

Void Mitigation Plan for Karst Terrain and Underground Mining

Pennsylvania Pipeline Project

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VOID MITIGATION PLAN FOR KARST TERRAIN AND UNDERGROUND MINING PENNSYLVANIA PIPELINE PROJECT

1.0 PROJECT DESCRIPTION

Sunoco Pipeline L.P. (SPLP) proposes to construct and operate the Pennsylvania Pipeline Project (Project or PPP) that would expand existing pipeline systems to provide natural gas liquid (NGL) transportation. The Project involves the installation of two parallel pipelines within an approximately 306.8-mile, 50-foot-wide right-of-way (ROW) from Houston, Washington County, Pennsylvania to SPLP's Marcus Hook facility in Delaware County, Pennsylvania with the purpose of interconnecting with existing SPLP Mariner East pipelines. A 20-inch diameter pipeline will be installed within the ROW from Houston to Marcus Hook (306.8 miles) and a second, 16-inch diameter pipeline, will also be installed in the same ROW. The second line is proposed to be installed from SPLP's Delmont Station, Westmoreland County, Pennsylvania to the Marcus Hook facility, paralleling the initial line for approximately 255.8 miles. For a detailed Project Description see Attachment 9 of the Project's Chapter 105 Joint Application for Permit.

2.0 SURFACE AND GROUNDWATER PROTECTION PLANS

SPLP has developed four plans that accompany the Erosion & Sedimentation Plan (E&S Plan) that are designed to assess the potential impacts and provide for the protection of surface and groundwater from contamination due to project activities, summarized below:

- Prevention, Preparedness, and Contingency Plan (PPC Plan) – Overarching plan designed to address spill prevention in general, and potential impacts to surface waters and public and private water supplies. Includes two supplemental plans, Water Supply Assessment, Prevention, Preparedness, and Contingency Plan (Water Supply Plan) and Inadvertent Return Assessment, Prevention, Preparedness, and Contingency Plan (IR Plan).
- Water Supply Plan – Provides for the assessment of the existing environment in terms of public and private water supplies in or along the project areas and impacted waters, as well as the prevention and preparedness measures to be implemented to protect those supplies.
- IR Plan – Outlines the preconstruction activities implemented to ensure sound geological features are included in the HDD profile, the measures to prevent impact, and the preparedness plan if an impact were to occur.
- Void Mitigation Plan for Karst Terrain and Underground Mining (Karst Plan) – Provided as part of the E&S Plan and provides an assessment of potential impacts and avoidance and mitigation measures that could occur during open-cut and drilling procedures.

The purpose of these plans is to protect surface and groundwater resources project-wide. The PPC Plan is provided as Attachment 12A of the Project's Chapter 105 Joint Application for Permit, and the Water Supply Plan as Attachment 12B, the IR Plan as Attachment 12C, and this Karst Plan as Attachment 12D.

3.0 KARST PLAN PURPOSE

Subsidence is sinking of a landform to a lower level as a result of earth movement, structural loading at or near ground surface, geologic conditions resulting in lowering of

the surface, or mining operations. Subsidence is a potential geologic hazard especially in areas of karst terrain or where underground mining has occurred. Karst terrain forms from dissolution of soluble rocks such as limestone, dolomite, and gypsum. It is generally characterized by topographic depressions at the surface or as subsurface channels, caves, and/or sinkholes. Groundwater aquifers within karst regions can be significantly impacted as a result of their formation. Karst aquifers can be very productive and are used for water supply in Pennsylvania.

Private and public water supply sources from groundwater wells are located along and/or downstream of proposed work areas. Encounters with subsurface voids by the Project activities could potentially impact groundwater resources, if the voids connect to the aquifer or transmit water through the aquifer. However, as detailed in the Water Supply Plan, SPLP has avoided direct impacts to all private water wells. In addition to the information gained from the landowners, SPLP utilized the Pennsylvania Groundwater Information System (PAGWIS) data to identify 22 approximate water well locations within 150 feet of all HDD alignments, including parcels that would be adjacent to, but not directly crossed by the Project. The distance of 150 feet was used based on Federal Energy Regulatory Commission (FERC) guidelines for identification of water wells in the vicinity of their authorized projects. The locations of these wells are kept within the Project files and are not displayed here to protect the rights of the individual owners. Although the PAGWIS data is made available to the public, the accuracy as stated within the metadata is not reliable and what SPLP has or will obtain represents exact well locations. Public water supply areas within one mile of the Project were identified by evaluating all available water supply data obtained from PADEP's eMapPA platform. The analysis resulted in the identification of 50 PWS areas within the 1.0mile buffer. In these correspondences, SPLP requested the locations of the authority's PWS groundwater well and/or surface intakes as well as an assessment of potential impacts. Many authorities did not provide intake locations, but did inform SPLP that impacts were not anticipated.

