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HYDROGEOLOGICAL ASSESSMENT OF KARST AREA IMPACTS CAUSED BY CONSTRUCTING THE MOUNTAIN VALLEY GAS PIPELINE ACROSS PETERS MOUNTAIN, MONROE COUNTY, WEST VIRGINIA

By Pamela C. Dodds, Ph.D., Licensed Professional Geologist
for
Indian Creek Watershed Association

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Cover: Spring-fed pond for trout fish hatchery near proposed MVP construction route, Milepost 194.5. The spring water issues from a cave entrance.

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By Pamela C. Dodds, Ph.D., Licensed Professional Geologist

EXECUTIVE SUMMARY

Mountain Valley Pipeline, LLC (MVP) submitted a Draft Environmental Impact Statement (DEIS), dated September 2016, to the Federal Energy Regulatory Commission (FERC), describing construction of a gas pipeline through West Virginia and Virginia. The proposed gas pipeline construction would extend across the karst area of Peters Mountain, Monroe County, West Virginia.

The hydrogeological assessment presented herein focuses on the portion of the proposed MVP pipeline route from approximately Milepost (MP) 194.0 to MP 195.0 within the karst area of Peters Mountain, located in the southeastern portion of Monroe County, West Virginia. Peters Mountain is within the Valley and Ridge Physiographic Province. Numerous springs, sinkholes, and caves are present in the karst area between MP 194.0 to MP 195.0. This area is also within the Red Sulphur Public Service District (PSD), which provides a public water supply. Construction of the proposed MVP gas pipeline across this karst area will cause environmental degradation and destruction which will adversely impact surface water and groundwater resources in the Red Sulphur PSD, including the following:

1) Deforestation for the proposed MVP gas pipeline construction will cause increased stormwater discharge.

Ground cover determines the amount of precipitation that will penetrate the ground as groundwater recharge or run off the surface. Forested areas intercept rainfall, allowing the rain to gently reach the ground surface. Therefore, in forested areas, the rain will penetrate the ground to recharge groundwater and will flow across the ground surface with less volume and velocity (discharge) than in non-forested areas. Even where sediment from stormwater discharge from construction areas is captured in erosion control structures, the increased discharge flowing into streams will result in stream bank erosion downstream and, consequently, increased sedimentation downstream. Where stream crossings are planned for the MVP gas pipeline construction, stream bedding forms will be destroyed, aquatic habitats will be destroyed.

2) Soil removal and compaction for the proposed MVP gas pipeline construction will adversely impact headwater area functions and groundwater recharge to springs, wetlands, and streams.

The composition of weathering products from the underlying bedrock determines characteristics of soils relating to water retention, pore space, and acidity. The organic fraction of the soils results from interactions between the available vegetation and soil organisms such as microbial communities, worms, and tree roots. Soil scientists estimate that a time period greater than 100 years is required for one inch of soil to form. For this reason, soil is considered a non-renewable resource. Soil removal and compaction within the work corridor will destroy the soils which regulate the transport of surface water, and also carbon, nitrogen, and oxygen, to headwater areas of first order high gradient streams and to wetlands. Soil removal and compaction would also result in increased stormwater discharge and decreased groundwater recharge to springs, wetlands, and streams.

3) Blasting conducted for leveling the proposed MVP gas pipeline work corridor and for trenching construction will adversely impact groundwater flow to springs, wetlands, and streams.

Blasting of bedrock to create a level work corridor and to install the proposed pipeline into trenches approximately 10 feet deep will intercept groundwater flow, thereby reducing the groundwater flow to seeps and springs. Reduced groundwater recharge decreases the hydraulic head that moves the groundwater downgradient to nearby seeps and springs and also to streams farther downgradient. Reduction of the hydraulic gradient decreases the amount of groundwater that can supply water to streams during times of drought.

4) The MVP gas pipeline construction will degrade karst environments.

Karst terrain is strongly developed in the limestone bedrock underlying Peters Mountain in the southeastern portion of Monroe County. This karst terrain contains a unique array of extensive cave systems, bedrock voids, and associated drainage basins. Proposed construction activities will result in increased stormwater discharge and decreased groundwater recharge, thereby increasing flow to sinkholes and changing the groundwater flow patterns through caves. Blasting along the proposed MVP work corridor will degrade fragile cave systems by causing collapse as well as by causing changes in the groundwater flow and direction responsible for maintaining the moist cave conditions. There is a strong potential for collapse of the gas pipeline where construction occurs in karst terrain.

5) The MVP gas pipeline construction will create the potential for pipeline collapse in areas known to have experienced earthquakes.

The U.S. Geological Survey (USGS) 2014 Seismic Hazard Map depicts Peters Mountain, Monroe County, in a zone of concern for earthquake events. The West Virginia Geological Survey 2014 earthquake map indicates several recent earthquakes in Monroe County. Although MVP discounts the seismic activity as insignificant, the combination of earthquakes in karst areas where the proposed MVP gas pipeline would be located presents definite concern because the karst areas are susceptible to collapse even without earthquakes.

6) Cumulative damage would result from the MVP gas pipeline construction.

It is stated in the MVP DEIS that, “Construction and operation of the Projects would likely result in only short-term impacts on water resources... These impacts, such as increased turbidity, would return to baseline levels over a period of days or weeks following construction.” The findings provided herein support the conclusion that construction of the proposed MVP gas pipeline project across the karst area of Peters Mountain would result in cumulative adverse impacts to surface and groundwater resources. The increased stormwater discharge from the proposed construction areas would cause increased stream velocity downstream, with the result of increased downstream stream bank erosion, increased turbidity, and increased sedimentation in the stream beds, which adversely impacts aquatic habitats. This cumulative damage to aquatic habitats, through time, will not disappear, but rather, will cause the death of aquatic organisms and will reduce water quality. When the turbidity returns to baseline levels, the sediment remains. The degradation of water quality will also adversely impact the public water supplies within the Red Sulphur PSD.

Increased surface water flow to sinkholes will cause warmer temperatures in karst environments, thereby adversely impacting cave-dwelling species. Reduced groundwater recharge will change moisture conditions in caves, thereby adversely impacting cave-dwelling species.

SECTION 1.0

THE KARST AREA OF PETERS MOUNTAIN, MONROE COUNTY

Peters Mountain is located in the Valley and Ridge Physiographic Province within the southeastern portion of Monroe County. The area is characterized by trellis stream drainage in closely spaced anticlines (arch-shaped bedrock folds) and synclines (trough-shaped bedrock folds). The combination of folded bedrock and downcutting by streams has created mountainous relief as much as 2,000 feet. Karst terrain, characterized by numerous springs, sinkholes, and caves, is well developed in the area proposed for the MVP gas pipeline project where it extends between approximately MP 194.0 to MP 194.4.

