ADELPHIA GATEWAY, LLC

RESOURCE REPORT NO. 6

Geological Resources

ADELPHIA GATEWAY PROJECT

January 2018

SUMMARY OF FILING INFORMATION			
Information	**Data Sources[a]**	**Found in Section**	**To be Filed**
Minimum Requirements to Avoid Rejection: 1. Identify the location (by milepost) of mineral resources and any planned or active surface mines crossed by the proposed facilities – Title 18 CFR § 380.12(h)(1&2)	L, S, DD	6.2	N/A
2. Identify any geologic hazards to the proposed facilities - 18 CFR § 380.12(h)(2)	L, AA, DD, II	6.3	N/A
3. Discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities - 18 CFR § 380.12(h)(3)	D, X	6.5.4	N/A
4. For LNG Projects in seismic areas, the materials required by 'Data Requirements for the Seismic Review of LNG Facilities,' NBSIR84-2833. - 18 CFR 380.12(h)(5)	N/A	N/A	N/A
5. For underground storage facilities, how drilling activity by others within or adjacent to the facilities would be monitored, and how old wells would be located and monitored within the facility boundaries - 18 CFR § 380.12(h)(6)	N/A	N/A	N/A

CFR = Code of Federal Regulations
N/A = Not Applicable
LNG = Liquefied Natural Gas

[a] L = Field Surveys
S = Mineral Resource Maps, Federal and State
DD = State Agencies
AA = Resource Report 2
II = Surficial Geologic and Bedrock Geologic Maps
D = Applicant
X = Natural Resources Conservation Service Soil Surveys or Soil Survey Geographic Database (SSURGO)

Source: FERC, 2017

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ACRONYMS AND ABBREVIATIONS

Adelphia	Adelphia Gateway, LLC
Delmarva Station	Delmarva-owned meter station (location of Parkway Lateral interconnect facilities)
Marcus Hook CS	Marcus Hook Compressor Station
MLV	Mainline Valve
Quakertown CS	Quakertown Compressor Station
PASDA	Pennsylvania Spatial Data Access
Project	Adelphia Gateway Project
Tilghman Station	Existing interconnect between PECO and TETCO systems at Tilghman Street.
USGS	United States Geological Survey

6 GEOLOGICAL RESOURCES

This resource report describes geological resources and hazards in the proposed Adelphia Gateway Project (Project) area, the associated characteristics and limitations, and the proposed mitigation for impacts that could occur as result of construction or operation of the Project. The Project consists of the following primary components: the approximately 4.4-mile 20-inch Mainline; the approximately 84-mile 18-inch Mainline consisting of the Southern Segment and the Northern Segment that will both transport solely natural gas; two new compressor stations (the Marcus Hook CS and the Quakertown CS); two laterals, including an approximately 0.25-mile 16-inch pipeline lateral (the Parkway Lateral) and an approximately 4.5-mile 16-inch pipeline lateral (the Tilghman Lateral); four existing meter and regulator (M&R) facilities that do not require any modifications and accordingly do not have any environmental impacts for review in this resource report; eight new M&R facilities at receipt and delivery interconnects located along the 18-inch Mainline and the laterals; eight new blowdown assemblies located at existing mainline valves; one new mainline valve; and use of an existing disturbed site as a wareyard.

6.1 GEOLOGIC SETTING

6.1.1 Physiography

The Project is located in the Atlantic Coastal Plain, Piedmont, New England, and Valley and Ridge Physiographic Provinces in Pennsylvania and in the Atlantic Coastal Plain in Delaware (PASDA,1995; USGS, 2017a).

The Lowland and Intermediate Upland Section of the Atlantic Coastal Plain Province is made up of a terrace that has been shaped by the action of many streams. Relief in this province is relatively low, and the surface of the terrace consists of sands and gravels (PADCNR, 2000). Project facilities within this section include the Marcus Hook Compressor Station (Marcus Hook CS) and wareyard, the Parkway Lateral and its associated interconnects/meter stations, and the Tilghman Lateral and its associated interconnects/meter stations.

