Mountain Valley Pipeline, LLC
Mountain Valley Pipeline Project
Docket No. CP16-10-000

Implementation Plan
Dated October 2017

Attachment IP-19

Mountain Valley Pipeline Project

Docket No. CP16-10-000

Landslide Mitigation Plan

Rev. 5, September 2017

(Updates from previous report highlighted in cyan.)

Table of Contents

List of Tables

List of Figures

Appendix

Landslide Mitigation Plan Typical Detail Drawings

1.0 INTRODUCTION

The Mountain Valley Pipeline (MVP) Project is a proposed 42-inch-diameter natural gas pipeline system that spans approximately 303 miles from northwestern West Virginia (Wetzel County) to southern Virginia (Pittsylvania County). The Project will be constructed and owned by Mountain Valley Pipeline LLC, which is a joint venture of EQT Corporation, NextEra Energy, Inc., Con Edison Gas Midstream, LLC, WGL Holdings, Inc., and RGC Midstream, LLC.

Many portions of the proposed Mountain Valley Pipeline Project (Project) route are in landslide susceptible areas as mentioned in Section 6.6 of Resource Report 6 (Ref. 1) and as shown on Figure 6.4-3 of the same report. Slope information along the Project is provided in Resource Report 1, Appendix 1-I. Landslides in the Project area occur primarily in weathered bedrock or colluvial soil and within old landslide debris located on steep slopes. Numerous landslides on the Appalachian Plateau have developed in soils derived from sedimentary rocks. Shale, especially red beds and shale-limestone sequences, disintegrate rapidly into clayey soil upon exposure. Most landslides involving soil and weathered bedrock consist of smooth, integrated, thin earth-flow slabs that may be many square yards in area but generally are less than about eight feet thick. Commonly, the slabs move no faster than about three feet or six feet per year and are normally underlain by material containing water with a hydrostatic head of as much as seven feet. In both the folded Appalachians and the Blue Ridge Mountains, numerous slow-moving debris slides form in colluvial soil and scree that are particularly abundant on slopes underlain by sandstone and metamorphic rocks.

MVP has performed a review of potential areas of landslide or rockfall concern along the pipeline alignment. This was completed through review of available historic aerial photographs, soils data, and topographic maps to identify indications of potential landslide hazards. Areas investigated as part of this report are shown on the project alignment sheets and erosion and sediment control plans.

MVP has developed this Landslide Mitigation Plan to outline the special procedures and best management practices (BMPs) that will be implemented during the pipeline installation and post-construction periods to mitigate landslide occurrence.

All mileposts (MP) reference herein refer to the October 2016 Proposed Route unless otherwise specified.

2.0 FIELD INSPECTION

MVP has completed field observations of the steep sidehill slope sites where potential stability issues were identified, as summarized Table 1 of this document. The field observations for these sites included slope characteristics, GPS mapping of observed slides, slumps, rockfalls, scarp locations, and the presence of geotropically affected trees, drainage features, and gullying. In 2015, investigations were conducted by a consulting geotechnical engineer with experience in landslide evaluation, whose resume is attached. In 2016 and 2017, additional site visits were conducted by MVP personnel with experience in landslide evaluation.

3.0 SLOPE EVALUATIONS

The occurrence of a landslide is dependent on a combination of site-specific conditions and influencing factors. Common factors that contribute to landslides principally fall into four broad categories (WSDOT 2014):

- Climatic/hydrologic (rainfall or precipitation)
- Geomorphic (slope form and conditions)
- Geologic/geotechnical/hydrogeological (material type and groundwater)
- Human activity

Climatic factors that influence landslides include the duration of rainfall events, intensity of rainfall, type of precipitation (rain or snow), and rainfall conditions over a period of time (antecedent conditions). It is common for landslides to occur after intense or prolonged periods of rain. Some episodes of widespread landslide occurrences correspond to storms that involve the rapid melting of previously accumulated snow by wind and warm rain. The most disastrous landslide events in the Appalachian Plateau region have been associated with persistent rainfall followed by a heavy downpour along steep slopes which causes debris flows and debris avalanches. Debris flows develop on steep slopes as a result of heavy rainfall that saturates the soil, which under the extra weight and lubrication breaks loose and becomes slurry that pulls surface vegetation and large trees downslope. Infiltration of precipitation into surface soils was considered in the mitigation measures presented in this report.

Geomorphic factors that affect slope stability include height and steepness, as well as vegetation and underlying geology. Increased steepness, concave topographic slopes and slope height generally correlate with reduced stability. A lack of vegetative cover will also increase the amount of rainfall that can infiltrate the slope surface. Vegetation generally inhibits surface soil erosion with erosion occurring much more rapidly on bare slopes. Whether water infiltrates into the ground or runs off is influenced by both surface vegetation and the permeability of the geologic substrate, its degree of saturation, and precipitation intensity. Either shallow bedrock conditions or a compact and fine-grained soil unit at depth will tend to cause a saturation and weakening of the near-surface, loosened soil. The approximate depth to bedrock along the pipeline is indicated in Resource Report 6, Appendix 6-B.

As mentioned in Section 1.0, the geologic and geotechnical characteristics of the region contribute to slope instability. Landslides along the project route will occur primarily in weathered bedrock or loose colluvial soil and within old landslide debris located on steep slopes. Exposed sedimentary rock formations can erode rapidly and create soils prone to landslides. Most landslides along the route are expected to be thin earth-flow type slabs rather than deep-seated circular failures. Rockfalls are also a potential hazard below bedrock outcroppings at or near the top of steep slopes associated with the cliff-forming formations such as sandstones, granite, and gneiss. These outcrops may be weathered by wind or rainfall and become loosened, leading to a violent cascade downhill, often triggering a larger landslide. Landslides also commonly recur in the same areas, thus evidence of previous events is important to the slope evaluations. Areas of high groundwater table and surface drainage paths can also contribute to the instability of slopes. Drainage paths or streams can over-steepen slopes from erosion. If known, the Hydrologic Soil Group for the surface soils is indicated in the site description. Hydrologic soil groupings are used to describe the minimum rate of infiltration obtained for bare soils after prolonged wetting.

Human activities are a common contributor to landslide events. Large excavations and fills located in mountainous areas related to rural development have increased the number of and potential for landslides. Development of this type tends to create over-steepened slopes and drainage alteration that leads to the potential for many landslides. The removal of surface vegetation during land development can affect slope stability through increased infiltration of rainfall.

Table 1 contains descriptive notes for each of the 37 slope areas of concern along the pipeline. These descriptions were obtained from Table 6.4-6 and augmented with notes from the field surveys, where possible. In addition, three areas within Jefferson National Forest (JNF), at the request of JNF personnel, and several areas identified in realigned areas of the route were also investigated and included in Table 1. Six additional areas were investigated at the request of the JNF and are discussed in detail in the *Site-Specific Design of Stabilization Measures in Selected High-Hazard Portions of the Route of the Proposed Mountain Valley Pipeline Project in the Jefferson National Forest*.

	Table 1 - Landslide Concern Areas Crossed by the Mountain Valley Pipeline					
Designation	**Beginning MP**	**Ending MP**	**Length Crossed (feet)**	**Slope (%) [a]**	**Signs of Recent Movement [b]**	**Notes [c]**
MVP-LMP-WE-01	3.3	3.8	2147	33	No*	Dormant slide and/or soil prone to movement. Intersects at least three natural drains.
MVP-LMP-HA-02	28.0	28.2	967	29	No*	Near well appurtenances. Side cut would run across at least three natural drains.
MVP-LMP-DO-03	32.4	32.6	749	32	No*	Dormant slide and/or soil prone to movement. Located at toe of slope. Hillside previously cleared.
MVP-LMP-HA-04	33.4	33.6	570	42	No*	Dormant slide and/or soil prone to movement. Located at toe of slope. Hillside previously cleared.
MVP-LMP-DO-05	34.2	34.4	377	28	No*	Moderate side slope, includes slight pipe bend. Cuts across at least one natural drain.
MVP-LMP-DO-06	34.4	34.6	907	28	No*	Downslope of ridge. Cuts across at least three, possibly four or five natural drains and one or two four-wheeler paths.
MVP-LMP-DO-07	35.1	35.4	869	40	No*	Construction equipment may need to be staged on sidehill here. Southeastern side less steep, may be better to stage.
MVP-LMP-LE-08	43.3	43.5	494	30	No*	Steep side slope, but ridge within right-of-way.
MVP-LMP-LE-09	46.2	46.5	1113	15-33	Yes*	Gravitropism and natural drains on a moderate side slope.
MVP-LMP-LE-10	46.6	46.8	448	36	Yes*	Existing dormant slide possibly upslope, and active within past twenty years. Cuts across at least one natural drain, possibly two.
MVP-LMP-LE-11	53.0	53.3	872	22	No*	Adjacent slopes composed of dormant slides. Moderate side slope directly below cemetery. Cuts across some kind of existing right-of-way or road, and at least two natural drains.
MVP-LMP-LE-12	55.1	55.2	224	35	No*	Moderate side slope, cuts across toe of slope. No signs of recent movement.
MVP-LMP-LE-13	57.2	57.7	806	18 - 40	No*	Right-of-way will run alongside hill with 32% grade and a 40% grade directly below it.
MVP-LMP-BR-14	66.8	67.0	826	15-34	No*	Moderate side slope subjacent to Weston and Gauley Bridge Turnpike Trail.
MVP-LMP-BR-15	69.2	69.5	1128	29	No*	Cuts across one large natural drainage. No signs of recent movement.