SECTION 1.0.1

GEOLOGY OF THE KARST AREA OF PETERS MOUNTAIN, MONROE COUNTY

It is in this southeastern portion of Monroe County that the proposed MVP gas pipeline route crosses the St. Clair fault. At this location, older limestone and dolostone carbonate rock units were thrust to the northwest over younger bedrock units. The St. Clair fault is therefore identified as an overthrust fault. Faulted areas are characterized as fault zones rather than just one fracture along which there has been displacement. Fault zones contain numerous faults and fractures. Limestone of the Ordovician aged Beekmantown Group, Stones River Group, and Moccasin Formation occur at successive distances to the southeast, away from the St. Clair fault zone. Further to the southeast are the Martinsburg Shale and then the Silurian Tuscarora Sandstone, which comprise the ridge-forming rocks of Peters Mountain. Figure 1.0.1-1 is a schematic geologic cross-section depicting the geologic bedrock units. The St. Clair fault zone is depicted where the tilted bedrock units, shown as orange, occur on the right side of the cross-section.

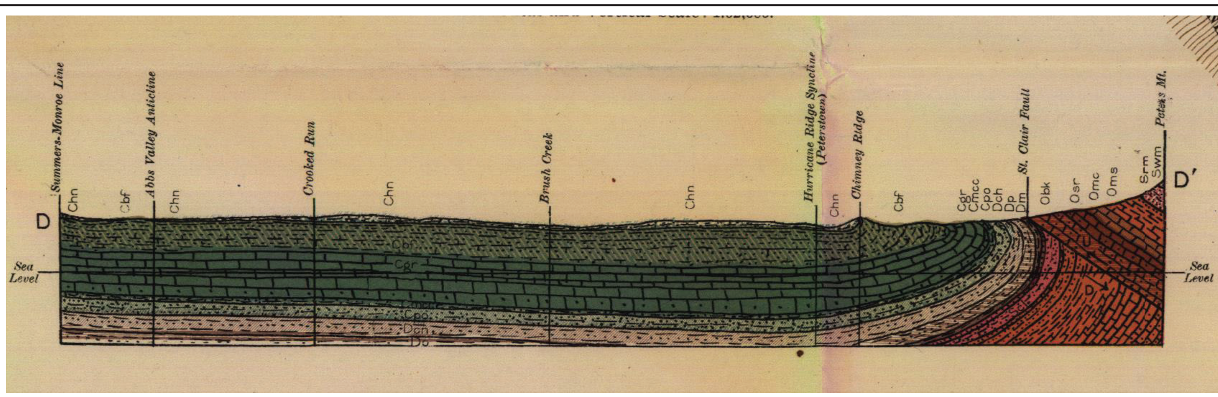


Figure 1.0.1-1 – Geologic cross-section of bedrock units in southeastern Monroe County from northwest (D) to southeast (D'), taken from Reger, et al, 1925. The St. Clair Fault (near the right side of the diagram) separates the younger rock units to the northwest from the older rock units to the southeast.

Bedrock outcrops provide the orientation of the bedrock and reveal the bedding planes and vertical fractures, as shown in Figure 1.0.1-2.

Figure 1.0.1-2 – Bedrock exposure near MP 194.3, showing the bedding planes parallel to the tilt of the bedrock and fractures perpendicular to the bedding planes.

SECTION 1.0.2

DEPTH TO BEDROCK

Specific soils series develop based on the following factors: parent material, topography, climate, living organisms, and time. Soils scientists estimate that a time period greater than 100 years is required for one inch of soil to form (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wa/soils/?cid=nrcs144p2_036333). Soil is therefore considered to be a non-renewable resource.
The Natural Resources Conservation Service (NRCS) provides soils information which includes the description of soils and the depth to bedrock. Within the karst area of Peters Mountain, the soils contain numerous rock fragments up to 6 inches long and the depth to bedrock ranges up to 5 feet deep. The depth to bedrock, based on soil descriptions, is generally less than 5 feet.

SECTION 1.0.3

KARST TERRAIN

Karst terrain in Monroe County is distinctive within the limestone and dolostone bedrock located southeast of the St. Clair fault zone. Karst terrain is characterized by the presence of sinkholes, caves, cavities (voids), sinking streams, and springs, as illustrated in Figure 1.0.2-1.

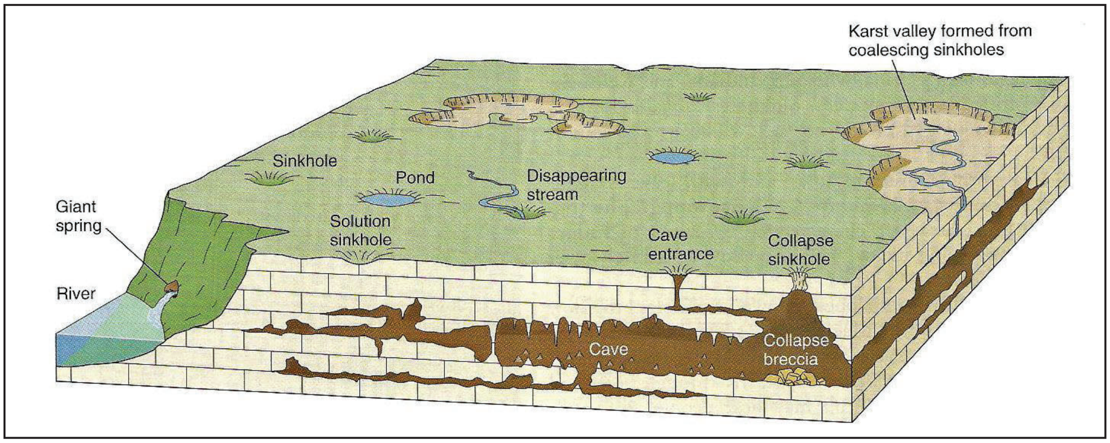


Figure 1.0.3-1 – Features typical of karst terrain.

Draper Aden Associates (DAA) prepared a "Karst Hazards Assessment (Desktop Review and Field Reconnaissance" (dated April 16, 2016) for MVP to present as DR2 RR2-12 to FERC in response to FERC's Environmental Information Request #2 (March 31, 2016). The report provides locations and descriptions of karst areas along the proposed MVP gas pipeline route, including the presence of karst features on Peters Mountain between MVP Milepost 193.90 and 194.78 in Monroe County, adjacent to the St. Clair fault zone where older limestone bedrock units occur at the ground surface. There are abundant springs in this area, located in the Red Sulphur PSD, which have historically provided water to a fish hatchery as well as a large number of private residences.