The Piedmont Upland Section of the Piedmont Province is a relatively flat plateau. MLV Option 1, MLV Option 2, the Chester Creek Gate Blowdown, Paoli Pike Gate Blowdown, and Pickering Creek Gate Blowdown would be located within this physiographic section.

The Gettysburg-Newark Lowland Section of the Piedmont Province is composed mainly of rolling low hills and valleys developed on red sedimentary rock. This section also includes isolated higher elevation hills that consist mainly of diabase and conglomerates. The basic drainage pattern is dendritic (PADCNR, 2000). Project facilities located within this Section include the Skippack Meter Station and the Quakertown Compressor Station (Quakertown CS) and associated meter station. Additionally, the French Creek Gate Blowdown, the Cromby Gate Blowdown, the Schuylkill River Gate Blowdown, the Perkiomen Gate Blowdown, and the East Perkiomen Gate Blowdown would be located in this physiographic section.

The Great Valley Section of the Valley and Ridge Province consists of very broad lowlands that have undulating hills eroded into shales and siltstones on the north side while the south side consists of a lower elevation flatter landscape developed on limestones and dolomites. The Martins Creek Station would be located within the Great Valley Section (PADCNR, 2000).

6.1.2 Topography

The topography across the Project area varies between gently, moderately, and highly sloped terrain, with elevations ranging from approximately 10 to 800 feet above mean sea level. Topography is illustrated in the U.S. Geological Survey (UGGS) 7.5-minute topographic quadrangle maps provided in appendix 1A (USGS, 2017b).

6.1.3 Geologic Formations

Table 6.1-1 below describes the bedrock that would be crossed by the Project. The Project mainly crosses sedimentary rock types including mudstone, siltstone, shale, and limestone. The Project also crosses beds of feldspathic sand such as the Pennsauken and Bridgeton Formations, undifferentiated and igneous rocks like anorthosite and diabase (USGS, 2005). With the exception of access roads (all of which would be existing), construction and operation of the new MLV (regardless of which location is selected) and blowdown assemblies would take place within the previously excavated and maintained existing IEC pipeline right-of-way.

Table 6.1-1
Geologic Formations in the Adelphia Project Area

Project Site	Formation/ Rock Type	Begin MP	End MP	Period/ Era	Primary Lithology	Secondary Lithology
Marcus Hook CS and wareyard	Anorthosite	0.0[a]	0.0[a]	Lower Paleozoic	Anorthosit e	Local alteration minerals
	Trenton Gravel			Tertiary	Gravelly sand	Sand, clay-silt beds
Parkway Lateral[b]	Trenton Gravel	PL 0.0	PL 0.0[c]	Tertiary	Gravelly sand	Sand, clay-silt beds
	Anorthosite	PL 0.0	PL 0.2	Lower Paleozoic	Anorthosit e	Local alteration minerals

Table 6.1-1 Geologic Formations in the Adelphia Project Area						
Project Site	**Formation/ Rock Type**	**Begin MP**	**End MP**	**Period/ Era**	**Primary Lithology**	**Secondary Lithology**
	Pensauken and Bridgeton Formations, undifferentiated	PL 0.2	PL 0.3	Tertiary	Feldspathic quartz sand	Gravel, clay, silt
Tilghman Lateral[b]	Anorthosite	TL 0.0	TL 0.3	Lower Paleozoic	Anorthosite	Local alteration minerals
	Trenton Gravel	TL 0.3	TL 1.0	Tertiary	Gravelly sand	Sand, clay-silt beds
	Anorthosite	TL 1.0	TL 1.2	Lower Paleozoic	Anorthosite	Local alteration minerals
	Trenton Gravel	TL 1.2	TL 1.9	Tertiary	Gravelly sand	Sand, clay-silt beds
	Wissahickon Formation	TL 1.9	TL 2.0	Lower Paleozoic	Oligoclase-mica schist	Hornblende gneiss, augen gneiss,
	Trenton Gravel	TL 2.0	TL 2.4	Tertiary	Gravelly sand	Sand, clay-silt beds
	Wissahickon Formation	TL 2.4	TL 2.5	Lower Paleozoic	Oligoclase-mica schist	Hornblende gneiss, augen gneiss,
	Trenton Gravel	TL 2.5	TL 4.2	Tertiary	Gravelly sand	Sand, clay-silt beds
Skippack Meter Station	Brunswick Formation	36.0[a]	36.0[a]	Jurassic	Reddish-brown mudstone, siltstone, and shale	Interbeds of green,and brown shale, red and dark-gray argilites near base.
Schuylkill River Gate Blowdown		28.0	28.0			
Perkiomen Creek Gate Blowdown		34.0	34.0			
East Perkiomen Gate Blowdown		36.8	36.8			
Quakertown CS and Quakertown M&R	Diabase	49.4[a]	49.4[a]	Jurassic	Medium to coarse grained, quartz-normative tholeiite	N/A

