	RMB	09/30/16	AAW	09/30/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		JTW	03/15/16	RMB	03/15/16	AAW	03/15/16
C	ADDED GEOTECH INFO	MRS	09/06/15	RMB	09/06/15	AAW	09/06/15
B	ISSUED FOR BID	MRS	07/31/15	DLM	07/31/15	AAW	07/31/15
A	ISSUED FOR REVIEW	RTT	03/27/15	RMB	03/27/15	AAW	03/27/15

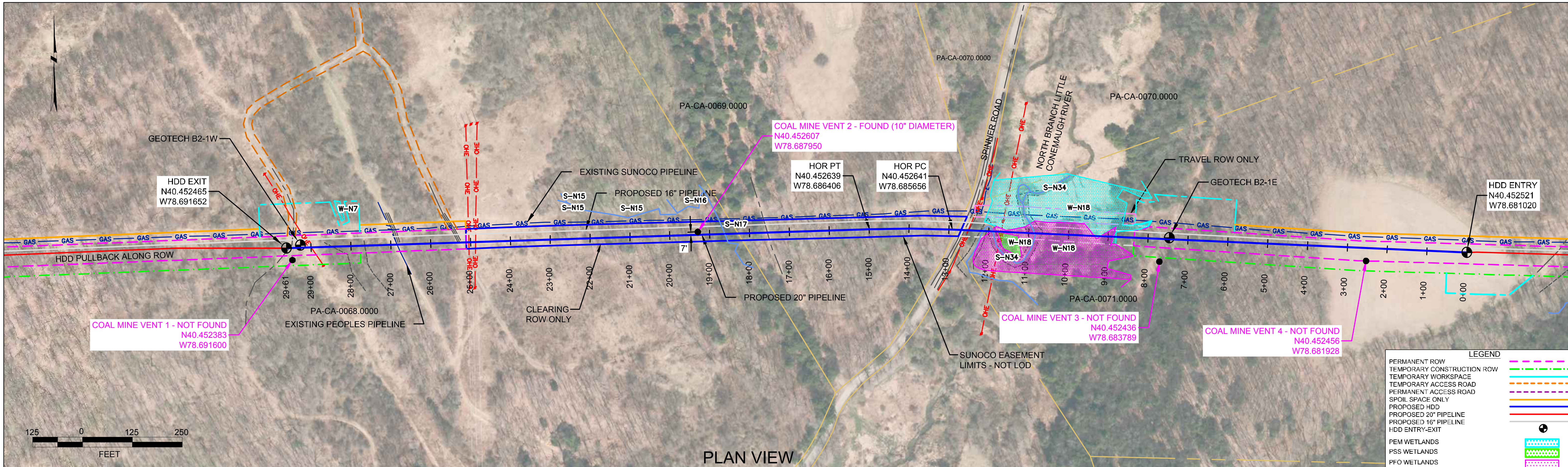
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

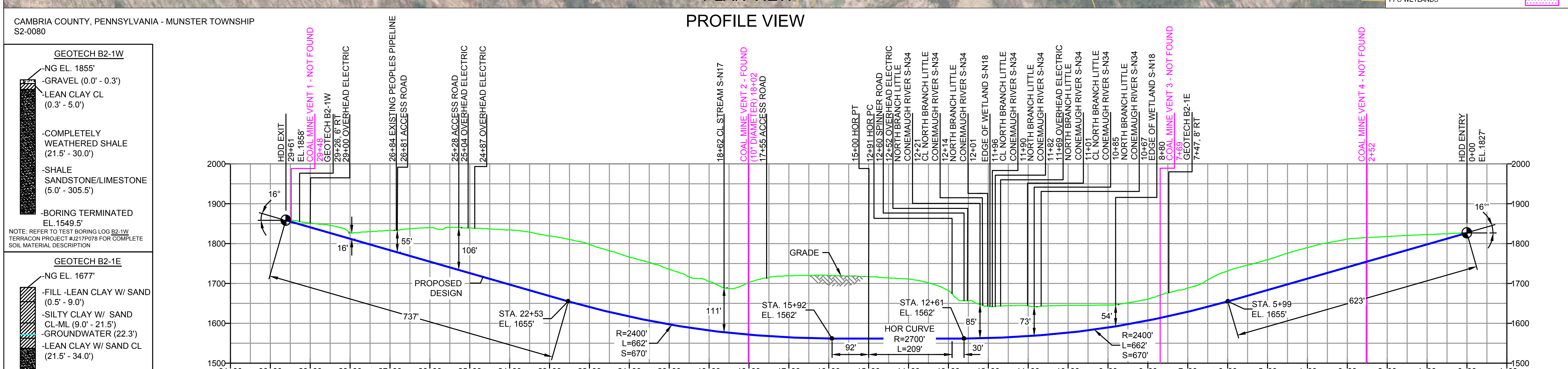
SUNOCO PIPELINE, L.P.