	Table 1 - Landslide Concern Areas Crossed by the Mountain Valley Pipeline					
Designation	**Beginning MP**	**Ending MP**	**Length Crossed (feet)**	**Slope (%) [a]**	**Signs of Recent Movement [b]**	**Notes [c]**
MVP-LMP-WB-16	81.8	82.1	1462	35	No*	Route crosses dormant slide area. Moderate side slope. No natural drains, but is directly above house or farm structure. Landowner issues may force it to be on the east side below the road, intersecting at least three natural drains.
MVP-LMP-WB-17	82.5	82.6	602	45	No*	Route cuts through a colluvial slope which is very prone to sliding. Very steep side slope, right above ravine, possibly crossing one natural drain.
MVP-LMP-NI-18	111.7†	111.8†	231	12 – 39	No	Moderately steep slope. Pipeline cuts through either dormant slide or slide-prone material. Not included in October 2016 Proposed Route.
MVP-LMP-NI-19	122.5	123.0	2547	7 – 43	No*	Crosses at least 5 streams or natural drains. Cuts through dormant slide or material prone to sliding.
MVP-LMP-NI-20	123.1	123.2	362	22	No*	Route crosses soil prone to movement. Mild side slope directly below power line right-of-way. Cuts across one natural drain.
MVP-LMP-NI-21	124.3	124.8	648	15 - 20	Yes*	Possible recent landslides, and this portion of route crosses through soil prone to movement.
MVP-LMP-NI-22	127.2	127.4	631	12 – 39	No*	Moderately steep slope below ridge. Cuts through dormant slide or material prone to sliding. Crosses an existing logging road.
MVP-LMP-NI-23	127.9	128.0	423	10 – 60	No*	Moderately steep slope below point. Cuts through dormant slide or material prone to sliding.
MVP-LMP-NI-24	132.0	132.1	646	25	No*	Portion of route is adjacent to soil prone to movement to the west and a dormant slide to the east. Moderate side slope. Cuts across at least one natural drain.
MVP-LMP-GB-25	145.3	146.1	8000	30 - 35	No*	Steep and very long side slope. Cuts across at least 3 natural drains. Two hard 90s one after the other in route.
MVP-LMP-SU-26	164.6	165.15	1320	33 - 43	No*	Steep side slopes outside of construction right-of-way. Two gullies at saddles are outside of the construction right-of-way.
MVP-LMP-MO-27	182.4	182.8	808	18 - 28	Yes*	Some slope movement is indicated on historical imagery within the past 20 years.
MVP-LMP-GI-28	197.4	197.6	1800	18 - 26	No*	Jefferson National Forest.
MVP-LMP-GI-29	198.4	199.1	2300	18 - 35	No*	Moderate slopes with active surficial erosion.
MVP-LMP-GI-30	204.4	204.8	1120	39	No*	Lateral slope side cut, paralleling transmission power line.
MVP-LMP-GI-31	211.5	211.8	1184	32 – 53	No*	Very steep slope, centerline may or may not be on ridge. Directly above U.S. 460.

	Table 1 - Landslide Concern Areas Crossed by the Mountain Valley Pipeline					
Designation	**Beginning MP**	**Ending MP**	**Length Crossed (feet)**	**Slope (%) [a]**	**Signs of Recent Movement [b]**	**Notes [c]**
MVP-LMP-MN-32	219.6	220.9	1200	25 - 40	No*	Jefferson National Forest:
MVP-LMP-MN-33	220.6†	220.7†	310	59	No	Very steep slope where route makes a 90 degree turn off the ridge. Very short section, but because of the severity of slope, could be prone to slippage. Cuts across one stream. Not included in October 2016 Proposed Route.
MVP-LMP-MN-34	221.8†	221.9†	380	46	No*	Steep slope runs alongside of knoll, directly above substation. Not included in October 2016 Proposed Route.
MVP-LMP-MN-35	229.2	229.3	640	28	No*	Slight sidehill. Crosses stream.
MVP-LMP-FR-36	261.2	261.2	179	40	No*	Steep side slope, but just for small section. Running just below ridge line through a gulley. Crosses one natural drain.
MVP-LMP-FR-37	263.9†	264.0†	368	34	No*	Steep side slope. Running just below ridge line through a gulley. Crosses one natural drain. Not included in MVP's October 2016 Proposed Route.
	[a] Design slope is based on desktop and field review, or range from map analysis of alignment. [b] Based on historical imagery. [c] Based on available landslide mapping and field survey. * A field review of this site was performed. † Refers to MVP Route 4.0.0 mileposts.					

4.0 STEEP SLOPES AND RED SHALE

The MVP route will cross numerous bedrock strata, including the Conemaugh, Monongahela, and Dunkard Formations and Mauch Chunk Group. These groups contain landslide-prone shale formations that are sometimes referred to as "red beds" and are frequently associated with landslides that occur in the project area. Detailed descriptions of each formation/group are presented below. Figure 1 illustrates areas where the aforementioned shale formations are present along the pipeline route.

Landslides are documented to be associated with red beds that form in the Conemaugh Formation, Monongahela Formation, Dunkard Group, and Mauch Chunk Formation. Red beds refer to shale or siltstone layers that can appear red, reddish-gray, or greenish-gray due to the presence of iron bearing minerals. These shales are generally slightly fissile, jointed, and slickensided. As these shales are exposed to water and oxygen near the surface they weather very easily into a thick mud. In addition, impervious layers located beneath the shale may trap water and cause the weathered shale to become saturated. Steep slopes, that are often present in these areas, along with the weathered shale and mud, produce conditions that increase the likelihood for landslides.

Two common types of landslides include rotational slump, and earthflow. Rotational slump is characterized by the movement of a large mass of weak rock or sediment as a block unit along a curved slip plane. These slumps are large, slow moving and produce several distinctive topographic features. The upper section (crown or head) is characterized by transversely oriented rupture scarps that can form terraces of displaced blocks. Depressions and pools of water may form and trees may become inclined upslope. The lower section (toe) is characterized by a fan-shaped, bulging mass, and radial ridges and cracks. Vegetation on the toe slopes may be seen leaning in strange directions. Earthflow landslides are smaller in size and result in weathered rock or sediment that flows downslope as a jumbled mass, forming a hummocky topography of ridges and swales.

Conemaugh Formation (Upper Pennsylvanian)

The Upper Pennsylvanian-aged Conemaugh Formation consists of cyclic sequences of shale, siltstone, sandstone, red beds, thin impure limestone, thin nonpersistent coal, and underclay, semi-flint clay, and flint clay. The Conemaugh Formation is formally divided into two members, the upper Casselman Formation and the lower Glenshaw Formation, however, several informal members exist as well. The lower member, the Sandy Grove Sandstone Member, is overlain by the Pittsburgh red shale. Sandstone in the Conemaugh Formation is described as medium-light-gray, very fine- to course grained, locally conglomeratic with well-rounded quartz pebbles and subangular limestone and shale fragments, thin bedded to massive. The shales and siltstones in the Formation are generally described as medium and greenish-gray to grayish-red, slightly fissile to poorly bedded, soft, clayey to silty; includes hematite nodules and discontinuous beds of limestone. The red beds and shales of the Conemaugh Formation are associated with landslides. Coal beds are also found in the Conemaugh Formation and are often underlain by underclay, flint clay, or semi-flint clay. These clays are described as medium-gray to grayish-red, poorly bedded with conchoidal fracture and containing fossil root prints. Coal and limestone beds in the Formation are generally thin bedded (around four feet). Limestones consists of medium-gray to light-grayish brown, nodular paleokarst surfaces, mudstone to packstone, and containing fossils.

Monongahela Formation (Upper Pennsylvanian)

The Upper Pennsylvanian-aged Monongahela Formation consists of non-marine cyclic sequences of sandstone, siltstone, red and gray shale, limestone, and coal. The Formation extends from the top of the Waynesburg coal to the base of the Pittsburgh coal and also includes the Uniontown, Sewickley, and Redstone coals. In West Virginia, the thickness of the Formation generally ranges from 170 feet to 300 feet. Sandstone in the Formation is described as medium-light-gray, very fine- to coarse-grained, conglomeratic with rounded quartz pebbles; thin-bedded to massive. Siltstone and shale in the Formation are described as medium- dark-gray to grayish-red, thin to poorly bedded, slightly fissile, silty, carbonaceous, and slightly calcareous. The shales and siltstones of the Formation, commonly known as red beds, are associated with landslides. Coal beds are also found in the Monongahela Formation and are often underlain by underclay, flint clay, or semi-flint clay. These clays are described as medium-gray, grayish-yellow, grayish-red, poorly bedded and brecciated with conchoidal fracture and containing fossil root prints.

Dunkard Group (Upper Pennsylvanian/Permian)

The Upper Pennsylvanian/Permian-aged Dunkard Group consists of non-marine cyclic sequences of sandstone, siltstone, red and gray shale, limestone, and coal. The Dunkard Group contains the Greene, Washington, and Waynesburg Formations. The maximum thickness of the Group, in Wetzel County, West Virginia, is estimated to be about 1,190 feet. Thin coal beds are often underlain with underclay, flint clay, or semi-flint clay that may contain fossil root prints. The coal beds are often overlain with multi-story, thick channel-form sandstone bodies with undulating, erosive bases and roof shale. Sandstones may grade upward back into siltstone, and gray, green, or red shale. Calcarious nodules and slickensides are also present in the shales. Red, green, or gray, mudstone or claystone paleosols may also develop indicating periods of wetting and drying. These paleosols are typically overlain by nonmarine lacustrine limestone beds. Individual limestone beds are generally less than five feet thick and display evidence of subaerial exposure. Limestone beds are frequently interbedded with argillaceous limestone, calcareous mudstone, and calcareous shale. Red facies of red colored shale, siltstone, and paleosols are prevalent throughout the Dunkard Group and are associated with landslides.

Mauch Chunk Group (Mississippian)

The Mississippian-aged Mauch Chunk Group consists of red, green, and medium-gray shale, siltstone, sandstone, and some conglomerate with a few thin limestones. The Mauch Chunk Group contains the Bluestone and Princeton, Hinton, and Bluefield Formations. In West Virginia, the thickness of the Group ranges from 970 feet to 4150 feet.