This Karst Plan addresses mitigation of voids that could be encountered during installation of proposed pipeline in karst-prone areas and historical underground mining operations. This Karst Plan includes mitigation during conventional pipe installation, boring, and horizontal directional drilling (HDD).

4.0 EXISTING ENVIRONMENT AND POTENTIAL PROJECT IMPACTS IN KARST GEOLOGY

Data and information regarding potential karst and abandoned mining locations were compiled and evaluated from the following sources and reports:

- Background literature research of state databases;
- Geographical Information System (GIS) data from the Commonwealth of Pennsylvania, displaying polygons of abandoned mines and karst features;
- Potential karst and mining areas summarized per land parcel (Appendix A);
- Results from the geotechnical subsurface investigation program at all HDD locations within areas containing carbonate rocks, including field observations during advancement of soil and rock borings, laboratory testing of collected representative soil and bedrock samples, review of regional geology, and provision of summary reports of findings;
- Geophysical investigations at areas of known sinkholes within the right of way (ROW) (Appendix C).

4.1 Karst in Pennsylvania

Environmental and engineering problems can arise in areas where natural geologic substrates (i.e. carbonate rock) are subject to solution and erosion, which can generate voids in the subsurface and associated subsidence. Such areas are collectively known as karst. The development of karst is primarily dependent on the presence of soluble rocks such as limestone, dolomite or gypsum. Karst terrain is characterized by disappearing streams, springs, caves, sinkholes, and productive aquifers. Sinkholes and surface depressions form as a result of water transporting residual material and soil through subsurface pathways established by the dissolution process. Both features are typically circular in shape and can vary in size. Sinkholes exhibit an actual break or hole on the land surface, whereas surface depressions are generally bowl-shaped hollows that do not show this land-surface break. Caves are formed as fractures widen by dissolution, creating large openings in the rocks (PADCNr 2015).

Karst aquifers are important sources of groundwater in Pennsylvania for commercial and domestic use and may be contaminated where sinkholes or karst solution openings are present at, or near ground surface. Karst aquifer systems have very low self-purification or filtering capabilities which makes karst groundwater susceptible to impact from erosion of surface materials, surface spills, and surface water runoff (USGS 2014).

Most of the carbonate bedrock occurs in the valleys and lowlands of south-central and southeastern Pennsylvania. Geotechnical and hydrologic attributes that facilitate karst development include the following:

- Low-density limestone/dolomite (low compressibility)
- highly fractured zones with interconnectivity
- flowable water source (surface/subsurface)
- high percentage of calcium carbonate (calcite)

In order to assess the presence of surface/subsurface karst features (voids and fractures) along the project route, a geotechnical boring program was implemented to gather site-specific geologic data along all HDD alignments, and to provide a risk assessment, based on encountered geologic conditions, for each HDD alignment. The boring program identified potential subsurface void space along the original route from Houston, PA through Montello, PA. Supplemental geophysical investigations were performed resulting in a re-route at this location (See Section 4.4 and Appendix C). No evidence of void space was encountered at any other geotechnical boring location within the HDDs. Based on the results of the geotechnical boring program, there is low potential to encounter karst features along the proposed HDD alignments.

4.2 Karst Mapping

Efforts to map karst distribution have normally taken a geology-based approach, delineating areas having potential for karst development by identifying areas of soluble rocks from geologic maps. While this approach is representative of karst potential, a complex interaction of many factors determines the formation, localization, and intensity

of karst development. These include the bedrock type and structure, tectonics, climate, sedimentary cover, vegetation, and local hydrologic conditions. The extent of outcrop of soluble rocks provides an approximation of the distribution of karst and potential karst areas, particularly in parts of the United States with a humid climate (USGS 2014).

The USGS Karst Map for Pennsylvania (Figure 1) shows carbonate rocks that are near or at land surface, and thus contain or are susceptible to the development of karst features. Also in Figure 1, the PPP Centerline Corridor and karst features (identified by PADCNr) are overlain. The karst features coincide with the carbonate rock distribution in the southcentral and southeastern portions of the state. The Project route and workspaces overlap with 32 surface depressions identified in the PADCNr database (PADCNr 2016). Appendix B.1 provides county-scale maps of carbonate rock, karst features, and HDD alignments.