20-INCH HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' DWG. NO: PA-CA-0069.0000-RD



CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2961'
   HDD PIPE LENGTH (S=):3031'
   20" x 0.456" W.T., X-65, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. PILOT HOLE SHALL BE COMPLETED USING THE INTERCEPT METHOD CONSISTING OF TWO PILOT HOLES DRILLING FROM BOTH SIDES OF THE DRILL.

Figure 2. Revised 20-Inch HDD Plan and Profile

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP7	DRILL DESIGN LENGTHENED PER CLIENTS REQUEST	MRS	04/06/18	RMB	04/06/18	CAG	04/06/18
EP6	ADDED COAL MINE VENT LOCATIONS	MRS	01/29/18	RMB	01/29/18	CAG	01/29/18
EP5	UPDATED GEOTECH BORE ELEVATION INFO PROVIDED BY DPS	MRS	11/28/17	RMB	11/28/17	CAG	11/28/17
EP4	UPDATED GEOTECH INFO PROVIDED BY DPS	MRS	11/14/17	RMB	11/14/17	CAG	11/14/17
EP3	RELOCATED HDD ENTRY / EXIT POINTS - DESIGN CHANGE BY DPS	MRS	11/07/17	RMB	11/07/17	CAG	11/07/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	MRS	09/30/16	RMB	09/30/16	AAW	09/30/16

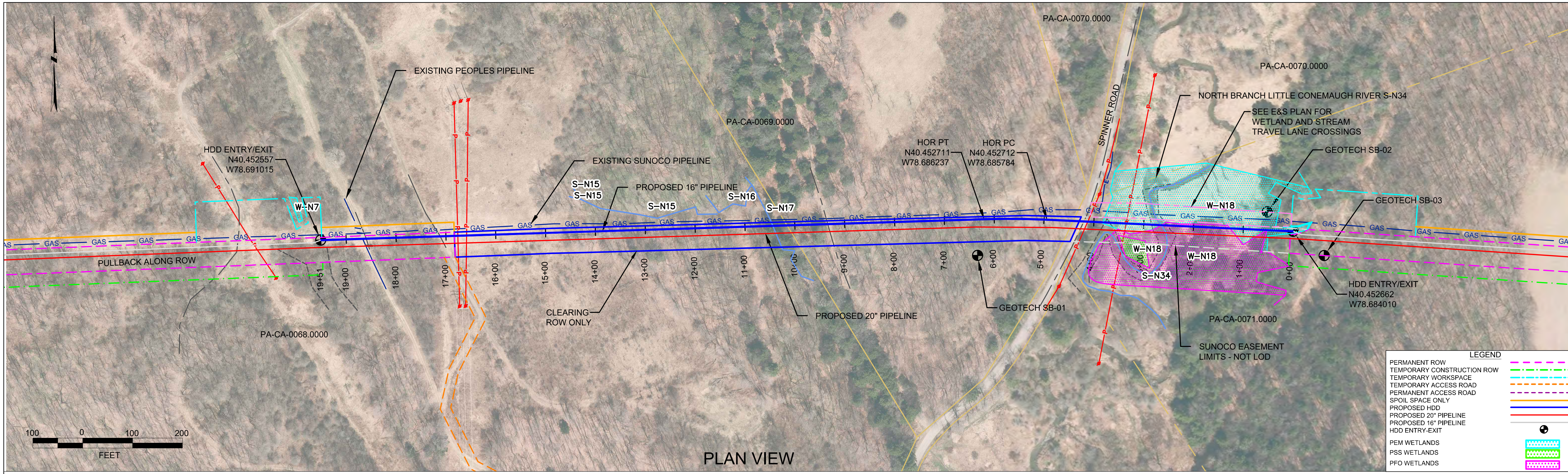
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792–5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250' DWG. NUMBER: PA-CA-0069.0000-RD



CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080-16

GEOTECH SB-01

- NG EL. 1712'
- TOPSOIL (0' - 0.3')
- CL/MH (0.3' - 6.5')
- SM/SC (6.5' - 18.5')
- SHALE (18.5' - 24.5')
- COMPLETION DEPTH EL. 1687'

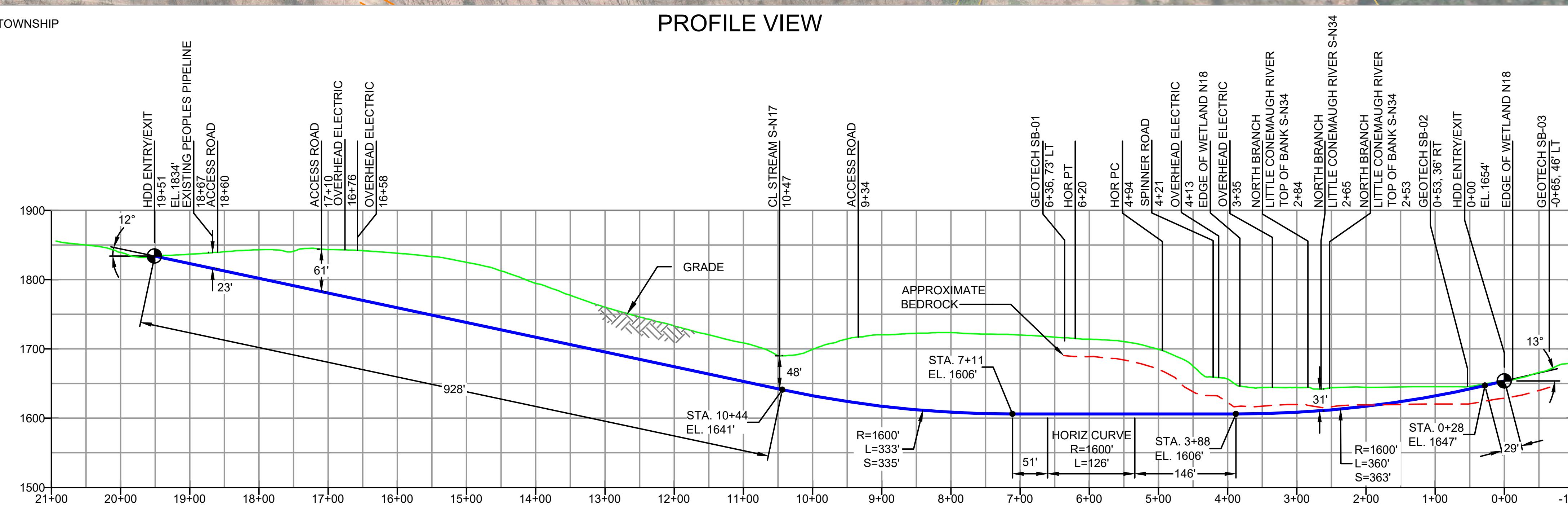
GEOTECH SB-02

- NG EL. 1646'
- TOPSOIL (0' - 0.1')
- GROUNDWATER (4.6')
- SM (0.1' - 21.0')
- SC/GC (21.0' - 24.0')
- SANDSTONE (24.0' - 26.2')
- COMPLETION DEPTH EL. 1620'