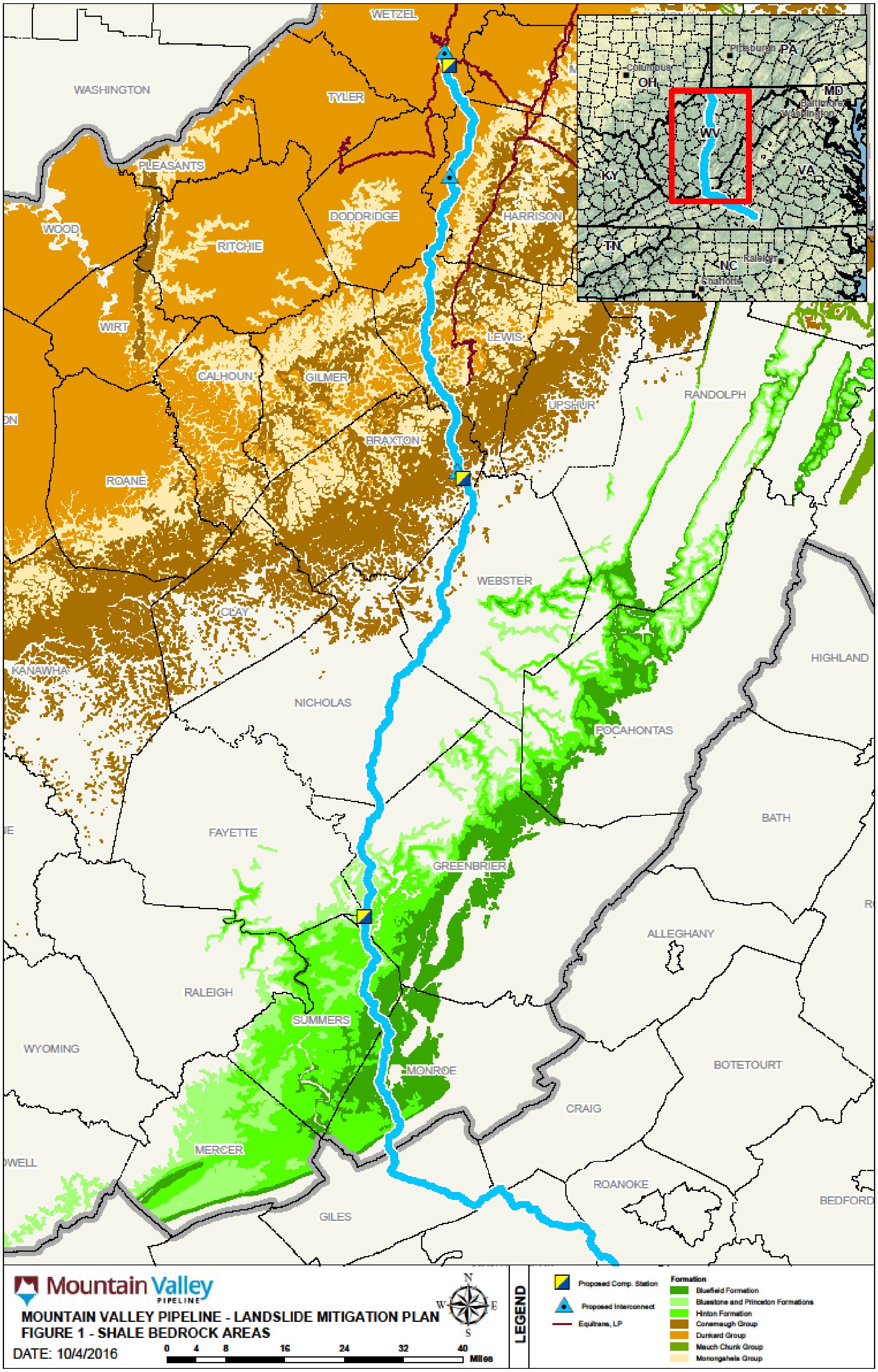
The Bluefield Formation of the Mauch Chunk Group consists of Limestone, siltstone, and shale. Limestone is light-grayish-brown, dolomitic, cherty, and fossiliferous. Shale is medium-gray to light-grayish-red, silty, thin and evenly bedded, very calcareous.

The Hinton Formation overlies the Bluefield Formation and consists of red shale and siltstone; sandstone, limestone, and dolomite are also present. The sandstone member at the base of the Formation is light-gray to white, very fine- to coarse-grained, cross-bedded quartzose with few scattered rounded quartz pebbles. The middle member of the Formation, the red member, consists of red silty shale that is locally calcareous and interbedded with thin beds of sandstone, siltstone and impure limestone, and dolomite. The limestone member of the Hinton Formation consists of dark calcareous shale or gray to brownish-gray, fossiliferous, impure shaly limestone. The upper member of the Hinton Formation consists of red, greenish-gray, and gray shale which is locally calcareous and contains several nonpersistent lenticular beds of sandstone and siltstone.

The Princeton Sandstone consists of white quartzose cross-bedded massive sandstone with rounded medium grains and some fine- to coarse-grained and conglomeratic zones. The sandstone is cemented with calcium carbonate or silica. Some gray to red shale, limestone, and coal are also present.

The Bluestone Formation consists of mostly interbedded shale, mudstone, siltstone, sandstone, limestone, and thin, impure coal seams. The lower member of the Bluestone Formation, the gray shale member, consists of gray and black shale which contains some beds of siltstone, sandstone, red shale, and limestone. The shale is calcareous and locally carbonaceous. The upper half of the member is mostly conglomeratic sandstone. The middle member, the red member, is composed of calcareous red shale with some siltstone, small amounts of calcareous sandstone and lenticular beds of limestone. The upper member of the Bluestone Formation consists of white, gray and greenish-gray sandstone. The sandstone is medium- to coarse-grained and locally conglomeratic and contains cross-bedding. The sandstone is interbedded with gray, green, black, and red shale and siltstone.

The Mauch Chunk consists of red and green shales, similar to the red beds found in the Conemaugh and Monongahela Formations. The shales are moderately high in clay minerals, are highly susceptible to weathering, and are prone to mass wasting. The residual soils have a moderate shrink-swell potential and are susceptible to gully erosion.


Mountain Valley PIPELINE
MOUNTAIN VALLEY PIPELINE - LANDSLIDE MITIGATION PLAN
FIGURE 1 - SHALE BEDROCK AREAS
DATE: 10/4/2016
0 4 8 16 24 32 40 Miles
N
S
E
W
LEGEND
Proposed Comp. Station
Proposed Interconnect
Equitrans, LP
Formation
Bluefield Formation
Bluestone and Princeton Formations
Hinton Formation
Conemaugh Group
Dunkard Group
Mauch Chunk Group
Monongahela Group
WETZEL
WASHINGTON
TYLER
PLEASANTS
WOOD
RITCHIE
DODDRIDGE
HARRISON
WIRT
LEWIS
CALHOUN
GILMER
UPSHUR
RANDOLPH
BRAXTON
ROANE
WEBSTER
CLAY
KANAWHA
HIGHLAND
NICHOLAS
POCAHONTAS
FAYETTE
BATH
GREENBRIER
ALLEGHANY
RALEIGH
SUMMERS
WYOMING
BOTETOURT
MONROE
CRAIG
MERCER
ROANOKE
BEDFORD
GILES
Pittsburgh
PA
Columbus
OH
MD
Baltimore
Washington
WV
KY
VA
TN
NC
Raleigh
Charlotte

5.0 POTENTIAL MITIGATION MEASURES

The basic strategies to protect against landslides and slope instability along the pipeline corridor during construction are stabilization, drainage improvement, and erosion and runoff control. Mitigation measures that may be used on MVP are outlined below and prescribed to specific project areas in Section 8.0. Construction typical drawings for selected mitigation measures are shown in the Appendix.

- Excavation and/or Regrading of Upgradient Head Soils: Regrading to a flatter slope upgradient of the pipeline excavation will increase the slope stability factor of safety by reducing the weight of soil at the top of the slope.
- Bedrock Embedment: Installing the pipeline completely within a bedrock trench will protect the pipeline integrity in the event of a surficial landslide.
- Dewatering: Dewatering a slope is often the most cost effective means to stabilize a slope and prevent future landslides. Saturated soil has an increased unit weight and higher pore water pressure, both of which negatively affect the slope stability factor of safety. To prevent soil from becoming saturated, runoff will be directed away from the potentially unstable slope and drains will daylight subsurface water.
- Erosion and Runoff Control: Typical erosion and sediment control BMPs will be implemented during pipeline construction and will be detailed in the Project plans. Installing additional erosion and sediment control measures will increase slope stability by minimizing soil saturation, as in dewatering. BMPs that are recommended for slope stabilization are summarized below.
    - Berms: Diversion berms will be used to intercept, divert, and convey surface runoff from steep slopes to decrease the chance of rill or gully erosion to occur which could weaken the stability of steep slopes. The outlet of all diversion berms will be armored with riprap to act as an energy dissipater and prevent localized erosion.
    - Rock Outlet Protection (Riprap): Rock outlet protection (riprap) will be used at the outlets of trench drains, sidehill low-point drains, berms, culverts, etc., to control the velocity and potential for erosion of the storm water runoff.
    - Sidehill Low-Point Drain: Sidehill low-point drains will be installed from the main pipeline trench at the upgradient side of a trench breaker to drain water out of the trench and outlet it to an area with rock outlet protection.
    - Trench Drain: Trench drains will be installed on side slopes and steep slopes in order to dewater the uphill slope.
    - Water Bar (Broad-Based Dip): Water bars will be used across the right-of-way, sloped to drain water off of the pipeline right-of-way.
    - Trench breakers (Trench Plugs): Trench breakers constructed of sandbags will be used in trenches along pipes to control water flowing through the pipeline trench. Excessive amounts of water will saturate the slope and destabilize it.
    - Hard Armor: Hard armoring existing drainage channels with riprap or articulated concrete block (ACB) will minimize slope saturation and erosion by stormwater. Areas susceptible

to future erosion, especially above the pipeline, may be armored with articulated concrete block (ACB) or riprap, as necessary.