Table 6.1-1 Geologic Formations in the Adelphia Project Area						
Project Site	**Formation/ Rock Type**	**Begin MP**	**End MP**	**Period/ Era**	**Primary Lithology**	**Secondary Lithology**
	Brunswick Formation			Triassic	Reddish - brown mudstone, siltstone, shale	Green and brown shale, argillites
Martins Creek Station	Epler Formation	84.4[a]	84.4[a]	Ordovician	Very finely crystalline , light-gray limestone interbedded with gray dolomite.	Coarsely crystalline limestone lenses present
MLV Option 1	Felsic and intermediate gneiss	6.7	6.7	Precambrian	Light medium grained felsic and intermediate gneiss.	Rocks of probable sedimentary origin.
MLV Option 2		7.9	7.9			
Chester Creek Gate Blowdown		9.5	9.5			
Pickering Creek Gate Blowdown		23.0	23.0			
Paoli Pike Gate Blowdown	Felsic Gneiss	14.5	14.5	Precambrian	Light medium grained gneiss	Rocks of probable sedimentary origin
French Creek Gate Blowdown	Stockton Formation	25.7	25.7	Triassic	Light-gray to buff, coarse-grained, arkosic sandstone	Reddish-brown to grayish-purple sandstone, siltstone , and mudstone.
Cromby Gate Blowdown	Lockatong Formation	27.3	27.3	Triassic	Dark-gray to black, thick-bedded argillite containing a few zones of thin-bedded black shale	Thin layers of impure limestone and calcareous shale.

MP = Project milepost

[a] This is an aboveground facility. The location provided is at the nearest Project MP.

[b] Pipeline laterals include associated interconnects/meter stations.

[c] MPs have been rounded to the tenths place. The End MP is greater than 0.0 mile but less than 0.05 mile.

Source: USGS, 2005

6.1.4 Blasting

Shallow depth to bedrock may be encountered at the Tilghman Lateral and associated M&R facilities where Made Land would be encountered, the Skippack Meter Station where the Penn silt loam would be encountered, and the Quakertown CS and associated M&R facilities where the Udorthents, shale and sandstone soils are located. Made Land, Penn silt loam, and Udorthents, shale and sandstone are all identified as having bedrock within 6 feet of the ground's surface (see Resource Report 7 – *Soils*). Prior to construction Adelphia would conduct a geotechnical soil analysis at the Quakertown CS to confirm blasting would not be required. Blasting would not be used to construct the new MLV or blowdown assemblies. The ground in these areas has been previously excavated during construction of the existing 18-inch and 20-inch pipelines.

6.1.5 Horizontal Directional Drill

Adelphia would use the horizontal direction drill (HDD) construction method to minimize impacts to numerous resources located along the proposed Tilghman Lateral. Table 6.1-2 identifies the HDD locations by milepost, the name of the HDD, the distance of the HDD, and geotechnical investigation status. Adelphia is in the process of conducting geotechnical investigations to determine the viability of using the HDD construction method at the proposed locations. Adelphia will provide the FERC with the results of the geotechnical investigations in a supplemental filing.

The HDD method avoids sensitive resources but may potentially cause an inadvertent return of drilling mud. Drilling mud is a non-hazardous fluid that is part of the HDD process and typically consists of water and bentonite. Inadvertent returns occur when the HDD encounters a pathway of lesser resistance to the surface than that of the intended mud flow. Instead of flowing back to the drill rig the mud is released at the ground surface. Adelphia is preparing an *HDD Inadvertent Release Contingency Plan* that will detail the measures that would be used to identify inadvertent releases, stop the inadvertent release, clean up and/or mitigate effects of the release, and report to the appropriate parties. Adelphia will provide its *HDD Inadvertent Release Contingency Plan* in a supplemental filing.