4.3 Karst Aquifer Characteristics

The Project from west to east crosses through the Appalachian Plateau, Valley and Ridge, and Piedmont aquifer systems, all of which contain areas of carbonate rock. General characteristics for the carbonate-rock within these aquifer systems are described below, with details associated with groundwater well data for specific carbonate formations (crossed by the Project) summarized in Table 1.

Appalachian Plateau – In the Appalachian Plateau, extensive, almost flat-lying confining units of shale, siltstone, clay, and dense limestone impede the vertical movement of water. This is especially true of the Pennsylvanian-age rocks, which cover a large part of the area. The aquifers and confining units are not as intensely fractured in the Appalachian Plateau as in the Valley and Ridge. The fractures also decrease in number with depth, and the circulation of water likewise decreases with depth. Most of the Appalachian Plateau lacks the thick, solution-riddled, carbonate-rock aquifers of the Valley and Ridge (USGS 1997). As shown in Table 1, the following averages (median) were determined for the Monongahela Group (mix of sandstone, silt, and limestone) crossed by the route: water level is 35 feet below grade, well depth of 126 feet, casing length of 21 feet, and well yield of 5 gallons per minute (gpm)(PADCNr 2016b).

Valley and Ridge – Most of the more productive aquifers are in carbonate rocks, primarily limestone, and most are in valleys. Although the water-yielding character of the carbonate rocks depends on the degree of fracturing and development of solution cavities in the rock, the limestone formations generally yield moderate to large volumes of water. The sedimentary formations of the Valley and Ridge Province are commonly thick and steeply tilted; thus, a water well usually penetrates only the consolidated rock formation exposed at the surface (USGS 1997). A range of averages (median) were determined for the carbonate formations crossed by the route: water level of 20 to 109 feet below grade, well depth of 104 to 301 feet, casing length of 22 to 94 feet, and well yield of 8 to 90 gallons per minute (gpm)(see Table 1, PADCNr 2016b).

Piedmont – The carbonate rocks of the Piedmont and the Blue Ridge Provinces have virtually no primary permeability or porosity, and water in these rocks moves through secondary openings, such as bedding planes, joints, faults, and other partings, within the rock that have been enlarged by dissolution. In rocks that have a large content of sand, clay, or other noncarbonate minerals, dissolution is inhibited and enlargement of openings might not be extensive. In such rocks, all the water might occur in fracture openings similar to those in unweathered crystalline rocks (USGS 1997). A range of averages (median)

were determined for the carbonate formations crossed by the route: water level of 22 to 26 feet below grade, well depth of 132 to 164 feet, casing length of 40 to 45 feet, and well yield of 17 to 39 gallons per minute (gpm)(see Table 1, PADCNR 2016b).

4.4 Site-Specific Montello Geophysics Review

Seismic refraction and seismic surface-wave geophysical surveys were conducted along proposed alignment and HDD crossings near the Sunoco Montello Terminal, located within an area of documented karst and sinkholes. In addition, soil borings were advanced along survey lines. Borings were advanced by either direct-push technology (DPT) or Standard Penetration Tests (SPT). Purpose of the borings was to compare results from the geophysical investigation to those from collected soil samples in order to correlate soil data with images generated during the geophysical investigation.

Based on information presented in the geophysics report prepared by Advanced Geological Services (AGS) (Appendix C) and subsurface conditions from the geotechnical borings, it does not appear that void spaces are present under the HDD alignments within the areas of the surveys (see map in AGS report). Although areas of low velocity, typically associated with either void spaces or soft soils, were identified during the geophysical survey, voids were not discovered during advancement of the soil borings.

Additional seismic refraction and surface wave geophysical surveys were performed along six survey lines at the Sunoco Montello Terminal to delineate areas of soft soil and potential voids underlying the proposed HDD alignments. For details on the methodology and locations of these surveys, refer to reports prepared by AGS (Appendix C).

After review of results of these investigations, a re-route and conventional design for the pipeline was prepared south of the concentrated area of karst and sinkhole features. Because the general area has a history of sink holes, data acquired during investigations should not be considered representative of the entire area, but only of the areas directly investigated during the study. Geophysical methods applied during the three investigations may be employed if large voids are encountered during pipeline installation.