- Rerouting: Minor route adjustments may be made to avoid landslide-prone areas identified during construction.

Construction operations will be staffed with geotechnical personnel who will prescribe additional mitigation measures as needed when subsurface conditions are revealed. These personnel, including geotechnical engineers and/or engineering geologists, shall have regional experience for constructing in and mitigating steep slopes and associated hazards. The following measures are not currently anticipated but may be implemented during construction, as needed.

- Buttressing: An earth, rock, or riprap fill buttress in front of an unstable slope will increase the weight of the material at the toe of the slope, thereby increasing the slope stability factor of safety.

- Reinforced Soil Slope: Incorporating multiple layers of geogrid or other geosynthetics between compacted lifts of soil or crushed stone will increase the shear strength of the fill, decreasing the risk of a slope movement.

- Rockfall Protection (Fencing): Protection measures such as rock fences, placement of concrete barriers, or creating catchment areas may be added where excavation is planned at the top of steep slopes to limit loose debris and protect downslope property or roadways.

- Soil-Nail Stabilization: Soil-Nail Stabilization is used to stabilize unstable soil slopes or allow for safe over-steepening (if required) of new or existing soil slopes. Tension-resisting steel elements will be inserted into holes in the soil surface and grouted or directly driven into the ground surface to anchor a steel cable or net system at the surface of the ground.

6.0 SLOPE STABILITY MONITORING PROGRAM

After pipeline construction and land reclamation are completed, Mountain Valley will implement a monitoring program to monitor slope stability in landslide-susceptible areas and provide Mountain Valley with indication of subtle ground movement that may indicate incipient slope failure. If subtle ground movement is detected, Mountain Valley will initiate post-construction slope evaluation and mitigation, described below. Recommendations for slope failure mitigation are discussed in Section 6.3. Specific mitigation measures will depend upon the results of the monitoring program and the landslide inspection team's field observations on actual conditions.

6.1 LiDAR Surveys

Mountain Valley will utilize aerial LiDAR surveys on a prescribed periodic basis (discussed below) to monitor the ROW for changes in ground topography that could indicate potential slope movement. LiDAR works by emitting multiple laser pulses over the same area, such that some pulses are reflected off intermediate surfaces (i.e. variable height vegetation, buildings, power lines, etc.) and some of the pulses find the underlying ground surface. The resulting data are processed to classify data that represent the ground surface (i.e., generate a bare Earth model), providing a detailed topographic and geomorphic landform model to detect subtle ground morphologies that define natural and human-triggered landslide and erosion hazards (i.e. scarps, settlement, hummocky terrain, depletion zones, accumulation zones, sag ponds, disrupted drainage, etc.).

A progression of LiDAR data collected over time on a slope of concern will be compared to historical data in order to identify whether subtle landform changes are occurring that could correspond with possible land movement or subsidence. The sequential LiDAR models of the area of concern will be configured as a "heat map" showing apparent areas of accumulation and depletion to more clearly identify slope changes.

6.2 Monitoring Schedule

Mountain Valley will conduct semiannual aerial LiDAR monitoring on slopes of concern during an initial two-year period after project construction is complete and the right of way is seeded. This spans a critical period of time post-construction to confirm that land reclamation is established, and that slopes are stable through two freeze-thaw cycles. Continued monitoring described below will used to confirm stabilization of the slopes in areas of concern.

If the slopes in the area of concern are demonstrated to be stable by sequential LiDAR monitoring data for the initial two years of semiannual monitoring (described above), the frequency of LiDAR survey will be reduced to annually for another two consecutive years. This will provide six LiDAR monitoring events over the span of four years in order to detect potential subtle slope movement.

If the slopes are demonstrated to be stable by sequential LiDAR monitoring data for the combined four years of monitoring (i.e., the initial two years of semiannual monitoring, followed by two years of annual monitoring), the frequency of LiDAR surveys will be further reduced to a five-year periodicity throughout the life of the pipeline.

As each new sequential LiDAR survey is completed (see monitoring schedule above), the data will be processed and compared to all historical LiDAR data (i.e., to produce a "heat map" of slope movement) to evaluate for potential ground movement over time.

6.3 Slope Stability Mitigation Measures

If slope movement is detected by the LiDAR monitoring program, Mountain Valley will engage a landslide inspection team to complete field verification and confirm actual conditions and governing reasons for the topographic changes. Recommendations for slope stability remedial measures will be provided to Mountain Valley based on the landslide inspection team's observations.

Examples of potential remedial measures:

- If slope movement is confirmed in surficial backfill in the ROW, enhanced backfill compaction (or replacement with engineered materials), enhanced water management, and aggressive revegetation will be implemented.
- If slope movement in native earth material outside of the ROW is confirmed, the landslide inspection team will provide recommendations to Mountain Valley for remediation measures.
- If the movement may have stressed the pipe, a stress relief excavation may be required to allow the pipeline to rebound to the non-stress condition prior to slope movement. Stress relief excavations typically start in the middle of the area where slope movement is observed, and extend in either direction until no rebound is observed, and generally continue for a minimum of an additional 50 feet. Surveys may be required during the excavation work to track pipeline rebound, and to confirm before and after pipeline location and elevation. Stress relief excavations would only be contemplated for relatively large-scale movement scenarios.

- Mountain Valley may also consider installing strain gauges on the pipeline during stress-relief excavation. The strain gauges would monitor potential accumulated pipeline strain in the future if differential ground movement continues. Strain gauge monitoring would be conducted manually on a yearly basis, unless LiDAR monitoring under the post-remediation timeframe continues to identify large-scale slope movement, in which case the strain gauges will be monitored on a six-month basis. Strain gauges would only be contemplated for relatively large-scale movement scenarios.

7.0 SIDEHILL CONSTRUCTION

In sidehill construction areas (as defined on the project alignment sheets), the following construction practices shall be observed (in addition to landslide mitigations prescribed for locations specified in this document):

- Seeps or springs encountered in the excavation shall be intercepted by transverse trench drains, cutoff drains, or similar, and directed out of the pipeline ditch to an energy dissipating structure (such as a riprap apron).
- Backfill material shall exclude organic material, vegetation, stumps, root systems, frozen material, and rocks larger than three inches in diameter.
- Backfill operations shall be performed when soil moisture content is suitable for compaction, at or near optimum moisture content (i.e., not immediately following a large precipitation event or when soil is excessively dry). Soil moisture content will be visually judged, and is subject to the discretion of project geotechnical personnel. Saturated materials or those exhibiting signs of pumping and rutting during placement shall be ammended by mixing with drier materials, spreading and drying, or other drying methods prior to fill placement.
- Backfill material shall be placed in compacted lifts no greater than 12 inches thick.
- Backfill compaction shall be accomplished using the back of an excavator bucket, sheep’s foot roller, or similar.
- Where a temporary cut and fill surface is required, any ground fractures forming near the cut/fill line or the pipeline ditch shall be repaired to prevent water infiltration.
- All streams, gullies, natural drains, field roads or trails, and other water conveying features shall be properly recontoured such that the permanent right-of-way is protected from preferential water accumulation and infiltration.

8.0 STEEP SLOPE CONSTRUCTION

On steep slope construction areas (15% slope or greater), the following construction practices shall be implemented (in addition to landslide mitigations prescribed for locations specified in this document):

- Seeps or springs encountered in the excavation shall be intercepted by trench breaker drains or similar, and directed out of the pipeline ditch to an energy dissipating structure (such as a riprap apron).
- Backfill material shall exclude organic material, vegetation, stumps, root systems, frozen material, and rocks larger than three inches in diameter.

- Backfill operations shall be performed when soil moisture content is suitable for compaction, at or near optimum moisture content (i.e., not immediately following a large precipitation event or when soil is excessively dry). Soil moisture content will be visually judged, and is subject to the discretion of project geotechnical personnel. Saturated materials or those exhibiting signs of pumping and rutting during placement shall be amended by mixing with drier materials, spreading and drying, or other drying methods prior to fill placement.
- Backfill material shall be placed in compacted lifts no greater than 12 inches thick.
- Backfill compaction shall be accomplished using the back of an excavator bucket, sheep's foot roller, or similar.

9.0 SITE SPECIFIC MITIGATION

Recommendations for landslide mitigation at each of the 37 areas identified in Table 1 are described below. Landslide mitigation typical detail drawings are appended. All drainage features prescribed below will be left in place permanently.

Generally, landslide mitigation will depend heavily on the installation of appropriate drainage and erosion control measures during pipeline construction (as described in Resource Report 6.6.1.2) and proper right-of-way reclamation. Backfilling operations in the areas discussed below and all sidehill construction areas identified on the alignment sheets (as discussed in Section 7.0) will be accomplished by following specific guidelines. Fill material will exclude organic material, vegetation, stumps, root systems, and rocks larger than three inches in diameter. When placed in the trench, this select material will be placed in compacted lifts of no greater than 12 inches thick. Compaction may be accomplished using the back of an excavator bucket, a sheep's foot roller, or similar. Where a cut and fill surface is required, contractors will ensure that any ground fractures that form at the interface of that surface and the pipeline ditch are repaired. Finally, inspectors or on-site engineers/geologists will ensure that all identified streams, gullies, natural drains, field roads or trails, and any other water conveying features are properly recontoured such that the permanent right-of-way is protected from preferential water accumulation and infiltration.

Additional mitigation measures beyond these may be required depending on site specific conditions. These are described below based on the results of the field investigations.

- **<u>MVP-LMP-WE-01 (MP 3.3 to 3.8)</u>:**

  The pipeline in this area runs along the crest of a ridge between MP 3.3 to 3.5, drops down along a steep side slope between MP 3.5 and 3.8, and continues along the ridgeline beyond MP 3.8. The primary area of concern falls between MP 3.55 and 3.77. The side slope in this area varies from 41.5 % to 51.2% below and above the pipeline, respectively.