Information from tables and maps presented in the DAA report is excerpted and summarized below (Table 1.0.3-1) for the Peters Mountain area in Monroe County; additional information provided on the DAA maps is shown in red. An "open throat" refers to an opening in the sinkhole, such as an open fracture, into which water can flow into the rock or cavity below the sinkhole. In some cases, an "open throat" provides an opening into which an animal or people could traverse downward into a rock cavity (cave) below. Figure 1.0.3-2 provides a map showing the approximate locations of sinkholes and caves noted in the DAA report.

Table 1.0.3-1 – Summary of karst features in Monroe County, excerpted from tables and maps (*map information shown in red*) by Draper Aden Associates for the MVP DR2 RR2-12 response to FERC.

MVP Milepost	Feature	Field Check	Description	Concerns
193.90	Begin Dolomite	No	St. Clair thrust fault	This area historically known to have extensive and well documented cave and karst development. High karst potential with significant cave and karst feature development.
194.24	Sinkhole	No	Sinkhole mapped by desktop review approximately 100 feet to east of proposed alignment. Proposed alignment crosses watershed associated with the sinkhole. Other small sinkholes are located approximately 150 feet northeast. *All these sinkholes are shown on the DAA map as having open throats.*	Construction across or in near vicinity of sinkhole may lead to long-term differential settlement and pipeline instability. Construction runoff and fluid discharge may impact sinkhole, which may in turn lead to subsurface discharge to groundwater. Sinkhole may have a hydraulic connection to nearby Bobcat Cave or Rich Creek Cave/Spring.
194.35	Sinkhole	No	Sinkholes mapped by desktop review more than approximately 800 feet west of alignment. *These sinkholes are shown on the DAA map as having open throats.*	Construction runoff and fluid discharge may impact sinkhole
194.36	Begin Limestone	No	Begin Limestone area	This area historically known to have extensive and well documented cave and karst development. High karst potential with significant cave and karst feature development
194.40	Sinkhole and Cave	No	Bobcat Cave, described as a small room located in a large sinkhole, location uncertain, to west. Mapped by desktop review.	Construction across or in near vicinity of an open throat sinkhole may lead to long-term differential settlement and pipeline instability. Construction runoff and fluid discharge may impact sinkhole, which may in turn lead to subsurface discharge to groundwater. Sinkhole may have a hydraulic connection to nearby Bobcat cave or Rich Creek Cave Spring.
194.55	Spring and cave	No	Rich Creek Spring (headwaters of Rich Creek, water supply for Red Sulphur PSD and Town of Peterstown, WV). Rich Creek Cave and Rich Creek Fish Hatchery were mapped approximately 1,500 feet west of the proposed alignment, which is at a higher elevation than the spring which distances it from potential impact. However, the presence of sinking streams and open throat sinkholes could provide direct conduit to the subsurface flow. Rich Creek Spring is large, serves a fish hatchery, headwater of Rich Creek which is back up water supply for Peterstown.	The primary concern is potential impact to water resources. Construction and maintenance may impact Rich Creek Cave and Spring and the downstream surface water body Rich Creek.
194.48	Sinkhole	No	Open throat sinkhole located approximately 600 feet west of the proposed alignment	These sinkholes are upstream of the MVP alignment.
194.58	Sinkhole	No	Sinkhole located approximately 80 feet east of the proposed alignment. *This sinkhole is shown on the map as having an open throat.*	Construction across sinkhole may lead to long-term differential settlement and pipeline instability. Construction runoff and fluid discharge may impact sinkhole, which may in turn lead to subsurface discharge to groundwater.

194.62	Sinkhole	No	Several sinkholes mapped by desktop review approximately 300 feet west of proposed alignment. *These sinkholes are shown on the map as having open throats.*	These sinkholes are upstream of the MVP alignment
194.78	End Limestone	Approxi-mate end of limestone	-	-