Table 6.1-2 Proposed HDDs Along the Tilghman Lateral				
HDD #	**Entry MP**	**Exit MP**	**Distance (miles)**	**Geotechnical Investigation Status**
1	0.3	0.9	0.6	Pending
2	1.1	1.7	0.6	Pending
3	1.8	2.2	0.5	Pending
4	2.4	2.6*	0.2	Pending
5	2.9	3.4	0.5	Pending
6	3.5	3.7	0.3	Pending
7	3.9	4.2	0.3	Pending
8	4.3	4.4	0.1	Pending
* As described in Resource Report 2, *Water Use and Quality*, Adelphia is analyzing two crossing methods (HDD and open-cut (dry or wet)) for a waterbody at approximately TL 2.7.				

6.2 MINERAL RESOURCES

Mineral resources in Pennsylvania consist of fuel sources such as coal, oil, and natural gas as well as non-fuel mineral resources such as stone, sand and gravel. Pennsylvania also contains major production areas for mineral resources such as peat, clay shale, dimension stone, and silica (USGS, 2013). Adelphia obtained data on fuel mineral resources in proximity to the Project in Pennsylvania through the Pennsylvania Spatial Data Access (PASDA) database. Adelphia's search included a review of abandoned mine lands, underground permit boundaries, coal mining operations, and digitized mined areas (PASDA, 2017a; 2017b; 2017c; 2017d). The Applicant used the PASDA *Industrial Mineral Mining Operations Data Layer* (PASDA, 2017e) to review the locations of non-fuel mineral resource extraction locations and the PASDA *Oil and Gas Locations Data Layer* to obtain oil and gas spatial data (PASDA, 2017f).

The state of Delaware is not known to produce coal or oil and gas fuel mineral resources (EIA, 2015a). Delaware does produce some non-fuel mineral resources such as sand and gravel. However, according to USGS Active Mines and Mineral Plants in the U.S. data layers and Delaware Department of Geologic Survey mapping, there are no non-fuel mineral resource producers within 0.25 mile of the Project (DGS, 2004; USGS, 2017c).

None of the proposed Project facilities would be within 0.25 mile of any active, inactive, or proposed coal mine, oil and natural gas wells, or non-fuel mineral resources (PASDA,2017a; 2017b; 2017c; 2017d).

6.2.1 Coal

Pennsylvania's coal resources are located across the state with bituminous coal fields located in western Pennsylvania and anthracite coal fields located toward the north east of the state. According to available PADEP mapping, there are no active, inactive, or proposed coal mines, or previously mined areas located within 0.25 mile of the Project (PASDA,2017a; 2017b; 2017c; 2017d).

6.2.2 Oil and Natural Gas

Pennsylvania's oil and natural gas fields are concentrated in the western part of the state and consist of both shallow and deep oil and gas fields (PADNR, 2014). According to the Pennsylvania Department of Environmental Protection Oil and Gas Well data layer, there are no oil and gas wells located within 0.25 mile of the proposed Project (PASDA, 2017f). The Marcellus Shale Formation, which is one of the richest gas fields in North America, is located over 10 miles away from the Project facilities and would not be affected by the Project (O&G Journal, 2016; PASDA, 2002).

6.2.3 Non-fuel Mineral Resources

Major non-fuel mineral resources in Pennsylvania consist mainly of aggregates such as sand, gravel, and crushed stone (USGS 2013). According to the PASDA, there are no industrial mineral resource extraction operations within 0.25 mile of the Project (PASDA, 2017e). In Delaware, there are no non-fuel mineral resource producers within 0.25 mile of the Project (DGS, 2004; USGS, 2017c; Google Earth, 2017).

6.3 GEOLOGIC HAZARDS

According to the National Park Service, geologic hazards are "any geological or hydrological process that poses a threat to people and or their property" (NPS, 2017). Geologic hazards that could occur in proximity to and pose a hazard to the Project include seismicity and soil liquefaction, subsidence and karst terrain, landslides, and flash flooding. Volcanism is not known in the Project area and is therefore not discussed further below.