  Although the field survey found no evidence of recent slides in this area, the state landslide topographic maps indicate dormant slides are located in this vicinity. The field survey did observe three primary gullies draining to the east down this bowl-shaped slope.

  As this area may be prone to landslides, the right-of-way will be kept drained by installing transverse trench drains along the right-of-way. The trench drain will convey water out of the pipeline trench. The gullies noted during the site visit will be restored to original contours to facilitate surface water drainage. The ultimate protective measure for the pipeline in this area will be embedment of the pipe within the local bedrock.

- **MVP-LMP-HA-02 (MP 28.0 to 28.2):**

The pipeline in this area runs entirely along the crest of a ridge with steep side slopes ranging from 31.2% to 54%. This location is near well appurtenances at MP 28.25 located approximately 40 feet east of the pipeline.

A 10-foot wide slump was noted in the field survey approximately 75 feet west of the pipe centerline at MP 27.95 on the side slope. A large rock outcrop was also noted on the east side near the pipe centerline at MP 28.0. Multiple gullies were observed outside of the right-of-way from MP 28.1 to 28.2.

As the pipeline follows the ridge and the existing slump will not be affected by construction operations, no additional mitigation is required at this location. Where practical, the pipe trench will be located in bedrock to protect the pipe in the event that the subjacent slope fails.

- **MVP-LMP-DO-03 (MP 32.4 to 32.6):**

The pipeline in this area runs downslope from a crest at a slope of 30% to 35% before crossing a stream and cutting across the toe of a side slope between MP 32.3 and MP 32.55. Although historical imagery shows no signs of recent movement, the hillside was previously cleared and landslide topographic maps show this portion of the route crossing through dormant slides and/or soil prone to movement. The soils in this region were classified as a Gilpin-Peabody Complex or Vandalia Silty Loam (NRCS Hydrologic Soil Group C).

The lower section of the slope was recently cleared and is mainly vegetated with grasses and/or small shrubs. The upper portion is vegetated with trees and overgrown with shrubs. Along the toe of the slope, the existing three-foot-wide stream is actively eroding the toe as indicated by the steep cut bank and slumping of material into the stream. A scarp was indicated in the field report at MP 32.4 that was approximately 12-feet tall and 50-feet long with evidence of gravitropism.

The area with visible scarp and steep side slopes following it may be prone to landslides. In this area, a trench drain will be installed on the high side of the right-of-way, daylighting to the low side. It should also be buttressed with a riprap fill at the edge of the right-of-way, if needed during construction. At the steep downslope before the stream crossing, water bars in conjunction with trench breakers and trench breaker daylight drains will be installed.

- **MVP-LMP-HA-04 (MP 33.45 to 33.6):**

The pipeline in this area runs entirely along the crest of a ridge with steep side slopes ranging from 34% to 48%. The primary area of concern falls between MP 33.45 to MP 33.6. As the pipeline excavation runs along the crest it crosses an existing right-of-way with an underground pipe near MP 33.55.

During the field observation no evidence of mass movement was observed on the vegetated slopes or existing cleared right-of-way. Soils in this section were classified as Gilpin-Peabody Complex or Gilpin-Upshur Complex (NRCS Hydrologic Soil Group C).

No additional mitigation measures are necessary in this area.

- **MVP-LMP-DO-05 (MP 34.2 to 34.4):**

  The pipeline in this area runs along a side slope and crosses a number of gullies between MP 34.25 and MP 34.35 with side slopes ranging from 25% to 48%. The primary area of concern lies between MP 34.25 and MP 34.35. Historical imagery shows no recent signs of landslide movement in the area, and the soils were classified as Gilpin-Peabody Complex (Very Stony, NRC Hydrologic Soil Group C).

  Rock armoring (or ACB) will be used between MP 34.25 to MP 34.32 after backfill of the pipeline excavation to help stabilize the gully crossings, which will be restored to their original contours. A trench breaker, in conjunction with a sidehill low-point drain which will outlet to a rock outfall protection location, will be used at the low point near MP 34.35. Where practical, the pipe trench will be located in bedrock to protect the pipe from shallow soil movements.

- **MVP-LMP-DO-06 (MP 34.4 to 34.6):**

  The pipeline in this area runs along steep side slopes and crosses a number of gullies as well as an area that is a cut slope adjacent to an existing road with visible slumps and associated scarps. The slopes in this area range from 17% to 42%.

  The most critical area is a 150-foot-long, 300-foot-wide section next to an existing cut slope with multiple large slumps and scarps. The field reports also noted a long coal seam with standing water and saturated slopes below the seam. The soils in this region were noted as Gilpin-Peabody Complex, very stony (NRCS Hydrologic Soil Group C).

  The area exhibiting slumps and scarps must be stabilized by removing and replacing the slumping soils prior to placing additional material in that area. Transverse trench drains will be installed uphill of the pipeline to cut off water ponding near the coal seam outcrop. Gullies will be restored to their natural contours to facilitate drainage across the right-of-way. Where practical, the pipe trench will be located in bedrock to protect the pipe in the event that the subjacent slope fails.

- **MVP-LMP-DO-07 (MP 35.15 to 35.35):**

  The pipeline in this area runs along the crest of a ridge between MP 35.15 to MP 35.35 with steep side slopes ranging from 27% to 69%. Historical imagery shows no signs of recent landslide movement and the soils in the area were classified as Gilpin-Peabody Complex, very stony (NRCS Hydrologic Soil Group C).

  A trench breaker should be used in the trench in conjunction with a sidehill low-point drain that outlets to a rock outfall protection location at the low point near MP 35.25. Where practical, the pipe trench will be located in bedrock to protect the pipe in the event that the subjacent slope fails.

- **MVP-LMP-LE-08 (MP 43.35 to 43.45):**

  The pipeline in this area will be constructed along the ridgeline between MP 43.15 to 43.2, then at the local peak turns slightly eastward and runs approximately 100 to 200 feet from the top of the adjacent ridgeline to the west between MP 43.2 to 43.45. The remainder of the pipeline in this area follows the existing saddles and ridgeline to the southwest between MP 43.45 through 43.65. The primary area of concern falls between MP 43.25 and 43.45.

The side slopes in this area vary from approximately 58% above the pipeline and 53% below the pipeline. The pipeline right-of-way in this area is crossed by an existing gas pipeline at approximately MP 43.35. During the field survey, multiple rock outcrops were observed along the top of the slope/ridgeline that were undercut at the base up to five feet. In addition, large boulders located downslope of these outcrops indicate that future rockfall in the area is possible. Some evidence of gravitropism was noted at the top of slope above the pipeline centerline, which indicates that soil movement has occurred in the past. Although the field survey found little to no evidence of recent slides in this area, the state landslide topographic maps indicate dormant slides are located in this vicinity. The NRCS soil classification for this area is Hydrologic Soil Group C soil that represents a sandy clay loam.

Transverse trench drains will be installed in the pipeline trench. Water bars in conjunction with trench breakers with drains will be installed in the steeper downhill sections of the pipeline. Where practical, the pipe trench will be located in bedrock to protect the pipe in the event that the subjacent slope fails.

- **MVP-LMP-LE-09 (MP 46.2 to 46.5):**

In this area, the pipeline right of way is aligned to the eastern side of a knoll from about MP 46.25 to 46.4 where it follows a saddle to about MP 46.5. Side slopes in the area range from approximately 15% to 33%. Soils in the area are classified as Gilpin-Upshur silt loams, corresponding to NRCS Hydrologic Soil Group C.

The site visit revealed numerous rock outcrops about the knoll between MP 46.25 and 46.4. Several swales and evidence of gravitropism were observed between MP 46.4 and 46.5. The area is forested.

Transverse trench drains will be installed in sidehill portions of the alignment and the ground surface will be restored to existing contours. Where practical, the pipeline trench will be located in bedrock to protect the pipe from shallow soil movements.

- **MVP-LMP-LE-10 (MP 46.6 to 46.8):**

The pipeline in this area has been rerouted since the initial field visit to be constructed generally along the ridgeline in this area. The primary area of concern falls between MP 46.5 and 46.8 on the western slope. The western side slopes in this area have an approximate 18 to 25% grade and the eastern side slope (located over the uphill ridgeline) have varying range of slopes (20 to 40%) with an average slope of approximately 25%.

During the field survey, one scarp and one gully were located on the eastern slope area and two gullies and two scarps were observed on the western side slope. The gullies have been delineated as streams. Some evidence of gravitropism was noted along the top of the western slope above the pipeline centerline, which indicates that soil movement has occurred in the past. Although the field survey found little to no evidence of recent slides in this area, the state landslide topographic maps indicate dormant slides are located in this vicinity and historical scarps were present. The NRCS soil classification for this area is Hydrologic Soil Group C soil that represents a sandy clay loam.

Transverse trench drains will be installed in the pipeline trench through the sidehill portion of the alignment. Water bars in conjunction with trench breakers will be installed in the steeper downhill sections of the right-of-way. Gullies will be restored to original contours to facilitate drainage across the right-of-way. Where practical, the pipe trench will be located in bedrock to protect the pipe from shallow soil movements.

- **MVP-LMP-LE-11 (MP 53.0 to 53.3):**

A majority of the pipeline in this area is to be constructed along the existing ridgeline on the western side slope between MP 52.9 to 53.35. An existing cemetery is located at the top of the slope approximately 100 feet east of MP 53.1 and creates a gently sloping ridgeline. A gated roadway located just south of the cemetery also parallels the proposed gas pipeline to the east along the ridgeline at a distance/offset of approximately 50 feet between MP 53.05 through 53.2. An abandoned road right-of-way located on the western slope crosses the gas pipeline at MP 53.1.

During the field survey, multiple road failures were identified along this abandoned right-of-way. An existing gas line that runs northwest to southeast intersects the new pipeline at MP 53.2. The primary area of concern falls between MP 53.0 and 53.15; the western side slopes in this area have an approximate 25% to 30% grade.