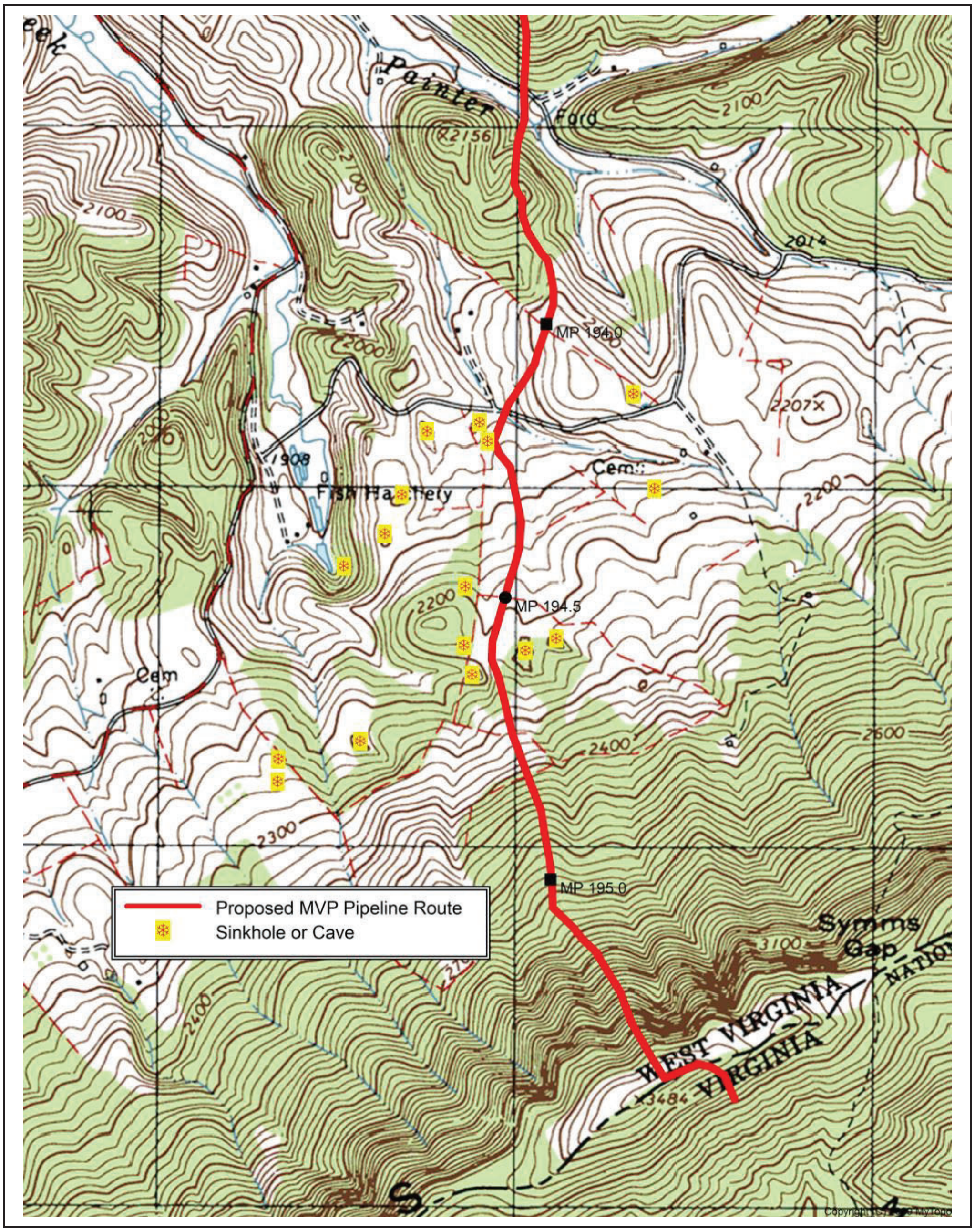


Figure 1.0.3-2 – Map showing approximate locations of caves and sinkholes described by DAA and listed in Table 1.0.3-1.

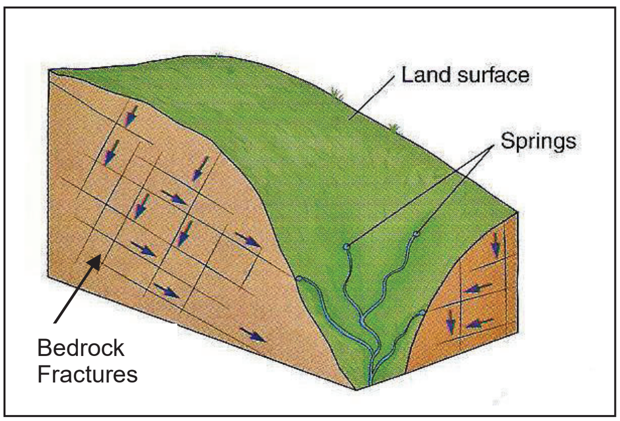
Many of the sinkhole depressions are not readily apparent. Several sinkholes were observed in the karst area of Peters Mountain which appeared to be simple depressions. However, the sediment within the sinkholes moved vertically upward or downward in response to the groundwater flow. Such sinkholes are highly unstable.

SECTION 1.0.4

GROUNDWATER

Table 4.3.1-1 in the MVP DEIS provides a listing of aquifers crossed by the MVP. This list indicates that the Valley and Ridge aquifer system flows through sandstone, shale, limestone, and dolomite within the Valley and Ridge Physiographic Province in Monroe County, West Virginia. Groundwater flow through karst areas (limestone and dolomite) exhibits both diffuse flow and conduit flow. Groundwater recharge occurs as diffuse flow where soils transfer precipitation downward to bedrock, where the flow continues downgradient through bedrock fractures and along bedding planes. As shown in Figure 1.0.4-1, seeps and springs occur where groundwater flows through bedrock fractures and bedding planes, intercepting the ground surface. Conduit flow consists of "integrated systems of openings ranging from solutionally widened joints and bedding plane partings to pipelike passages many meters in diameter" (White, 1988). Pipelike passages and larger solutionally widened joints and bedding plane partings can be observed in the caves throughout the area, and are also present, although inaccessible for observation, in limestone and dolomite throughout the area.

Figure 1.0.4-1 – Fractures within any rock provide conduits through which groundwater may flow downward or at angles to the ground surface. Where bedding planes of the rock or where fractures in the rock intercept the ground surface, it is common for springs or seeps to occur. Seeps and springs also provide water directly to streams.



Dasher (2000) provides descriptions of groundwater in extensive karst sub-basins of caves in Greenbrier and Monroe counties. Dye traces provide evidence of the groundwater flow directions within the limestone. Springs attest to the flow of groundwater through fractures and along bedding planes within the limestone, in addition to flow through interconnected voids in the limestone. The karst groundwater flow does not correlate with surface water flow of streams on the ground surface.

Rich Spring, located near MP 194.5, issues from a cave and provides water to a fish hatchery, as shown on the cover photo of this hydrogeological assessment report. Numerous springs and sinkholes occur within the area, illustrating the connected groundwater routes within the limestone.

Groundwater recharge depends on ground cover. Forested ridges provide the ground cover facilitating the greatest amount of groundwater recharge. The trees on the mountain ridges intercept rainfall so that it gently penetrates the ground as groundwater rather than flowing overland as runoff. This means that 1) the rain will gently fall to the ground and recharge groundwater and 2) the surface flow of rainwater on the ground will be slower than in cleared areas, thereby reducing the velocity and quantity of stormwater drainage. Conversely, where development occurs on forested ridges or where there are numerous roads constructed on forested ridges, the protective tree canopy is lost, the stormwater flow is greater in the cleared areas, groundwater is intercepted by road construction, and increased stormwater drainage results in habitat destruction within streams and the consequent death of aquatic organisms.

As depicted in Figure 1.0.4-2, when rainwater is intercepted by trees on forested ridges, the rainfall gently penetrates the ground surface and migrates downward through the soil to bedrock. The water then flows through bedrock fractures and along bedding planes to continue migrating downward or to form seeps and springs where the fractures or bedding planes intercept the ground surface. Seeps and springs can occur at various elevations on mountain slopes, depending on where the bedrock fractures or bedding planes intercept the ground surface, and can also occur along streams and rivers. As the quantity of groundwater accumulates beneath the ground surface, a hydraulic gradient forms, causing the groundwater to move downgradient to nearby streams and rivers or to lower areas where the water may reach streams and rivers that are farther away.

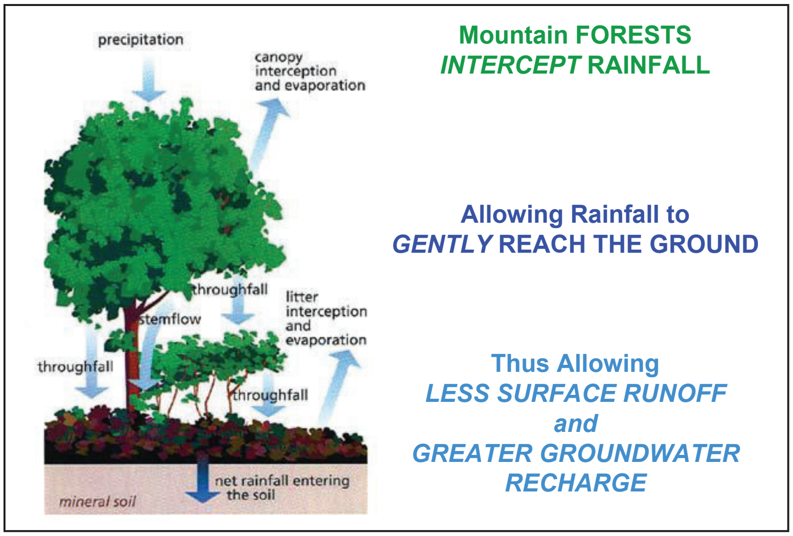


Figure 1.0.4-2 – Forests on ridges facilitate groundwater recharge and reduced stormwater runoff.