6.3.1 Seismic Hazards and Liquefaction

Seismicity is the occurrence or frequency of earthquakes for a given area. A seismic disturbance or earthquake can be due to natural or manmade causes. Earthquakes result when two blocks of earth overcome the frictional forces holding them in place and suddenly slide past each other (USGS, 2017d). The USGS has created seismic hazard maps used to depict probabilistic ground motions with a set probability of exceedance in 50 years. The proposed Project would be located in an area where Peak Ground Accelerations of 0.05 the force of gravity has a ten percent probability of being exceeded in 50 years (Peterson et al., 2014). The USGS has also created an Interactive Fault Map that identifies quaternary faults, which are faults that demonstrate geologic evidence of surface deformation within the last 1.6 million years (the Quaternary). No faults from this database were identified within 0.25 mile of the proposed Project (USGS, 2017e).

Seismic disturbances such as earthquakes can also cause other hazards such as soil liquefaction. Soil liquefaction is a phenomenon where normally solid and stiff soils lose strength and temporarily act like a liquid due to the stress applied by seismic shaking. Typically, in order for soil liquefaction to occur three criteria must be met. The soil must be loose and non-cohesive (such as with Holocene deposits), the soil must be saturated with water, and the soil must have the potential to experience strong ground shaking (USGS, 2006). As indicated above, the potential for strong prolonged and significant ground shaking to occur within the Project area is low, and therefore the likelihood for soil liquefaction to occur is also low.

Well maintained and designed carbon steel pipelines that are constructed using modern arc-welding techniques with full penetrating welds have performed generally satisfactorily and have not been ruptured by ground shaking caused by an earthquake. Wave propagation damage to modern steel pipelines is not common, and there are many oil and gas transmission pipelines that have been located in seismic regions and performed satisfactorily through moderate earthquakes (FEMA, 1992).

6.3.2 Subsidence and Karst Terrain

Subsidence is defined as the gradual caving or sinking of an area of land and can occur due to previous mining (mine collapse) or the development of sinkholes through the dissolution of limestone. As stated above, there are no known areas of previous underground mining in proximity to the Project.

According to the USGS, “karst is a terrain with distinctive landforms and hydrology created from the dissolution of soluble rocks, principally limestone and dolomite. Karst terrain is characterized by springs, caves, sinkholes, and unique hydrogeology that results in aquifers that are highly productive but extremely vulnerable to contamination” (USGS, 2017f). The Martins Creek Station would be in proximity to several surface depressions. The remaining Project facilities would not be located within 0.25 mile of any known karst features (PASDA, 2017g).

According to the *Karst in the United States: A Digital Map Compilation and Database*, no potential karst feature forming rocks exist within 0.25 mile of the Project in Delaware (Weary and Doctor, 2014). No karst features were identified in proximity to the two MLV locations being considered, the blowdown assemblies, or the Skippack Meter Station (PASDA, 2017g).

6.3.3 Landslides

Landslides include a wide range of ground movements, such as rock falls, deep failure of slopes, and shallow debris flows. Contributing factors to landslides can include erosion, over-steepening of slopes, slope weakening due to saturation, earthquakes, and extra weight from rain and snow (USGS, 2017g). The topography in the areas of the Project is nearly level to gently undulating and would not be susceptible to debris flows or landslides (USGS, 2017b). The Southwestern Pennsylvania Commission has identified previously active documented landslides, none of which are located within one mile of the Project (PASDA, 2017h). According to the *Landslide Overview Map of the Conterminous United States*, the entirety of the Project is located in an area with low susceptibility and low incidence of landslide occurrence (Radbruch-Hall, et al., 1982).