Seven gullies, some of which were delineated as streams, were identified on the western slope. Although the field survey found no evidence of recent slides in this area, the state landslide topographic maps indicate dormant slides are located in this vicinity. The NRCS soil classification for this area is Hydrologic Soil Group C soil that represents a sandy clay loam.

In areas where the pipeline crosses gullies and natural drains, the grade will be restored to original contours to facilitate drainage. Water bars in conjunction with trench breakers will be installed in the steeper downhill sections of the right-of-way. Transverse trench drains will be installed in sidehill sections of the right-of-way to prevent saturation of the trench backfill. Where practical, the pipe trench will be located in bedrock to protect the pipe from shallow soil movements.

- **MVP-LMP-LE-012 (MP 55.1 to 55.2):**

The pipeline in this area will be constructed perpendicular to a valley. The northwestern slope section of the pipeline starts at MP 54.9 (top of slope) and runs down slope to MP 55.1 at Copley Road located at the toe of slope. The pipeline will then cross under an existing drainage ditch, Copley Road, and stream. The pipeline then ascends the adjacent slope from MP 55.1 (Copley Road at toe of slope) to MP 55.25 (top of slope). The primary areas of concern are the two aforementioned side slopes that fall between MP 54.95 and 55.25.

The northwestern side slope in this area is well vegetated with trees and shrubs and has an approximate grade that ranges from 35% to 45%. A 20-foot high rock outcrop is located at the toe of slope on the northwestern side of Copley Road. A “Falling Rocks” warning sign is also located along this section road. Many of the trees located throughout this slope show signs of gravitropism that indicates soil movement on the slope has occurred in the past. The southeastern side slope is also well vegetated with trees and shrubs and has an approximate grade that ranges from 43% to 53%. The NRCS soil classification for this area is Hydrologic Soil Group C soil that represents a sandy clay loam.

Water bars in conjunction with trench breakers will be installed along the pipeline in this area. Trench breaker daylight drains will be installed at the base of some trench breakers to allow for discharge of infiltrated water from the trench to areas outside or downstream of the area of concern. At this time, stabilization measures for the very steep slope superjacent to Copley Road have not been finalized as the work will require approval from the owner of the road, but MVP anticipates that a highwall revetment may be required.

- **MVP-LMP-LE-13 (MP 57.2 to 57.7):**

The pipeline in this area runs along the crest of a ridge, then at a local peak runs along steep side slopes on the west side of the ridgeline between MP 57.3 and 57.6. The slope below this area of concern also has two gullies with one associated seep located down gradient to the northwest, off of the right-of-way. The gullies lead to a creek at the toe of the slope that is approximately 10 feet wide. The creek did not form significant cut slopes or show signs of significant toe erosion. Across the side slopes, signs of gravitropism were observed. Tree deformation was more significant at the steep section and was present down to the toe of the slope. The corridor in this area also crosses two abandoned roads. The forest floor has little to no vegetative cover, occupied by small shrubs and ferns with silty clayey sand and sandstone cobbles and boulders scattered across the slope. Historical imagery shows no recent signs of movement.

Transverse trench drains will be installed in the pipeline trench through the sidehill area of the alignment. Where practical, the pipe trench will be located in bedrock to protect the pipe from shallow soil movements.

- **MVP-LMP-BR-14 (MP 66.8 to 66.95):**

The pipeline in this area is to be constructed subjacent to the Weston and Gauley Bridge Turnpike Trail, sidehill along a moderate side slope. The trail follows the ridgeline with moderate side slopes in the vicinity. The pipeline crosses the trail at approximately MP 66.95. Soils in this area are classified as Gilpin-Upshur silt loam (NRCS hydrologic soil group C).

The area is generally wooded but is a vegetated open field in the vicinity of MP 66.9 to 66.95. No evidence of recent or historic slope movement was observed at this location.

Transverse trench drains will be installed in the sidehill portion of this area.

- **MVP-LMP-BR-15 (MP 69.2 to 69.5):**

The pipeline in this area is to be constructed along the ridgeline between MP 69.0 to 69.2, then runs approximately 500 feet downslope from the adjacent ridgeline to the west between MP 69.2 to 69.45. The remainder of the pipeline in this area follows the existing saddles and ridgeline to the southwest of MP 69.45. The primary area of concern falls between MP 69.2 and 69.45.

As the property could not be accessed due to landowner restrictions, no field survey or report was prepared for this sidehill area, and the preliminary evaluation was prepared based on summary descriptions provided by routing engineers and publically available imagery and information for the area. The side slopes upgradient (west) of the pipeline right-of-way range from approximately 41% to 67% and downgradient (east) from 28% to 36%. The area is well vegetated with trees. Historical imagery does not suggest recent landslide/soil movement in the area, nor does it cross an existing or dormant slide. The NRCS soil classification for this area is Hydrologic Soil Group C soil that represents a sandy clay loam.

Transverse trench drains will be installed on the upgradient edge of the right-of-way, conveying the water out of the area of concern. Water bars in conjunction with trench breakers will be installed at the steep downhill sections of the right-of-way. Sidehill low point drains will be installed at selected trench breakers.

- **MVP-LMP-WB-16 (MP 81.8 to 82.1):**

The pipeline in this area will be constructed along the upgradient edge of an existing, ephemeral drainage between MP 81.8 and 82.0 with moderately steep side slopes. Dave Cowger Hill Road is located upgradient of this pipeline segment. The upgradient slopes between the road and the pipeline range from 40% to 45% and 150 to 250 feet in length. The pipeline then runs up the moderately steep slope to the south (approximately 52% grade) to the top of a saddle at MP 82.05. From the top of the saddle, the pipeline runs at an angle across a relatively steep slope (slope grade ranges from 28% to 63% with angled pipeline grade ranging from 18% to 35% in the trench) to the toe of slope in a valley at MP 82.3.

All of the slopes appear to be heavily vegetated with trees and the forest floor is comprised of scattered shrubs and sparse vegetation. During the field survey, five significant gullies were identified between MP 81.9 and MP 82.0. These gullies range in width from three feet to 20 feet; four of them are delineated as streams. Although the field survey found no evidence of recent slides in this area, the state landslide topographic maps indicate dormant slides are located in this vicinity. The NRCS soil classification at MP 81.8 is Hydrologic Soil Group B soil that represents a silt loam or loam and MP 81.9 to 82.1 is Hydrologic Soil Group C soil that represents a sandy clay loam.

Water bars in conjunction with trench breakers will be installed at the steep downhill sections of the pipeline in this area. Transverse trench drains will be installed in the pipeline trench. Gullies will be restored to their natural contours to facilitate drainage across the right-of-way; the gully not delineated as a stream will be armored with rock or ACB to minimize erosion. Where practical, the pipe trench will be located in bedrock to protect the pipe from shallow soil movements.

- **MVP-LMP-WB-17 (MP 82.5 to 82.6):**

The pipeline runs up a moderate side slope to the south, across a natural drain, and up a steep ridge. The side slopes vary from 37% to 70%. However, the pipeline alignment avoids the steepest sections. At MP 82.6 the pipeline crosses a significant natural drain. From MP 82.6 to 82.9 the pipeline runs directly up a steep slope (44% to 55%).

Both the historical imagery and the field survey indicated no signs of recent slope movement or gravitropism. The soil type in this area has been identified as sandy clay loam, but colluvial material may be present near the drain paths which could be unstable.

In areas where the pipeline crosses gullies and natural drains, the grade will be restored to original contours to facilitate drainage. Transverse trench drains will be installed in the sidehill portion of the alignment in this area. Water bars in conjunction with trench breakers and drains will be installed in the steeper downhill sections of the right-of-way.

- **MVP-LMP-NI-18 (MP 111.7 to 111.8 -MVP Route 4.0.0):**

The area of concern runs between MP 111.7 and 111.85 (MVP Route 4.0.0) where the pipeline corridor goes down a ridge with side slopes between 35% and 47%. At MP 111.85, the pipeline corridor makes a 90-degree bend and continues normal to the slope, reaching a significant drainage crossing at MP 111.92.

Historical imagery shows no signs of recent landslide movement However, the landslide topographic maps show the pipeline running through dormant slides and/or material prone to landslide movement. No field survey or report was completed in this area as the property could not be accessed due to landowner restrictions. The soil in this area was classified as Clifftop Channery Silt Loam, very stony (NRCS Hydrologic Soil Group C).

The pipeline in this area has been re-routed and this area is no longer of concern.

- **<u>MVP-LMP-NI-19 (MP 122.5 to 123.0)</u>:**

The pipeline in this section traverses side slopes ranging from 28% to 43% and crosses four drainages and under a transmission line and road.

Although historical imagery reveals no signs of recent landslide movement, this section cuts through an area with dormant slides and/or material prone to sliding. Soils in the region were classified as a variety of different soil groups (NRCS Hydrologic Soil Groups A, C and D). The field survey revealed numerous natural drains and several large boulders along and adjacent to the route. Some areas showed evidence of gravitropism and hummocky terrain.

Transverse trench drains will be installed in the pipeline trench throughout the sidehill area. Numerous boulders and rock outcrops suggest that bedrock will be relatively shallow in the area and that the pipeline trench will be located in bedrock, minimizing the potential for damage due to earth movement.

- **<u>MVP-LMP-NI-20 (MP 123.1 to 123.2)</u>:**

The pipeline in this area crosses an existing gully and seep at MP 123.1, crosses a sidehill parallel to a cleared existing power line right-of-way at a slope of 12.5% between MP 121.13 to 123.2, and then runs normal and downhill on a well-vegetated steep slope with slopes ranging from 30% to 60% between MP 123.13 to 123.2.

The field survey noted one seep near MP 123.2 that was actively flowing to a gully that crosses the corridor just to the north. The gully becomes up to 10 feet wide and three feet deep near the corridor centerline and has been delineated as a stream. Although the historical imagery shows no signs of recent movement, the landslide topographic map shows this portion of route crosses through soil prone to movement. The field survey defined the soil as decomposed plant material, silt loam, and silty clay loam.