SECTION 1.0.5

PUBLIC WATER SUPPLY IN MONROE COUNTY

The Source Water Assessment and Protection Program (SWAPP) was established under the Safe Drinking Water Act. This Act requires every state to 1) delineate the area from which a public water supply system receives its water; 2) inventory land uses within the recharge areas of all public water supplies; 3) assess the susceptibility of drinking water sources to contamination from these land uses; and 4) publicize the results to provide support for improved protection of sources. Source Water Assessment Reports were prepared by the West Virginia Bureau for Public Health, Source Water Assessment and Protection Unit (WVBPH) to identify the most significant potential contaminant sources that could threaten the quality of the Public Supply District (PSD) public water supplies. In 2005, the WVBPH prepared the Source Water Assessment Report for the Red Sulphur PSD in Monroe County. The report provides two maps: 1) a map showing the Watershed Delineation Area, which for the Red Sulphur PSD comprises 26 square miles of the Upper New River Watershed; and 2) a map showing the Zone of Critical Concern, which delineates a corridor along all the streams within the Watershed Delineation Areas in order to define the susceptibility to potential surficial contaminants. The corridor width from each bank of a principal stream is 1,000 feet and the corridor width from each bank of a tributary draining to a principal stream is 500 feet. The corridor provides the Zone of Critical Concern (ZCC).

In response to the FERC Environmental Information Request #2, dated March 31, 2016, the MVP Attachment DR2 RR2-6 (submitted April 15, 2016 by Draper Aden Associates), selected maps provided in the Source Water Assessment Reports that show the Zones of Critical Concern for water quality assessment, including the Red Sulphur PSD for public water supply in Monroe County. However, the Watershed Delineation Maps, also provided in the WVBPH reports, are not included. The Zones of Critical Concern address only water quality; they do not address water quantity. The focus of the WVBPH in preparing the Source Water Assessment Reports was primarily on water quality. In 2004, the West Virginia legislature enacted the West Virginia Water Resources Protection Act (WV Code §22-26-1), which requires consideration of the quantity of public water supplies, in addition to the quality of public water supplies. However, the West Virginia Department of Environmental Protection did not develop a plan for this legislation until 2008, after the WVBPH Source Water Assessment Reports were completed. The Watershed Delineation Area maps provided in the reports indicate that in the Rich Creek watershed, Monroe County, the proposed MVP gas pipeline route extending from approximately MVP milepost 190.2 to 195.4 is located in the Red Sulphur PSD area of concern. Numerous headwater areas of first order high gradient stream tributaries are located in the Red Sulphur PSD. These headwater areas are critically important to maintaining water quality, water quantities, groundwater recharge, and watershed functions in the river continuum. The proposed MVP pipeline route crosses a first order high gradient stream at MP 194.2.

In the Red Sulphur PSD SWAPP, concern is expressed about the amount of stormwater runoff as it impacts the water quality within the PSD. The biological and chemical health are also of great concern. Increased stormwater runoff transports sediment to streams, causing turbidity. Increased stormwater discharge to streams causes downstream stream bank erosion, which releases sediment into streams, thereby reducing the water quality. The biological health of the stream is degraded where sediment accumulates in the stream bed, destroying aquatic habitats.

SECTION 1.0.6

SEISMIC HAZARDS

In the abstract, “West Virginia Earthquakes: Crustal Adjustments Along The Rome Trough Or Something Else?” (by Ronald R. McDowell, J. Eric Lewis, and Phillip A. Dinterman; West Virginia Geological and Economic Survey, 1 Mont Chateau Road, Morgantown, WV 26508; http://www.wvgs.wvnet.edu/www/presentations/2014/WV-seismic_2014.pdf), it is stated that there have been isolated earthquakes since 1966 which are associated with ancient faults. A map is provided (Figure 1.0.6-1) showing that most of these earthquakes have occurred in the western part of West Virginia within an area known as the Rome Trough. However, it is evident on the map that several earthquakes have occurred in Summers and Monroe Counties.

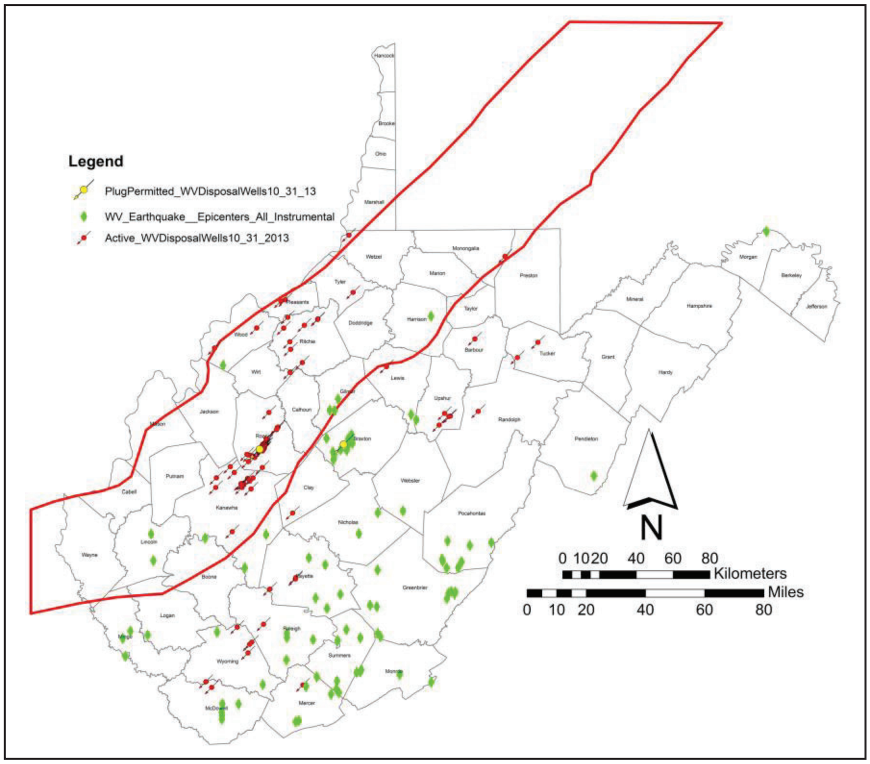


Figure 1.0.6-1 – WVGES map showing the location of several earthquake epicenters in Summers and Monroe Counties.