GEOTECH SB-03

- NG EL. 1673'
- TOPSOIL (0' - 0.1')
- SM (0.1' - 14.5')
- LIMESTONE (14.5' - 15.2')
- COMPLETION DEPTH EL. 1620'

NOTE: REFER TO TEST BORING LOG S2-0080 FOR COMPLETE SOIL MATERIAL DESCRIPTION



DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXITING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=): 1951'
   HDD PIPE LENGTH (S=): 1978'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE R95)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGN FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. SUNOCO PIPELINE, L.P.'S HORIZONTAL DIRECTIONAL DRILL INADVERTENT RETURN CONTINGENCY PLAN WILL BE IMPLEMENTED AT ALL TIMES.
13. SUNOCO PIPELINE, L.P.'S EROSION AND SEDIMENTATION CONTROL PLAN WILL BE IMPLEMENTED AT ALL TIMES.

Figure 3. Original 16-Inch HDD Plan and Profile

NOTES

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

REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/18/16	RMB	05/18/16	AAW	05/18/16
EP		JTW	03/15/16	RMB	03/15/16	AAW	03/15/16
B	ADDED GEOTECH INFO	MRS	09/06/15	RMB	09/06/15	AAW	09/06/15
A	ISSUED FOR BID	MRS	08/31/15	RMB	08/31/15	AAW	03/27/15

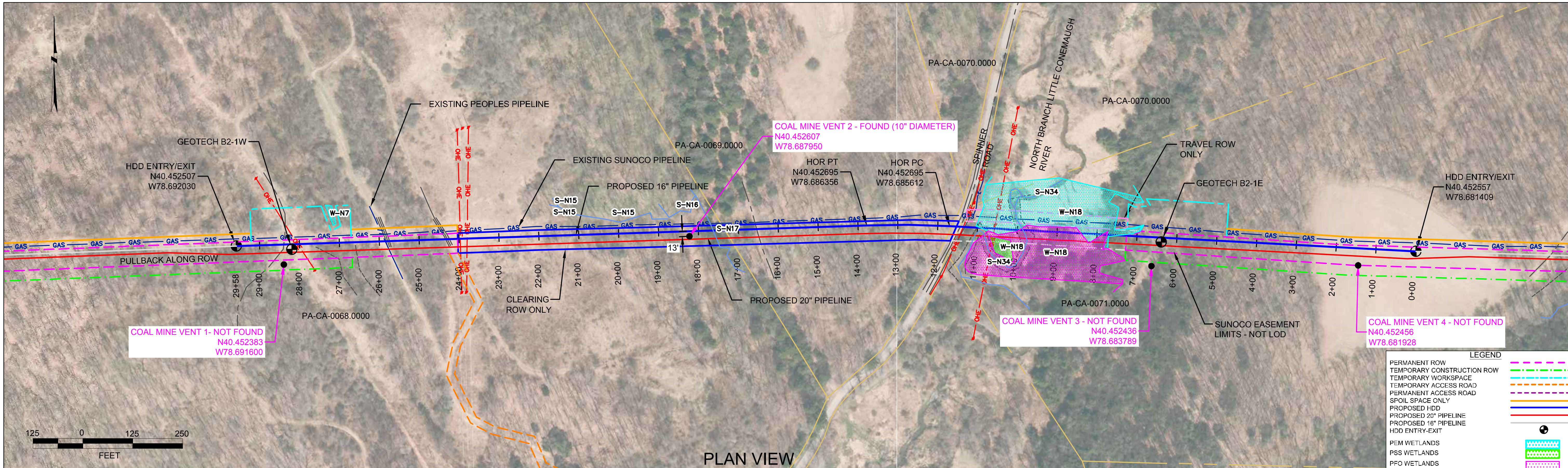
Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