4.5 Project Impacts

Potential impacts from construction activity (trenching, conventional bore, and HDD) in karst geology are described below. The project proposes 51 HDD and 85 bores through areas of carbonate rocks. Of these, one HDD (PA-CU-0174_0001-RD) overlaps with three clustered surface depressions, and one bore overlaps with one surface depression. The rest of the pipeline would be installed by open cut methods in vicinity to the identified surface depressions. Eighteen HDDs are proposed with the Appalachian Plateau karst aquifer, 29 HDDs are proposed in the Valley and Ridge karst aquifer, and 4 HDDs are proposed within the Piedmont karst aquifer. Results and data obtained from the geotechnical boring program for the HDD alignments are summarized in Appendix B.2, and includes a risk assessment designation based on geotechnical lab tests and field observations. None of the HDDs were determined as high or medium-risk; most of the HDDs were determined as very low-risk; with a small number of low-risk HDDs, as shown in Appendix B.2. Spread 2: locations were all determined as very low probabilities.

The low probabilities assigned to HDD locations in Spreads 3 thru 6 were due to the presence of limestone and the vicinity of surface depressions. However, the drills were designed to be either deep in competent bedrock or above the limestone. Low potentials

are summarized below and the geological information is provided in Appendix B.2:

Spread 3: PA-BL-0122.0000-WX, PA-BL-0125.0000-RD, PA-HU-0020.0008-SR, PA-HU-0019.0002-RD, PA-HU-0078.0000-WX.

Spread 4: PA-CU-0136.0000-RD, PA-CU-0136.0002-WX, PA-CU-0136.0003-RD, PA-CU-0136.0012-RD, PA-CU-0136.0020-RR, PA-CU-0174.0001-RD, PA-CU-0174.0014-RD, PA-CU-0174.0019-RD, PA-CU-0189.0000-RD, PA-DA-0030.0000-RR, PA-DA-0039.0000-RD, and PA-DA-0063.0000-RD.

Spread 5: PA-LE-0055.0000-RD and PA-BR-0036.0000-RD.

Spread 6: PA-CH-0212.0000-RD and PA-CH-0219.0000-RDa&b.

Conventional Open-Cut – Grading and Trenching of the ROW

- Disturbed and excavated soil from trenching operations, installed at depths of 5 to 7 feet below grade, could be transported into karst surface features through erosion, and could impact local springs or wells, manifested as increased turbidity. Please refer to Erosion and Sediment Control Plan for countermeasures to prevent or mitigate this occurrence.
- Inadvertent spills to karst features from equipment refueling and/or leaks could impact groundwater quality through rapid transport of contaminants to the aquifer or discharge locations such as springs, wells, or surface water bodies. Please refer to the PPC Plan for countermeasures to prevent or mitigate this occurrence.
- Open-cut installation in karst terrain areas can expose karst—prone rocks to air and moisture, thus providing potential for subsurface erosion. Following procedures outlined in this document will minimize this potential.

Conventional Bore

- Conventional Bores would excavate and disturb the subsurface to slightly greater depths about 4 to 15 feet below grade; however, the types of impacts are similar to open-cut. Procedures outlined to seal the annulus surrounding the pipe are designed to prevent the migration of fluids beyond the borehole.
- Grout could be introduced into fractures, thereby sealing it; however, due to the relatively shallow depth, should not significantly impact the aquifer.

Horizontal Directional Drill

- Should the drill intersect a large fracture in the aquifer there is potential for introduction of drilling fluid (bentonite clay and water) into the aquifer that could manifest as temporarily increased turbidity. See the mitigation procedures in this plan for mitigating small voids and routing around large voids encountered.
- Inadvertent releases of drilling mud could enter surface waterbodies that could manifest as temporarily increased turbidity. See the Inadvertent Return Plan for mitigation countermeasures.

4.6 **Best Management Practices and Mitigation Measures**

Best Management Practices (BMPs) and mitigation measures are presented in sections 7.1 thru 10.0 of this Void Mitigation Plan for Karst Terrain and Underground Mining, and are summarized below.

General Pipeline Installation BMPs include the following:

- Stormwater control measures will be implemented to minimize surface water runoff into known or encountered karst
- If voids are encountered, the trench excavation may be backfilled with grout or impermeable plugs, as described in the Void Mitigation Plan.
- Restoration of construction workspace will occur as rapidly as possible following pipeline installation.
- Proper grading at the site will be maintained to minimize diversion of stormwater to areas identified as prone to sinkhole development.
- Post-construction monitoring of identified areas will occur annually to identify any evidence of further sinkhole development, with implementation of any measures necessary to prevent further solution of underlying bedrock.

Open-Cut Installation and Void Mitigation measures are described in Section 7.0 and subsections. BMPs associated with surface construction and planned hydrostatic testing discharges, are described in Section 8.0 and subsections. Conventional bores Installation and Void Mitigation Measures are described in Section 9.0. Horizontal Directional Drilling Installation Void Mitigation Measures are described Section 10.0 and subsections.