The U.S. Geological Survey provides a map on its website http://earthquake.usgs.gov/earthquakes/states/west_virginia/images/westvirginia_haz.jpg which shows areas of seismic hazard, with Summers and Monroe Counties being in a zone of concern (Figure 1.0.6-2).

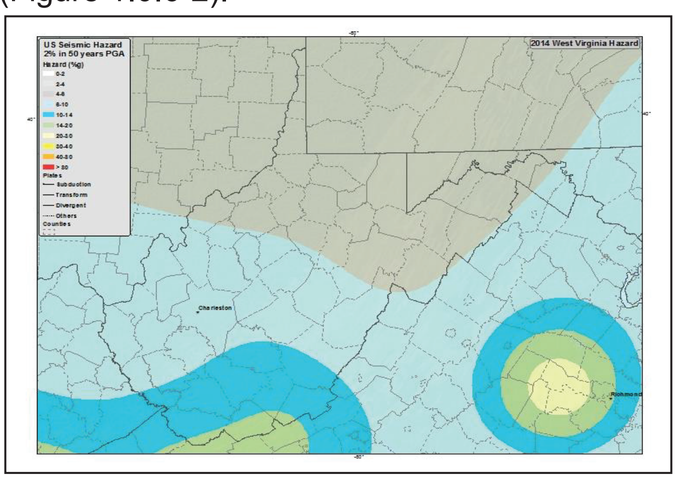


Figure 1.0.6-2 – USGS 2014 Seismic Hazard map showing Summers and Monroe Counties in a zone of concern.

Figure 1.0.6-3 is an Earthquake Epicenter Density map provided by the Virginia Department of Mines, Minerals, and Energy (https://dmme.virginia.gov/DGMR/EQHazardMapping.shtml)

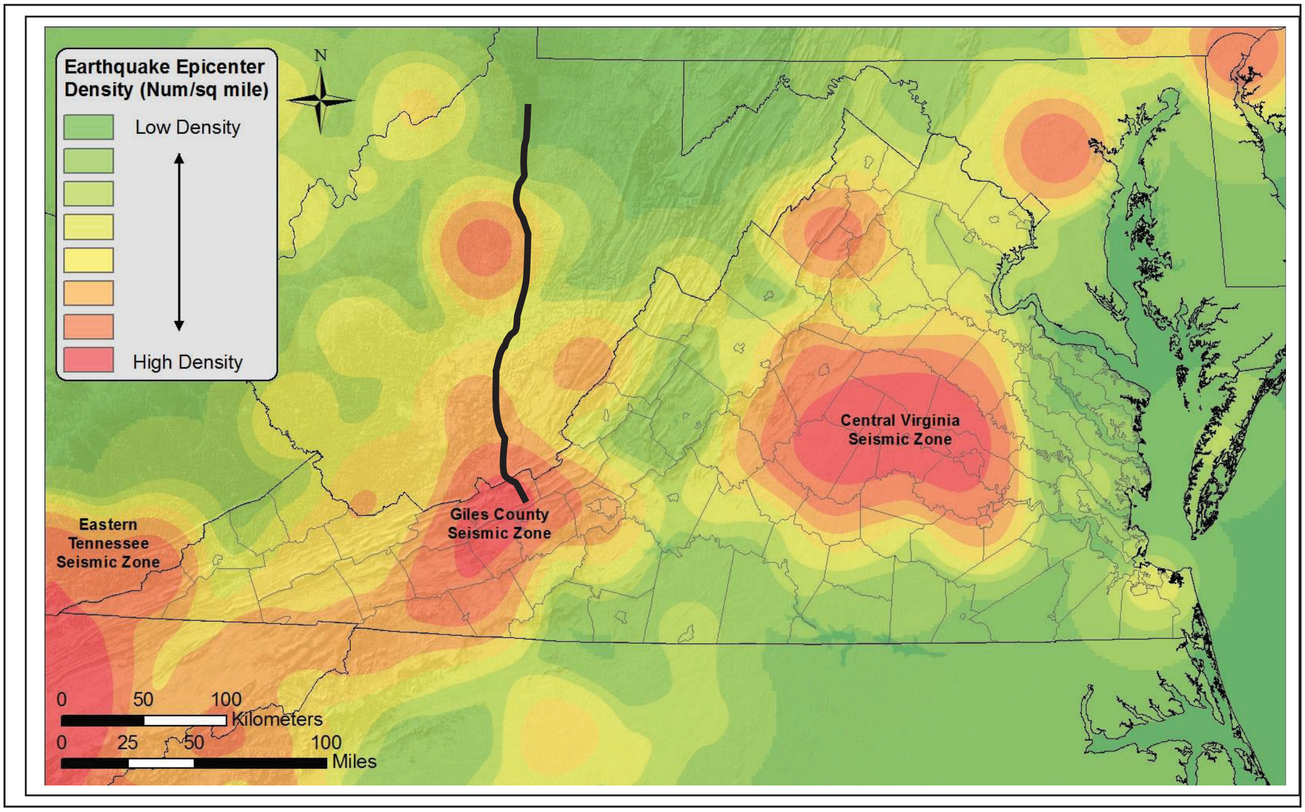


Figure 1.0.6-3 – Map showing the densities of earthquake epicenters, provided as a color scale indicating the relative densities in numbers per square mile. Three major earthquake zones are identified. The Giles County Seismic Zone extends into Monroe and Summers Counties, West Virginia. The black line is the approximate location of the proposed MVP gas pipeline.

SECTION 2.0

DESCRIPTION AND REQUIREMENTS FOR CONSTRUCTION OF THE MVP GAS PIPELINE IN THE KARST AREA OF PETERS MOUNTAIN

The route of the proposed MVP gas pipeline crosses ridgelines and intervening mountainsides as well as streams and rivers. The MVP reports include details of the requirements for placing their 42-inch diameter pipelines into trenches which are mostly located on mountain ridges. In the MVP DEIS, the temporary construction easement for the pipeline installation work corridor is 125 feet.

In the MVP General Project Description Resources Report 1 (RR1), dated October, 2015, provides: “Generally, the trench will be excavated at least 12 inches wider than the diameter of the pipe. The sides of the trench will be sloped with the top of the trench up to 12 feet across, or more, depending upon the stability of the native soils. The trench will be excavated to a sufficient depth to allow a minimum of three feet of soil cover between the top of the pipe and the final land surface after backfilling (minimum of 18 inches of cover will be provided in consolidated rock in Class 1 or greater locations or in ditches, where 24 inches of cover is required). Locations such as waterbodies, roads and railroads will include 36 inches of cover per applicable permits."