In areas where the pipeline crosses gullies and natural drains, the grade will be restored to original contours to facilitate drainage. Water bars in conjunction with trench breakers will be installed in the steeper downhill sections of the right-of-way. Transverse trench drains will be installed in the sidehill portions of the alignment.

- **<u>MVP-LMP-NI-21 (MP 124.35 to 124.75):</u>**

The pipeline in this area runs along the crest of a moderately sloping ridge then continues to run south downslope off the ridge though a valley with steep slopes. The valley located between MP 124.5 and 124.6 has a seasonal stream located at the toe of the slope. The steep slopes around the valley are mostly vegetated by trees. The forest floor has little to no vegetative cover and was covered in fallen leaves at the time of the site visit. No signs of erosion were observed from the seasonal stream at the toe of the slope but erosion around the base of trees was observed.

Historical imagery shows possible signs of recent movement and the landslide topographic map shows this portion of the route crosses through soil prone to movement.

Trench breakers and drains will be installed in the steeper downhill sections of the right-of-way.

- **MVP-LMP-NI-22 (MP 127.2 to 127.4)**:

The pipeline in this area runs northwesterly upslope along a crest of a ridge then turns southerly downslope between MP 127.2 to MP 127.0. The primary area of concern runs from MP 127.2 to MP 127.5. The steep slopes off the side of the crest where the pipeline runs along the slope vary from 30% to 40%.

Historical imagery and the site visit revealed no signs of recent landslide movement. However, landslide topographic maps show materials that are prone to landslide movement. Rock outcrops were observed along the pipeline right of way during the site visit. An existing logging road with steep high-side cut, approximately three feet high, is located at the southern end of the segment.

Transverse trench drains will be installed at low points along the pipeline alignment to facilitate drainage of the pipeline trench and prevent slope saturation.

- **MVP-LMP-NI-23 (MP 127.9 to 128.0):**

The pipeline in this area runs along the crest of a ridge between MP 127.8 to 127.92, then drops down along a steep side slope between MP 127.92 to MP 128.0. The primary area of concern falls between MP 127.92 and MP 128.0. The side slope in this area varies from 30% to 40% along the pipeline.

The site visit revealed that the sidehill area of the pipeline route contained numerous rock outcrops. Historical imagery shows no sign of recent landslide movement. However, landslide topographic maps show slide prone material. NRCS data show the soils in this area to be a sandy loam and silt loam.

If possible, the pipeline alignment should be rerouted to traverse directly uphill to the peak of the knoll and back downhill, eliminating the sidehill portion. If this is not possible, transverse trench drains will be installed in the sidehill portion of this area. Water bars in conjunction with trench breakers and drains will be installed in the steeper downhill sections of the right-of-way.

- **MVP-LMP-NI-24 (MP 132.0 to 132.1):**

The pipeline in this area runs along a side slope and crosses a gully with two contributing seeps west of the pipeline between MP 132.0 to MP 132.1 and then continues southeasterly down a moderately steep slope.

Although the field survey and historical imagery show no signs of recent landslide movement, the landslide topographic maps show soil prone to movement uphill (west) of the pipeline excavation and a dormant slide downhill (east) of the pipeline excavation. The soil type in this area has been defined as a Clifftop Channery silt loam, very stony, Hydrologic Soil Group C.

The primary area of concern lies between MP 131.9 and MP 132.1 with side slopes ranging from 25% to 35% below and above the pipeline. Transverse trench drains will be installed along the pipeline trench and will outlet the water away from the area of concern.

A second area of concern lies between MP 131.8 to MP 132.0, where steep slopes and a drainage way are present. Where the pipeline crosses a gully, the grade will be restored to original contours to facilitate drainage. Water bars in conjunction with trench breakers will be installed in the steeper downhill sections of the right-of-way.

- **MVP-LMP-GB-025 (MP 145.3 to 146.1):**

This pipeline section starts along the broad crest, and crosses a number of drainage ways and small access roads, with some minor turns and two 90-degree bends. The area of concern falls between MP 145.8 and MP 146.1. After a 90-degree bend, the pipeline runs downhill normal to the slope, then crosses a paved road and river.

The steep slopes to the west of the corridor were noted as densely vegetated and overgrown with abandoned logging roads remaining. There will be some gully and road crossing in this area but no mitigation measures are recommended for potential landslides in this area. The soils in the area of concern include sandy loam and silty loam from NRCS soil groups A and C, respectively.

Water bars in conjunction with trench breakers and drains will be installed in the steeper downhill sections of the right-of-way.

- **MVP-LMP-SU-26 (MP 164.6 to 165.15):**

The pipeline in this section begins running perpendicular to a steep upslope (MP 164.6 to MP 164.75), runs across three rounded peaks and follows the crest of the ridge between the peaks. From MP 165.0 to MP 165.15, the route runs normal to a moderately steep downslope with a gully at the bottom.

The field report noted the soils in this area as silty clayey sand with scattered sandstone cobbles. The field report also noted that the pipeline crosses two significant gullies located near MP 164.93 and MP 165.15. The NRCS soil type is this section is silt loam from Soil Group C.

Water bars in conjunction with trench breakers and drains will be installed in the steeper downhill sections of the right-of-way.

- **MVP-LMP-MO-27 (MP 182.4 to 182.8):**

The pipeline in this area runs along the toe of a steep side slope then crosses Slate Run Creek, a local road, and a cleared transmission right-of-way, and State Route 122 between MP 182.4 to 182.8. The area traverses grassed clearings interrupted by dense vegetation of trees and shrubs.

Exposed bedrock (sandstone/siltstone outcrop) was observed in the field down gradient from the pipeline corridor along State Route 122. No signs of movement were observed along the cleared area but signs of gravitropism were noted during the field report on the well-vegetated steep slope up gradient of the corridor. Historical imagery shows movement within the past twenty years, but no slumps were noticeable during the field investigation. The soils in this section are silt loam according to the NRCS classification and of Soil Group D.

Water bars in conjunction with trench breakers and drains will be installed superjacent to State Route 122.

- **MVP-LMP-GI-28 (MP 197.4 to 197.6 - Jefferson National Forest)**:

The pipeline in this area runs across a moderately sloped knob before following a moderately steep ridgeline downgradient. The adjacent side slopes are steep. The pipeline parallels Mystery Ridge Road in this area.

The field report noted that slopes were mostly silty sand with sandstone cobbles and boulders scattered throughout, and the soil type in the area was defined as Lily-Bailegap Complex or Nolichucky Very Stony Sandy Loam (NRCS Hydrologic Soil Group B). Some of the side slopes off the ridge were observed to have minor signs of gravitropism. Water bars in conjunction with trench breakers will be installed in the steeper downhill sections of the right-of-way and transverse trench drains will be installed throughout the sidehill portion of the alignment.

- **MVP-LMP-GI-29 (MP 198.4 to 199.1)**:

The pipeline in this area runs along moderate slopes thoroughly vegetated by grasses and used as a cow pasture from MP 198.4 to 198.8. The pipeline then crosses through dense forest and cleared pasture while crossing a smaller two-track road and two streams. The intermittent stream near MP 198.83 has very steep slopes with little to no vegetative cover on the forest floor. The soil is a very loose organic soil with active surficial erosion across the slope. No failures were observed during the field visit. The corridor intersects a perennial stream near MP 198.93 with moderate slopes and dense vegetation. From this stream the corridor traverses a moderately steep sidehill to a broad, relatively flat ridge.

The soils in the area were noted as Nolichucky Loam (NRC Hydrologic Soil Group B). Overall the slopes are well vegetated with no signs of mass movement except for the steep short slopes leading to the stream near MP 198.93.

In areas where the pipeline crosses the intermittent streams, the grade will be restored to original contours to facilitate drainage. Water bars in conjunction with trench breakers and drains will be installed in the steeper downhill sections of the right-of-way.

- **MVP-LMP-GI-30 (MP 204.4 to 204.8):**

The pipeline in this area runs diagonally upslope from MP 204.4 to MP 204.6, then transitions to upslope on a broad ridge to MP 204.7. The slopes along this section vary between 30% and 45%. This section parallels an existing cleared right-of-way for transmission lines. A gully near MP 204.6 is indicated on the topographic mapping and was confirmed in the field.

The site is mostly wooded with little underbrush, except in areas near the existing overhead lines where dense briars were encountered. Some evidence of gravitropism was observed. Numerous natural drains were observed at the site, in addition to the previously discussed gully, which has been delineated as a stream. Near MP 205.5, the right-of-way approaches an existing dirt road.

NRCS classifies soil in this region as silt loam (NRCS Hydrologic Soil Group C) or Carbo-Rock outcrop complex (NRCS Hydrologic Soil Group D).

Where the right-of-way crosses the stream and natural drains, the grade will be restored to facilitate drainage. Any seeps and springs encountered in the excavation will be provided with drains. Water bars in conjunction with trench breakers and drains will be installed in the steeper downhill sections of the right-of-way.

- **MVP-LMP-GI-31 (MP 211.55 to 211.8):**

The pipeline in this area runs across an existing access drive and alongside moderate slopes just south of a crest before heading downslope between MP 211.55 and MP 211.8. The primary area of concern falls between MP 211.55 and MP 211.7 where the pipeline right-of-way comes within approximately 15 feet of a nearly vertical slope. US Route 460 is located directly below this steep slope. The remainder of the area of concern crosses drainages with side slopes ranging from 30% to 47%.

Historical imagery and site reconnaissance show no signs of landslide movement or slope instability. Soils in this area were classified as Carbo-Rock outcrop complex (NRCS Hydrologic Soil Group D) or Gilpin silty loam (NRCS Hydrologic Soil Group C).

Water bars in conjunction with trench breakers and drains will be installed in the steeper downhill section of the right-of-way. Where practical, the pipe trench will be located in bedrock to protect the pipe from shallow soil movements. A transverse trench drain will be installed at the low point near MP 211.65.