The PPC, Water Supply, and IR plans provide for a course of action to protect the local environment and any assets from an event that interrupts the normal operation at the site and could result in a threat to health and/or the environment if not properly addressed. Spill and leak prevention and responses are described in detail in these plans, including encounters with unanticipated impacted soil, and summarized below:

- Petroleum and Petroleum-Related Materials: In dealing with a petroleum spill, the immediate response action is to attempt to eliminate the source of the spill. In the event of an accidental spill, emergency measures will be implemented to isolate the spilled material and prevent the release from entering surface water or groundwater.
- Soil that is impacted as a result of an accidental spill or release will be containerized for subsequent disposal. Clean-up protocol for the spill will be followed.
- Unanticipated discovery of contaminated soil conditions protocols.
- Inadvertent Returns from Horizontal Directional Drilling: The immediate response actions in dealing with an inadvertent return of drilling fluids (primarily bentonite and water) from a horizontal direction drill include discontinuing drilling operations, identifying the area of the inadvertent return, and isolating the inadvertent return. In the event of an inadvertent return, emergency measures will be implemented to isolate the returns and prevent or minimize the extent of the release that will enter surface water.

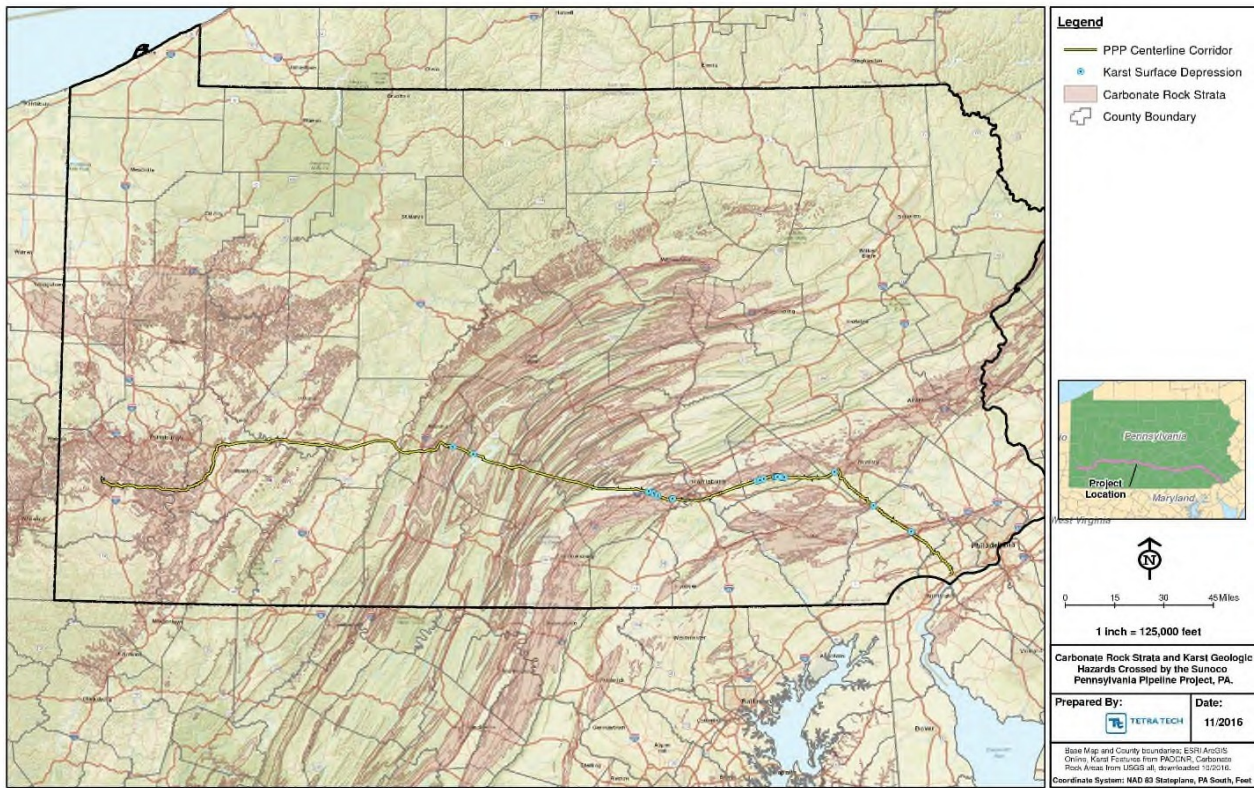


Figure 1: Map of Carbonate Rock and Karst Surface Depressions identified within the Project Route