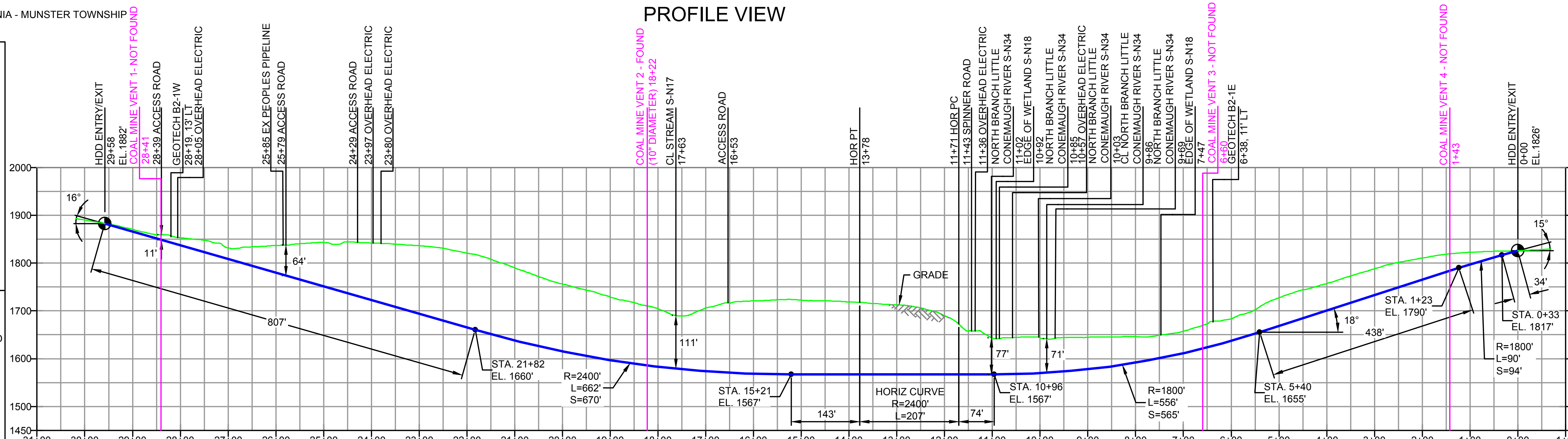
16-INCH HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=200' | DWG. NO: PA-CA-0069.0000-RD-16



CAMBRIA COUNTY, PENNSYLVANIA - MUNSTER TOWNSHIP
S2-0080-16

PROFILE VIEW



GEOTECH B2-1W

- NG EL. 1855'
- GRAVEL (0.0' - 0.3')
- LEAN CLAY CL (0.3' - 5.0')
- COMPLETELY WEATHERED SHALE (21.5' - 30.0')
- SHALE SANDSTONE/LIMESTONE (5.0' - 305.5')
- BORING TERMINATED EL.1549.5'

NOTE: REFER TO TEST BORING LOG B2-1W TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

GEOTECH B2-1E

- NG EL. 1677'
- FILL -LEAN CLAY W/ SAND (0.5' - 9.0')
- SILTY CLAY W/ SAND CL-ML (9.0' - 21.5')
- GROUNDWATER (22.3')
- LEAN CLAY W/ SAND CL (21.5' - 34.0')
- SILTSTONE/MUDSTONE (34.0' - 102.5')
- BORING TERMINATED EL.1554.5'

NOTE: REFER TO TEST BORING LOG B2-1E TERRACON PROJECT #J217P078 FOR COMPLETE SOIL MATERIAL DESCRIPTION

DESIGN AND CONSTRUCTION:

1. CONTRACTOR SHALL FIELD VERIFY DEPTH OF ALL EXISTING UTILITIES SHOWN OR NOT SHOWN ON THIS DRAWING.
2. THE MINIMUM SEPARATION DISTANCE FROM EXISTING SUBSURFACE UTILITIES SHALL NOT BE LESS THAN 10 FEET AS MEASURED FROM THE OUTSIDE EDGE OF THE UTILITY TO OUTSIDE OF PROPOSED PIPELINE.
3. DESIGNED IN ACCORDANCE WITH CFR 49 195 & ASME B31.4
4. CROSSING PIPE SPECIFICATION:
   HDD HORZ. LENGTH (L=):2958'
   HDD PIPE LENGTH (S=):3032'
   16" x 0.438" W.T., X-70, API5L, PSL2, ERW, BFW
   COATING: 14-16 MILS FBE WITH 30-35 MIL ARO (POWERCRETE OR ENGINEER APPROVED EQUAL)
5. INTERNAL DESIGN PRESSURE 1480 PSIG (SEAM FACTOR 1.0, DESIGH FACTOR 0.50).
6. INSTALLATION METHOD: HORIZONTAL DIRECTIONAL DRILL (HDD).
7. PIPELINE WARNING MARKERS SHALL BE INSTALLED ON BOTH SIDES OF ALL ROAD, RAILWAY, AND STREAM CROSSINGS.
8. CARRIER PIPE NOT ENCASED.
9. PIPE / AMBIENT TEMPERATURE MUST BE NO LESS THAN 30°F DURING PULLBACK WITHOUT PRIOR WRITTEN APPROVAL FROM THE ENGINEER.
10. CONDUCT 4-HOUR PRE-INSTALLATION HYDROTEST OF HDD PIPE STRING TO MINIMUM 1850 PSIG.
11. SEE SUNOCO PENNSYLVANIA PIPELINE PROJECT ESRI WEBMAP FOR ACCESS ROAD ALIGNMENT.
12. PILOT HOLE SHALL BE COMPLETED USING THE INTERCEPT METHOD CONSISTING OF TWO PILOT HOLES DRILLING FROM BOTH SIDES OF THE DRILL.

Figure 4. Revised 16-Inch HDD Plan and Profile

NOTES

1. ALL COORDINATES SHOWN ARE IN LATITUDE AND LONGITUDE. ALL MSL ELEVATIONS ARE NAD83
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REF. DRAWING

DWG NO		DWG NO	DESCRIPTION
ES-2.47	TO	ES-2.48	EROSION & SEDIMENT PLAN
SHEET 29	TO	SHEET 30	AERIAL SITE PLAN

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK	DATE	APP	DATE
EP6	ADDED COAL MINE VENT LOCATIONS	MRS	01/29/18	RMB	01/29/18	CAG	01/29/18
EP5	UPDATED GEOTECH BORE ELEVATION INFO PROVIDED BY DPS	MRS	11/28/17	RMB	11/28/17	CAG	11/28/17
EP4	UPDATED GEOTECH INFO PROVIDED BY DPS	MRS	11/14/17	RMB	11/14/17	CAG	11/14/17
EP3	RELOCATED HDD ENTRY / EXIT POINTS - DESIGN CHANGE BY DPS	MRS	11/07/17	RMB	11/07/17	CAG	11/07/17
EP2	REVISED PER PADEP COMMENTS RECEIVED 09-06-16	DLM	10/07/16	RMB	10/07/16	AAW	10/07/16
EP1	REVISED PER PADEP COMMENTS	JTW	05/18/16	RMB	05/18/16	AAW	05/18/16

Sunoco Logistics Partners L.P.

TETRA TECH ROONEY
(303) 792-5911

SUNOCO PIPELINE, L.P.

HORIZONTAL DIRECTIONAL DRILL
SPINNER ROAD
PENNSYLVANIA PIPELINE PROJECT

SCALE: 1"=250'
DWG. NO. PA-CA-0069.0000-RD-16