6.3.4 Flash Flooding

Flash flooding is possible within waterbody floodplains during or after large and/or sudden rain events (NSSL, 2017). Although the proposed Project activities would not cross any major waterbodies, the Tilghman Lateral would cross floodplains between mileposts TL 2.4 and TL 2.5 where the Tilghman Lateral right-of-way and additional temporary workspace would occur within the 100-year floodplain, and between mileposts TL 2.6 and TL 2.8 where the Tilghman right-of-way and ATWS would occur within the 100-year floodplain and a regulatory floodway (see Resource Report 2 – *Water Use and Quality*) (FEMA, 2016). A small portion of the Project's ATWS would be within the 500-year floodplain near MP TL 4.4 where the Tilghman Lateral terminates. The Schuylkill River Gate Blowdown would be located within the 500-year floodplain of the Schuylkill River. The Paoli Pike Gate Blowdown would be located within the 100-year floodplain and in close proximity to a regulatory floodway. The Chester Creek Gate Blowdown would be located within the 100-year floodplain of Chester Creek.

6.4 PALEONTOLOGICAL RESOURCES

None of the rock types crossed by the proposed Project are known to contain significant fossil resources (PADCNR, 1964; USGS, 2005; Bascom et al, 1931). Although fossils have been found in the Brunswick formation, this is considered to be rare (Bascom et al, 1931). Therefore, it is unlikely that a significant fossil discovery during excavation would occur. Work associated with the proposed new MLV and blowdowns would be done within previously disturbed and maintained right-of-way. Any paleontological resources potentially occurring in the area would have been discovered during the original 18-inch and 20-inch pipeline construction.

6.5 CONSTRUCTION AND OPERATION IMPACTS

6.5.1 Mineral Resources

There are no historical, current, or known planned coal mines, non-fuel mineral resource operations, or oil and gas wells within proximity to the proposed Project. Activities associated with the construction and operation of the proposed Project are therefore not expected to adversely affect or be adversely affected by these resources either in Delaware or Pennsylvania.

6.5.2 Geologic Hazards

As stated above, earthquakes, soil liquefaction, subsidence, and landslides are unlikely to occur within the Project area. Therefore, these geologic hazards are unlikely to affect Project construction or operation. Similarly, karst terrain, which has only been mapped in the area of the Martins Creek Station, is not likely to affect Project construction or operation due to the limited nature of the karst features and because Project activities at the Martins Creek Station would be limited to the installation of a chain-link fence at an existing industrial facility.

Flash flooding could occur in the Project area at the two locations where the Tilghman Lateral crosses the 100-year flood zone. Adelphia has performed preliminary buoyancy calculations and has determined that once installed and backfilled, weighted pipe would not be needed even in the event of flash flooding. During construction, measures would be implemented to handle waterbody flow increases. Weather forecasts would be monitored and necessary steps taken prior to storm events to prevent flooding impacts.

6.5.3 Blasting

Shallow bedrock is not expected in most construction areas as only the Tilghman Lateral, Skippack Meter Station, and Quakertown CS contain soils that have the potential for shallow bedrock. The soil at the Tilghman Lateral is Made Land, and Adelphia does not expect blasting would be required to install the pipeline or associated M&R facilities in these areas. Additionally, a large portion of the Tilghman Lateral would be constructed via HDD. Adelphia would conduct a geotechnical site investigation of the Quakertown CS and associated M&R facilities site prior to construction to determine if blasting would be required. Additionally, geotechnical investigations would be conducted for the eight HDDs located along the Tilghman Lateral, which would characterize the likely depth of bedrock and geologic conditions in the general Tilghman Lateral area. Adelphia would first attempt to use conventional means (e.g., hydraulic hammers and mechanical rippers) to remove any shallow bedrock encountered during construction. If consolidated bedrock that cannot be removed by chipping or ripping is encountered, blasting may be required. If blasting is required, Adelphia would implement pre- and post-blasting surveys, coordinate with the appropriate local authorities, and develop a Project and Site-specific *Blasting Plan* that would outline the regulations, safety measures, pre- and post-blast inspection, and monitoring involved with blasting activities. Adelphia and its contractors would adhere to local, state, and federal regulations that govern controlled blasting.

6.5.4 Horizontal Directional Drill

Adelphia will conduct geotechnical investigation to verify the viability of conducting HDD at the proposed locations and determine the potential for an inadvertent return to occur. If an inadvertent return were to occur during the HDD process, Adelphia would follow the procedures within its *HDD Inadvertent Release Contingency Plan*. Adelphia is currently preparing this plan and will provide the plan for FERC review and approval in a supplemental filing.

6.7 REFERENCES

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