Table 1. Aquifer Characteristics by Physiographic Province of Pennsylvania

Physiographic Province	Physiographic Section	Aquifer Formation-Carbonate Rock	Static Water Level (ft) (median)	Well Depth (ft) (median)	Casing Length(ft) (median)	Well Yield (gal/min)	No. of HDD/No. of Bores	No. of Surface Depression
Appalachian Plateaus	PG	Monongahela Group	35	126	21	5	18/35	
Valley and Ridge	AM	Bellefonte and Axemann Formations, undivided	43	180	36.5	9.65	1/0	1
	AM	Clinton Group	34.8	180	40	12	1/2	
	AM	Coburn Formation through Loysburg Formation, undivided	35.4	165	30	7.75	1/1	
	AM	Gatesburg Formation	108.5	245	94	10	0/1	
	AM	Hamilton Group	20	106	25	13.5	2/1	1
	AM	Keyser and Tonoloway Formations, undivided	31.4	147.5	48	15	3/2	
	AM	Mauch Chunk Formation	25.2	117.5	29	12	2/0	
	AM	Nittany and Stonehenge/Larke Formations, undivided	72.25	185	53.75	10.5	0/2	
	AM	Onondaga and Old Port Formations, undivided	35.6	140	48	10	5/3	
	AM	Rockdale Run Formation		136	55.5	15	2/2	1
	AM	St. Paul Group	31.75	150	40	10	5/2	5
	GV	Buffalo Springs Formation	45.2	288	57.5	45	0/6	13
	GV	Chambersburg Formation	26.95	162.5	23	10	1/0	
	GV	Epler Formation	52.5	175	60	30	1/1	
	GV	Millbach and Schaefferstown Formations, undivided	31	103.5	51	30	0/2	
	GV	Millbach Formation	68.5	301	72.5	90	1/6	1
	GV	Pinesburg Station Formation	32.45	107.5	21.5	7.95	1/1	
	GV	Richland Formation	38.2	167	55.5	20	0/1	
	GV	Shadygrove Formation	48.85	160	52	14.9	1/4	2
	GV	Snitz Creek Formation	43	150	37	8.5	1/10	3
	GV	Stonehenge Formation	38.85	137	40	12	1/1	
Piedmont	GN	Limestone fanglomerate	22.5	131.5	42.5	35	0/2	
	PL	Conestoga Formation	25	163.5	40	17	2/0	
	PL	Ledger Formation	25.85	144	45	39	2/0	2
	PU	Franklin Marble	No Data	No Data	No Data	No Data	0/1	

Source: PADCNR 2016b

5.0 SUBSURFACE MINING

The approximate 50-mile ROW from Houston, Pennsylvania to Delmont, Pennsylvania is the same ROW where the previous ME1 pipeline was installed. Although this area is shown as potential abandoned mining area, no voids were encountered during the ME1 pipeline installation. West of Delmont, one mining entry location within project workspace (proposed conventional installation) is mapped in Cambria County. This location was field

verified to not be a mine opening. The proposed Project alignment through abandoned mine land is shown in Appendix B.1.

6.0 MITIGATION IMPLEMENTATION REVIEW

Drilling contractors and engineers experienced in karst and historical mining terrain were consulted to provide proven methods for mitigation of possibly encountered voids. Additionally, the following Reference Documents (Appendix D) will be considered during the mitigation process:

- Appendix D.1: Sinkhole Mitigation Guidance, August 8, 2005. West Virginia Department of Environmental Protection Division of Water and Waste Management Groundwater Protection Program.
- Appendix D.2: PADEP Erosion and Sediment Control Manual, March 2012. "CHAPTER 7 – Sediment Basins, Design Criteria Summary, Karst Topography." "CHAPTER 17 – Areas of Special Concern, Sinkhole Repair."
- Appendix D.3: Penn DOT Pub_293_Part_1: Section 1.6.1.4.5 (Micropiles), Section 1.6.1.6 (Voids), and Section 1.6.1.8 (Temporary Shoring).

The PADEP Manual does not specify mitigation in regards to potential voids in relation to mining. Mine voids of a similar size to surface karst voids will be mitigated in the same manner as referenced in this report for Karst Voids. Mine Voids encountered indicating a potentially more complex problem, will require notification to PADEP. Because of differences among sinkholes and historical underground mines, and to ensure proper execution of the plan to mitigate voids, mitigation will proceed with direct consultation of a professional geologist and/or professional geotechnical engineer. An on-site geotechnical specialist may also be available to identify potential problems with the planned mitigation, and/or provide options to either avoid such problems or adjust the plan when anomalies are encountered. Provision of a professional geologist inspector to oversee HDD installations is provided within the Project's IR Plan.