Summarizing, the trench for the pipe itself is 5.5 feet wide. However, because the walls are sloped upward to the surface, the surface of the trenched area will be 12 feet wide. The Typical Drawings provided in RR1, Appendix 1-C1, do not indicate the trench depths. Trench descriptions in RR1 provide that the depth of excavation is 3 feet at the surface down to the pipe, plus 3.5 feet of pipe, plus up to 2 feet of cover at the base of the trench. The total depth is, then, approximately 8.5 feet.

The work corridor of approximately 125 feet will be leveled by deforestation, excavation, and grading (Figure 1). RR1 describes trench dewatering procedures: "The storm water will be pumped from the trench to a location down-gradient of the trench. The trench will be dewatered in a manner that does not cause erosion and does not result in heavily silt-laden water flowing into any waterbody or wetland. The storm water will be discharged to an energy dissipation/filtration dewatering device, such as a hay bale structure." On the left side of Figure 2.0-1, a hill has been excavated to its intersection with a ravine. Water can be observed in the trench by the ravine where the pipeline is to be placed. Groundwater from the hillside would also flow toward the ravine and the pipeline trench. However, MVP provides no discussion concerning the interception of groundwater on cut slopes/hillsides.

Figure 2.0-1 – Leveled work corridor for pipeline installation, showing cut hillsides and evident dewatering into the pipeline trench. Heavy equipment and pick-up trucks provide a scale.

SECTION 3.0

IMPACTS OF THE PROPOSED MVP GAS PIPELINE CONSTRUCTION TO THE KARST AREA OF PETERS MOUNTAIN

Deforestation within the proposed MVP work corridor will result in increased stormwater discharge and decreased groundwater recharge. Increased stormwater discharge within the karst terrain of Peters Mountain will increase the flow of surface water to sinkholes, introducing warmer water to the cave environment. Cave dwelling species require cooler temperatures and will be adversely impacted by the warmer conditions. The increased stormwater discharge flowing into streams will result in stream bank erosion downstream and, consequently, increased sedimentation downstream. Where the stream crossing is proposed for the MVP gas pipeline construction at MP 194.2, stream bedding forms will be destroyed and aquatic habitats will be destroyed. The increased stream bank erosion downstream of this crossing will result in turbid stream conditions and cumulative sedimentation.

The MVP DEIS provides the following description of the adverse impacts of sedimentation: "Increased sedimentation and turbidity resulting from in-stream and adjacent construction activities would displace and impact fisheries and aquatic resources. Sedimentation could smother fish eggs and other benthic biota and alter stream bottom characteristics, such as converting sand, gravel, or rock substrate to silt or mud. These habitat alterations could reduce juvenile fish survival, spawning habitat, and benthic community diversity and health. Increased turbidity could also temporarily reduce dissolved oxygen levels in the water column and reduce respiratory functions in stream biota. Turbid conditions could also reduce the ability for biota to find food sources or avoid prey."

It is stated in the MVP DEIS that, "Construction and operation of the Projects would likely result in only short-term impacts on water resources... These impacts, such as increased turbidity, would return to baseline levels over a period of days or weeks following construction." The findings provided herein support the conclusion that there would be cumulative adverse impacts resulting from increased stormwater discharge from the construction areas of the proposed pipeline. Increased turbidity results in increased sedimentation in the stream beds, which adversely impacts aquatic habitats. When the turbidity returns to baseline levels, the sediment remains. With increased stormwater discharge from the construction sites, increased stream volumes and velocities cause downstream stream bank erosion, resulting in more sediment accumulation in the stream beds. This cumulative damage to aquatic habitats, through time, will not disappear, but rather, will cause the death of aquatic organisms and will reduce water quality within the Red Sulphur PSD ZCC.

Blasting along the proposed MVP work corridor will degrade fragile cave systems by causing collapse as well as by causing changes in the groundwater flow and direction responsible for maintaining the moist cave conditions. There is a strong potential for collapse of the gas pipeline where construction occurs in karst terrain.

SECTION 4.0

CONCLUSIONS

The findings of this report provide evidence that construction of the proposed MVP gas pipeline will result in adverse impacts on numerous springs, sinkholes, and caves present in the karst area between MP 194.0 to MP 195.0. This area is also within the Red Sulphur Public Service District (PSD), which provides a public water supply. Construction of the proposed MVP gas pipeline across this karst area will cause environmental degradation and destruction which will adversely impact surface water and groundwater resources in the Red Sulphur PSD, including the following:

1) Increased stormwater discharge will result from deforestation for the proposed MVP gas pipeline construction.

Ground cover determines the amount of precipitation that will penetrate the ground as groundwater recharge or run off the surface. Forested areas intercept rainfall, allowing the rain to gently reach the ground surface. Therefore, in forested areas, the rain will penetrate the ground to recharge groundwater and will flow across the ground surface with less volume and velocity (discharge) than in non-forested areas. Even where sediment from stormwater discharge from construction areas is captured in erosion control structures, the increased discharge flowing into streams will result in stream bank erosion downstream and, consequently, increased sedimentation downstream. Where stream crossings are planned for the MVP gas pipeline construction, stream bedding forms will be destroyed, aquatic habitats will be destroyed.

2) Soil removal and compaction for the proposed MVP gas pipeline construction will adversely impact headwater area functions and groundwater recharge to springs, wetlands, and streams.

The composition of weathering products from the underlying bedrock determines characteristics of soils relating to water retention, pore space, and acidity. The organic fraction of the soils results from interactions between the available vegetation and soil organisms such as microbial communities, worms, and tree roots. Soil scientists estimate that a time period greater than 100 years is required for one inch of soil to form. For this reason, soil is considered a non-renewable resource. Soil removal and compaction within the work corridor will destroy the soils which regulate the transport of surface water, and also carbon, nitrogen, and oxygen, to headwater areas of first order high gradient streams and to wetlands. Soil removal and compaction would also result in increased stormwater discharge and decreased groundwater recharge to springs, wetlands, and streams.

3) Blasting conducted for leveling the proposed MVP gas pipeline work corridor and for trenching construction will adversely impact groundwater flow to springs, wetlands, and streams.

Blasting of bedrock to create a level work corridor and to install the proposed pipeline into trenches approximately 10 feet deep will intercept groundwater flow, thereby reducing the groundwater flow to seeps and springs. Reduced groundwater recharge decreases the hydraulic head that moves the groundwater downgradient to nearby seeps and springs and also to streams farther downgradient. Reduction of the hydraulic gradient decreases the amount of groundwater that can supply water to streams during times of drought.