- **MVP-LMP-MN-32 (MP 219.6 to 220.9 - Jefferson National Forest):**

From MP 219.6 to MP 219.8, the pipeline corridor follows a generally flat profile along the toe of a slope, then swings south and climbs a steep ridge to MP 220.7. The section of pipeline running up the ridge has an average slope of 30% with side slopes ranging from 40% to 80% downslope to drainage ways. From MP 220.65 to 220.95, the pipeline corridor follows relatively flat or gently up sloping terrain with a gravel road crossing at MP 220.7.

This section was mostly vegetated by trees and shrubs but has occasional sandstone outcrops along the ridgeline. The topsoil was thin and underlying soil was gravelly with gravels composed of fragments of sandstone. Drainage areas from the ridge drain west into Craig Creek. The soil was classified as either Berks and Weikert or Berks and Weikert very stony (NRCS Hydrologic Soil Group B).

Due to the relatively shallow depth of bedrock in this area (approximately 2.75 feet bgs), it is anticipated that the pipe will be installed/embedded within the bedrock from MP 220 to the end of this area of concern. Water bars in conjunction with trench breakers and drains will be installed in the steeper downhill sections of the right-of-way.

Refer to *Site-Specific Design of Stabilization Measures in Selected High-Hazard Portions of the Route of the Proposed Mountain Valley Pipeline Project in the Jefferson National Forest*, JNF Priority Site #6 for more information.

- **MVP-LMP-MN-33 (MP 220.6 to 220.7 – MVP Route 4.0.0)**:

The pipeline in this area runs down the crest of a broad ridge between MP 220.5 to MP 220.65 (MVP Route 4.0.0), then turns 90-degrees down at a slope of approximately 30% for 150 feet before the pipeline corridor crosses a drainage way near MP 220.66 (MVP Route 4.0.0). The primary area of concern is from MP 220.6 to MP 220.7 (MVP Route 4.0.0). Two additional significant drainage crossings were encountered at MP 220.8 and MP 220.98 (MVP Route 4.0.0), which have been delineated as streams

No field survey or report was completed for this area due to landowner restrictions, but soils in this region are classified as either Berks-Weikert Complex or Berks and Weikert Soils (NRCS hydrologic Soil Group B).

In areas where the pipeline crosses gullies and natural drains, the grade will be restored to original contours to facilitate drainage. Rock armoring or ACB will be utilized to minimize erosion across the pipeline right-of-way at gullies not delineated as streams. A sidehill low-point drain will be installed in the trench at the drainage crossings.

- **<u>MVP-LMP-MN-34 (MP 221.8 to 221.9 -MVP Route 4.0.0):</u>**

The pipeline in this area runs along relatively flat terrain but, while avoiding a substation to the south, cuts through a knoll for a short 400-foot section between MP 221.8 to MP 221.9 (MVP Route 4.0.0).

The area is located at the edge of a pasture and a wooded area adjacent to an existing powerline right-of-way. It does not appear that construction will impact the slope subjacent to the substation. During the field visit, a sinkhole was observed between the edge of the proposed right-of-way and the substation. Soils in this area were classified as either Frederick and Vertrees gravelly silt loam or Duffield-Ernest Complex (NRCS Hydrologic Soil Group B).

No landslide mitigation measures are required in this area and the sinkhole was delineated in MVP's karst study. This area will no longer affect the pipeline alignment following acceptance of the Mount Tabor Alternative.

- **<u>MVP-LMP-MN-35 (MP 229.2 to 229.3):</u>**

The pipeline in this section runs adjacent to and crosses a power line right-of-way and intermittent stream. After crossing the stream near MP 229.3, the pipeline follows a slight sidehill trajectory above the stream to the power line right-of-way. The forest floor is mostly bare with leaves and some small shrubs, but the area is forested. Soils in the area correspond to NRCS Hydrologic Soil Class A and B and were observed to be very stony.

No landslide mitigation measures are recommended in this area.

- **<u>MVP-LMP-FR-36 (MP 261.2 to 261.2)</u>:**

The pipeline in this area crosses State Route 697 and then turns downslope before crossing moderately steep side slopes for approximately 600 feet. The area of concern is in the vicinity of MP 261.2. Houses are located within 200 feet or less of the pipeline corridor but both are uphill from the corridor.

The area is gently sloping with a dense forest of young trees with sparse low-growing vegetation. No evidence of prior slope movement was observed. Soils in the area were classified as Clifford-Hickoryknob Complex (NRCS Hydrologic Soil Group B).

No landslide mitigation measures are required in this area.

- **MVP-LMP-FR-37 (MP 263.9 to 264.0 -MVP Route 4.0.0):**

The pipeline in this section runs across two existing gravel roads and a cleared right-of-way for transmission lines before turning across a moderate side slope just south of a substation. The primary concern is the steep side slope adjacent to the substation between MP 264.05 to MP 264.1 (MVP Route 4.0.0).

The right-of-way is brush- and tree-covered in this vicinity. Several boulders were visible at the ground surface, but soil along the right-of-way may have been disturbed during construction of the substation or associated power lines. Just south of the substation, an existing drainage culvert runs downhill to a catch basin on the north side of Energy Boulevard. It appears that this culvert drains to the south side of Energy Boulevard. This drainage should be restored following pipeline construction. The soil type in this section is Clifford fine sandy loam of NRCS soil group B.

No landslide mitigation measures are required in this area.

This area will no longer affect the pipeline alignment following acceptance of the Blackwater Alternative.

10.0 ADDITIONAL AREAS OF CONCERN

10.1 Peters Mountain, Sinking Creek Mountain, Brush Mountain, and Giles County Seismic Zone

Potential landslide hazards in the areas of the Giles County Seismic Zone (GCSZ), Peters Mountain, Sinking Creek Mountain and Brush Mountain in southern West Virginia and Southwestern Virginia along the proposed route for the Mountain Valley Pipeline are summarized below. It should be noted that the GCSZ is not a specifically mapped geographic area, but corresponds to a generalized area that is relatively seismically active.

Landslide, debris flow, debris avalanche, earthflow and creep, rockfall (Wieczorek and Snyder, 2009), and rock slump and rock block slides (Schultz and Southworth;1989) are the general categories of mass wasting hazards that may be observed in southern West Virginia and southwestern Virginia. Landslides, flow, avalanche and creep are characteristic of failure in unconsolidated overburden or highly weathered shallow bedrock.

Rock block failure involves gravity-induced movement of massive and intact blocks of bedrock. Schultz and Southworth (1989) identify rock slumps and rock block slides as a specific mass wasting hazard somewhat unique to Peters Mountain, Sinking Creek Mountain and Brush Mountain.

According to Schultz and Southworth (1987, 1989): *Rock block slides tend to occur on the southeast slopes of anticlinal folds composed of sandstone, siltstone and shale. Where these folded beds dip steeply (45 degrees or more) rock slides are relatively small and confined to the uppermost parts of the slope. Where dips are less than 30 degrees, slides show more movement and are areally extensive. Most of the rock block* *slides are relict features from the Pleistocene Epoch. Dip-slope rock block failure occurs over an extended period of time, and no evidence of recent movement in these areas have been found.*

Trigger events for rock block failure are thought to be primarily associated with pore pressure effects from sustained long-duration or short duration intense precipitation events (Schultz and Southworth, 1987, 1989; Wieczorek and Snyder, 2009). Some researchers postulate that seismic shaking may trigger slope failure, but no direct evidence is available to support this suggestion. D.G. Honegger Consulting (2015) presents an analysis and recommendations for mitigating seismic-induced risks to MVP.

Rock block failure progresses from an initial stage of downslope sagging and bulging to downslope slumping to brittle fracture along lateral break-away scarps (Schultz and Southworth, 1987). This typified behavior presents an opportunity to establish a monitoring program along the southeast slopes of Peters Mountain, Sinking Creek Mountain and Brush Mountain to provide advanced warning of potential rock block failure, as summarized below.

Mountain Valley Pipeline will monitor for potential rock block slides on the southeast slopes of Peters Mountain, Sinking Creek Mountain and Brush Mountain. As discussed above, rock block slides in these areas of concern are relict features, and if further sliding or slumping is occurring it is a very slow process. The pace of such failures is conducive to establishing a monitoring program and if future observations dictate, establishing an evaluation and mitigation program for the pipeline in areas observed to be at risk. MVP will conduct aerial inspection of these slopes with LIDAR, and evaluate the slope characteristics for notable bulging or bowing, and other observations of possible slope movement. If this monitoring program suggests evidence for rock block slumping or incipient failure, Mountain Valley will deploy a field inspection team to the area of concern and establish a mitigation program commensurate with the results of an incipient slope failure study.

The rock block slides in the vicinity of the proposed alignment appear to be stable under current site conditions. Past triggering mechanisms for the slides are postulated to be related to either, or both, ancient seismic activity and Pleistocene climate. Mountain Valley's construction and reclamation Best Management Practices will provide for stable slopes during and post-construction. As a safeguard, the JNF lands surveillance monitoring program described above will provide advanced warning of landform changes that may signal potential slope movement, allowing Mountain Valley time to plan and execute stabilization measures if needed.

10.2 Debris Flow Potential along Kimballton Branch

Debris flows are a type of mass movement comprised of soil and rock moving along a shallow sliding surface within soil or weathered, foliated and jointed rock materials. Debris flows are often associated with steep gullies and may be triggered by significant precipitation events.

The pipeline crosses the headwaters of Kimballton Branch (which flows to Big Stoney Creek) between MP 195.7 and 195.8. During construction, an engineering geologist or geotechnical engineer familiar with debris flows will evaluate the area and will be present during pipeline construction to observe the trench and earth materials. Based on the results of these observations, MVP will determine if minor adjustments to the proposed alignment are warranted to mitigate the potential for a debris flow or avoid an existing debris flow. If this area appears to be prone to debris flow recurrence but an alignment adjustment is not practical, mitigation measures, which may include drains and soil reinforcement or other measures depending on subsurface conditions encountered, will be implemented.

11.0 REFERENCES

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APPENDIX