7.0 OPEN-CUT PIPELINE INSTALLATION VOID MITIGATION

Geotechnical investigations did not occur outside of HDD areas. Possibly present voids will be identified during open-cut pipe trench excavations. Open-cut installation in karst terrain areas can expose carbonate bedrock to air and moisture, thus providing potential for subsurface erosion. Adherence to site erosion and sediment (E&S) plans, construction during dry weather, prompt backfilling of trench with compacted soil, and vegetative stabilization will minimize potential for future subsidence. If a void is encountered during trench excavations, trench boxes and/or an engineered shoring system will be utilized to support sidewalls of the excavation and prevent cave-ins.

If voids are encountered in the subsurface, a professional geotechnical engineer and/or geologist will initially evaluate site conditions. Possible mitigation measures to address voids will include the following:

- West Virginia DEP Sinkhole Mitigation Guidance in WV (Appendix D.1).
- PADEP E&S Manual March 2012, Chapter 17 – Areas of Special Concern – Sinkhole in PA (Appendix D.2).
- In-filling of voids with flowable fill material (grout).

Other sources of mitigation measures also may be consulted—mitigation procedures not discussed in this section are described in Appendices D.1 and D.2.

7.1 Void Mitigation Procedures Utilizing Flowable Fill

1. Excavate void to locate the "throat" of the sink-hole. If the throat cannot be readily located, use water to locate and expose the throat (See Appendix D for depictions).
2. Once the throat is located and excavated out to the extent practicable (removal of most soil and loose rock), design and implement the plugging. Where voids are relatively small it may be appropriate to import and pour a flowable fill (grout) into the void until the void is plugged and filled to 1 foot below the proposed pipe trench bottom elevation. In this case, allow the flowable fill to cure for a minimum of 1 day, ensuring that the top is firm and stable. Where the void is relatively large it may be necessary to implement a design intended to maintain local drainage and groundwater flow patterns. In these cases the design of the plug may be to fill the throat of the void with rip rap, followed finer stone in an upward fining sequence of layers, geofabric, and fine grain compacted soil to the elevation of the trench bottom. The Geotechnical Engineer/Professional Geologist will determine the appropriate design of the plug based on field conditions.
3. Place a 1-foot layer of compacted clay (Unified Soil Classification System [USCS]: CL or CH) over cured flowable fill, bringing top of clay to bottom of pipe trench elevation.
4. At this point, normal pipe installation and trench backfill may proceed, except that the uppermost 1 foot of backfill shall consist of compacted clay (USCS: CL or CH), placed directly below the topsoil layer, to minimize surface water infiltration into backfill.
5. Place a trench plug of clay soil (USCS: CL or CH) along the pipe trench a distance of approximately 10 feet beyond each side of the void area. The trench plug must backfill the entire pipe trench, from bottom to top of trench, including around the pipe (i.e., no bedding sand or gravel). Minimum length of trench plug shall be 5 feet. Purpose of trench plug is to prevent flow into the sink-hole area of water that may be present in upgradient pipe bedding sand/gravel or trench backfill areas.
6. Contractor will defer to specifications for flowable fill of local township and/or Sunoco.

Depending on nature and size of encountered voids, another potential option to support pipeline loads is installation of micropiles. Micropiles are particularly efficient where natural or man-made obstructions occur—in areas of karst geology, where rock surfaces are erratic and large voids are typically present. Micropiles can typically be designed to resist compression, uplift, and lateral loads, and have been used to support a variety of facilities. It is important that installation of the micropile rock socket occur in adequate bedrock to support the proposed loads. (Refer to Appendix D.3 – Penn DOT Geotechnical Engineering Manual, Publication 293, 2014 Edition). The method of mitigation of a sink-hole/void during open-cut excavations will depend on the nature and extent of the void.

8.0 SURFACE ENVIRONMENTAL BMPs ASSOCIATED WITH SURFACE VOID MITIGATION

8.1 Pipeline Installation BMPs

- Stormwater control measures will be implemented to minimize surface water runoff into known or encountered karst or mining areas.
- If voids are encountered, the trench excavation may be backfilled with grout or impermeable plugs (e.g., clay) to minimize flow of water to karst features. Trench plugs would be incorporated prior to backfill operations to prevent or limit subsurface

water flow within the trench or along the pipeline bedding and backfill.