4) The MVP gas pipeline construction will degrade karst environments.

Karst terrain is strongly developed in the limestone bedrock underlying Peters Mountain in the southeastern portion of Monroe County. This karst terrain contains a unique array of extensive cave systems, bedrock voids, and associated drainage basins. Proposed construction activities will result in increased stormwater discharge and decreased groundwater recharge, thereby increasing flow to sinkholes and changing the groundwater flow patterns through caves. Blasting along the proposed MVP work corridor will degrade fragile cave systems by causing collapse as well as by causing changes in the groundwater flow and direction responsible for maintaining the moist cave conditions. There is a strong potential for collapse of the gas pipeline where construction occurs in karst terrain.

5) The MVP gas pipeline construction will create the potential for pipeline collapse in areas known to have experienced earthquakes.

The U.S. Geological Survey (USGS) 2014 Seismic Hazard Map depicts Peters Mountain, Monroe County, in a zone of concern for earthquake events. The West Virginia Geological Survey 2014 earthquake map indicates several recent earthquakes in Monroe County. Although MVP discounts the seismic activity as insignificant, the combination of earthquakes in karst areas where the proposed MVP gas pipeline would be located presents definite concern because the karst areas are susceptible to collapse even without earthquakes.

6) Cumulative damage would result from the MVP gas pipeline construction.

It is stated in the MVP DEIS that, "Construction and operation of the Projects would likely result in only short-term impacts on water resources... These impacts, such as increased turbidity, would return to baseline levels over a period of days or weeks following construction." The findings provided herein support the conclusion that construction of the proposed MVP gas pipeline project across the karst area of Peters Mountain would result in cumulative adverse impacts to surface and groundwater resources. The increased stormwater discharge from the proposed construction areas would cause increased stream velocity downstream, with the result of increased downstream stream bank erosion, increased turbidity, and increased sedimentation in the stream beds, which adversely impacts aquatic habitats. This cumulative damage to aquatic habitats, through time, will not disappear, but rather, will cause the death of aquatic organisms and will reduce water quality. When the turbidity returns to baseline levels, the sediment remains. The degradation of water quality will also adversely impact the public water supplies within the Red Sulphur PSD.

Increased surface water flow to sinkholes will cause warmer temperatures in karst environments, thereby adversely impacting cave-dwelling species. Reduced groundwater recharge will change moisture conditions in caves, thereby adversely impacting cave-dwelling species.

SECTION 5.0

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My education includes a bachelor's degree in Geology and a doctoral degree in Marine Science (specializing in Marine Geology), both from the College of William and Mary in Williamsburg, VA. I have a Credential in Ground Water Science from Ohio State University and I am a Licensed Professional Geologist. I have held teaching positions at the high school level and at the college level, and have provided geology and hydrogeology presentations, workshops, and classes to state and federal environmental employees, to participants in the Regional Conference in Cumberland, MD for the American Planning Association, and to participants in the WV Master Naturalist classes. I have served as an expert witness in hydrogeology before West Virginia government agencies.

As a Hydrogeological Consultant (2000 – Present), I have conducted hydrogeological investigations, provided hydrogeological assessment reports, served as an expert witness in hydrogeology before the West Virginia Public Service Commission in three cases and before the West Virginia Environmental Quality Board in one case, and provided numerous presentations and workshops in hydrogeology to state and federal environmental employees (including USFWS and WV FEMA Managers), participants in the Regional Conference in Cumberland, MD for the American Planning Association, participants at civic and landowner meetings, and participants in the WV Master Naturalist classes.

As a Senior Geologist for the Virginia Department of Environmental Quality (1997-1999), I determined direction of groundwater flow and the pollution impacts to surface water and groundwater at petroleum release sites and evaluated corrective actions conducted where petroleum releases occurred. At sites where the Commonwealth of Virginia assumed responsibility for the pollution release investigation and corrective action implementation, I managed the site investigations for the Southwest Regional Office of the Virginia Department of Environmental Quality (DEQ). This included project oversight from contract initiation through closure.

As a Senior Geologist and Project Manager for the Environmental Department at S&ME, Inc. (Blountville, TN, 1992-1997), I conducted geology and groundwater investigations. I supervised technicians, drill crews, geologists, and subcontractors. The investigations were conducted in order to obtain permits for landfill sites and to satisfy regulatory requirements for corrective actions at petroleum release sites. My duties also included conducting geophysical investigations using seismic, electrical resistivity, and ground penetrating radar techniques. I conducted numerous environmental assessments for real estate transactions. I also conducted wetlands delineations and preparation of wetlands mitigation permits.

As the District Geologist for the Virginia Department of Transportation (1985-1992), my job duties included obtaining and interpreting geologic data from fieldwork and review of drilling information in order to provide foundation recommendations for bridge and road construction. My duties included supervision of the drill crew and design of asphalt and concrete pavements for highway projects. Accomplishments included preliminary foundation investigations for interstate bridges and successful cleanup of leaking underground gasoline storage tanks and site closures at numerous VDOT facilities.

While earning my doctoral degree at the College of William and Mary, I worked as a graduate assistant on several grant-funded projects. My work duties included measuring tidal current velocities and tidal fluctuations at tidal inlets; land surveying to determine the geometry and morphology of numerous tidal inlets; determining pollution susceptibilities of drainage basins using data from surface water flow parameters, hydrographs, and chemical analyses; developing a predictive model for shoreline erosion during hurricanes based on calculations of wave bottom orbital velocities resulting from various wind velocities and directions; performing sediment size and water quality analyses on samples from the Chesapeake Bay and James River; conducting multivariate statistical analyses for validation of sediment laboratory quality control measures; reconnaissance mapping of surficial geologic materials in Virginia, North Carolina, and Utah for publication of USGS Quaternary geologic maps; teaching Introductory Geology laboratory classes at the College of William and Mary; and serving as a Sea Grant intern in the Department of Commerce and Resources, Virginia.

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JOB-RELATED TRAINING COURSES:

2007: Certified Volunteer Stream Monitor, West Virginia (Dept. of Environmental Protection)
2006: Certified Master Naturalist, West Virginia (Dept. of Natural Resources)
1996: Karst Hydrology, Western Kentucky University
1996: Global Positioning Systems (GPS) for Geographic Information Systems (GIS) applications, seminar conducted by Duncan-Parnell/Trimble
1995: Safe Drinking Water Teleconference, sponsored by the American Water Works Association
1992-1998: OSHA Hazardous Waste Site Supervisor training with annual updates
1990: Credential in Ground Water Science, Ohio State University

JOB-RELATED LICENSE:

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PROFESSIONAL ORGANIZATIONS

West Virginia Academy of Sciences
National Speleological Society