- Restoration of construction workspace will occur as rapidly as possible following pipeline installation. The trench will be backfilled quickly to re-establish vegetative cover and limit time of exposure of the site to concentrated stormwater flow.
- Proper grading at the site will be maintained to minimize diversion of stormwater to areas identified as prone to sinkhole development. Trench plugs may also be used to prevent collection of stormwater within the identified area.
- Post-construction monitoring of identified areas will occur annually to identify any evidence of further sinkhole development, with implementation of any measures necessary to prevent further solution of underlying bedrock.

8.2 Hydrostatic Testing

To reduce potential for sinkhole development during hydrostatic testing, test water from a new pipe will not be discharged directly into the vicinity of a known karst feature open to the surface. The water will be discharged downgradient of identified karst features. If site conditions prevent a downgradient discharge, the water will be discharged as far from the karst feature as practicable, utilizing sediment and erosion control features detailed in the Project E&S Control Plan. Alternatively, a frac tank could be utilized to discharge water off site at a permitted facility. Post- construction monitoring will ensure proper re-vegetation and restoration of these areas.

9.0 CONVENTIONAL BORES INSTALLATION VOID MITIGATION

Conventional bores will be installed with no fluids to depths ranging from approximately 4 to 15 feet below ground surface (bgs). The 20-inch-diameter pipe will be installed in a 22-inch borehole, and pressure grouting will fill the annulus in the borehole surrounding the pipe. Injected grout under pressure should fill any encountered voids, cavities, and/or soft zones within any encountered karst or mining features. Similar procedures will be used for the 16" pipe. If no returns from the injected grout occur, mitigation may follow procedures previously described for open-cut installation and mitigation.

As required by 49 Code of Federal Regulations, Parts 192.613 and 195.204, route surveillance will occur during construction and operation of the facilities, along with training of surveillance personnel, to monitor the pipeline alignment for evidence of subsidence, surface cracks, or depressions that could indicate sinkhole formation. Signs of sinkhole formation, ground subsidence, or surface depressions will be immediately and clearly marked. Work will be temporarily halted and the immediate area around the depression evacuated until it is deemed safe and stable. The project geotechnical engineer will also be notified of the occurrence. Based on direction of the geotechnical engineer, the area may be backfilled with clean sand fill to temporarily stabilize the area pending further evaluation that may include geophysical and/or geotechnical testing. Compaction grouting may be used at one or more points to seal the rock surface, fill void, and push into the loose, weak soil—compacting and strengthening it. Compaction grouting is typically completed in stages, from bottom up. If no returns from the injected grout occur, mitigation may follow the procedures described for open-cut installation and mitigation.

10.0 HDD INSTALLATION VOID MITIGATION

Loss of drilling fluid return to the drilling rig is often an indication of encounter with fractures and/or voids. Mitigation of these depend on the size of the fracture/void, and may include

filling the voids with additional drilling fluid or pulling back drilling equipment and either proceeding deeper or off-setting the HDD. Size of the void encountered during drilling will determine the course of action by the HDD driller. Possible actions in this regard are described in the following paragraphs.

10.1 **Small Voids**

When smaller voids or open seams are encountered, the driller will usually not experience significant drop in inclination or loss in returns of drilling fluid back to the drilling rig. In these instances, the driller can often fill or seal off the void with additional drilling fluid. By doing so, the driller hopes to build a layer of bentonite in the void and seal the borehole, thus re-establishing circulation of drilling fluid and returns back to the entry/exit pits. Another option in these situations is to adjust composition of the drilling fluid. By mixing natural materials such as wood fibers, or by using special polymer fibers, the driller can thicken the drilling fluid to help seal the void and allow the drill to continue on its current designed path. Materials utilized will be from the PADEP Approved List of thickening additives. When this course of action is chosen, the drilling contractor and the site environmental representative choose the appropriate material and/or product to thicken the drilling fluid.

10.2 **Large Voids**

When a larger void is encountered, the driller will usually experience a significant drop in inclination, loss in fluid pump differential pressure, and loss in returns to the drilling rig—indicating that the drilling fluid is not circulating back to the pit and is being lost to a big void or seam. When encountering a large void, drilling will stop and the driller will re-group with the project team to evaluate options of how to proceed. The first course of action would be to change the composition of the drill fluid, as detailed above addressing Small voids. If pumping more fluid does not seal the void, the course of action may be to pull back the drill stem and have a geophysicist perform an investigation to evaluate the extent of the void. When this is determined, the applicable course of action may be to either drill deeper into the bed rock or offset 10 feet either direction from the original centerline, but within the ROW, and re-drill the area.