KARST HAZARDS ASSESSMENT
(DESKTOP REVIEW AND FIELD RECONNAISSANCE)

Prepared for:

Mountain Valley Pipeline
Suite 1700
625 Liberty Avenue
Pittsburgh, PA 15222-3111

October 10, 2016

Prepared by:

Draper Aden Associates
Engineering • Surveying • Environmental Services

DAA Project Number: B14188B-01
Draper Aden Associates (DAA) prepared this document (which may include drawings, specifications, reports, studies and attachments) in accordance with the agreement between DAA and Mountain Valley Pipeline, LLC.

The standard of care for all professional engineering, environmental and surveying and related services performed or furnished by DAA under this Agreement are the care and skill ordinarily used by members of these professions practicing under similar circumstances at the same time and in the same locality. DAA makes no warranties, express or implied, under this Agreement in connection with DAA’s services.

Conclusions presented are based upon a review of available information, the results of our field studies, and/or professional judgment. To the best of our knowledge, information provided by others is true and accurate, unless otherwise noted.

Any reuse or modification of any of the aforementioned documents (whether hard copies or electronic transmittals) prepared by DAA without written verification or adaptation by DAA will be at the sole risk of the individual or entity utilizing said documents and such use is without the authorization of DAA. DAA shall have no legal liability resulting from any and all claims, damages, losses, and expenses, including attorney’s fees arising out of the unauthorized reuse or modification of these documents. Client shall indemnify DAA from any claims arising out of unauthorized use or modification of the documents whether hard copy or electronic.
TABLE OF CONTENTS

1.0 INTRODUCTION .......................................................................................................................... 1
2.0 KARST FEATURES AND ASSOCIATED HAZARDS.................................................. 3
   2.1 Methods for Desktop Review and Field Reconnaissance .............................................. 3
   2.2 Coordination on Geologic Formation Names ............................................................... 4
   2.3 Karst Features Identified ............................................................................................... 9
   2.4 Karst Feature Mitigation .............................................................................................. 9
   2.5 Bibliography ................................................................................................................. 10
   2.6 Figures 1 Through 3 ..................................................................................................... 12
       Figure 1  MVP alignment and alternatives underlain by karst terrain .............. 13
       Figure 2  MVP alignment underlain by karst terrain in WV ............................... 14
       Figure 3  MVP alignment and alternatives underlain by karst in VA .......... 15

TABLE
Table 1 – Stratigraphic Nomenclature (table embedded in report text)
Table 2 – Karst Features and Hazards Analysis

APPENDIX A - MAP SET
Map Sheets (1-37) for Karst Hazards Assessment
1.0 INTRODUCTION

Mountain Valley Pipeline, LLC (Mountain Valley), a joint venture between EQT Midstream Partners, LP and affiliates of NextEra Energy, Inc., WGL Holdings, Inc. Vega Energy Partners, Ltd., RGC Midstream, LLC, and Con Edison Gas Midstream, LLC, is seeking a Certificate of Public Convenience and Necessity from the Federal Energy Regulatory Commission (FERC) pursuant to Section 7(c) of the Natural Gas Act authorizing it to construct and operate the proposed Mountain Valley Pipeline (MVP) Project located in 17 counties in West Virginia and Virginia. Mountain Valley plans to construct an approximately 301-mile, 42-inch-diameter natural gas pipeline to provide timely, cost-effective access to the growing demand for natural gas for use by local distribution companies, industrial users and power generation facilities in the Mid-Atlantic and southeastern markets, as well as potential markets in the Appalachian region.

The proposed pipeline will extend from the existing Equitrans, L.P. transmission system and other natural gas facilities in Wetzel County, West Virginia to Transcontinental Gas Pipe Line Company, LLC’s (Transco) Zone 5 compressor station 165 in Pittsylvania County, Virginia. In addition to the pipeline, MVP project components will include approximately 171,600 horsepower of compression at three compressor stations along the route, as well as measurement, regulation, and other ancillary facilities required for the safe and reliable operation of the pipeline. The pipeline is designed to transport up to 2.0 million dekatherms per day (MMDth/d) of natural gas. Resource Report 1 provides a complete summary of the MVP project and a general location map of the MVP components.

This Karst Hazards Assessment (KHA) presents the results of desk top review and field reconnaissance identifying karst hazards. The KHA is part of the MVP Resource Report 6, which was prepared and organized according to the FERC Guidance Manual for Environmental Report Preparation (August 2002). Resource Report 6 describes existing geologic setting and resources, potential impacts, geologic hazards and mitigation in relation to MVP components.

Mountain Valley previously submitted interim drafts of the KHA to FERC in October 2015 and April 2016 that identified karst features and associated hazards along the initial proposed alignment and various alternatives of the MVP. The current KHA submitted herein presents an
assessment of karst features and associated hazards within 1/4-mile of the currently October 2016 proposed route.
2.0 KARST FEATURES AND ASSOCIATED HAZARDS

Figure 1 illustrates the proposed MVP alignment and alternatives (including the current October 2016 proposed route) that are underlain by karst terrain. Figure 2 and Figure 3 illustrate more detail in terms of MVP alignment and alternatives underlain by karst terrain in West Virginia and Virginia, respectively.

Karst features within ¼-mile (generally termed the secondary karst buffer) and within 150 feet (corresponding to the construction easement) of the October 2016 proposed route were identified through desktop review of public and proprietary data (discussed below). Field confirmation was completed on properties where landowners allowed access in order to verify the desktop review results and identify previously unmapped karst features.

Karst features identified within the secondary karst buffer (¼ mile) and the construction easement (150 feet) are summarized in Table 2, and are illustrated in Map Sheets 1 through 37 in Appendix A. Karst features associated with minor potential for impact are highlighted in yellow, and with moderate potential for impact in orange. Mountain Valley made numerous adjustments to the proposed MVP alignment to avoid significant karst features (note that there are no red highlighted karst features or concerns in Table 2). Karst features that are at negligible risk from pipeline construction, or pose negligible risk to pipeline construction and long-term operation, are not highlighted in color in Table 2.

Mountain Valley prepared a Karst Mitigation Plan (under separate cover) that provides mitigation protocols for karst features that cannot be avoided through minor variations within the construction easement. Mountain Valley will deploy Karst Specialist inspection teams during construction to monitor karst features and provide recommendations for avoidance or mitigation.

2.1 Methods for Desktop Review and Field Reconnaissance

The KHA was completed under the direction of the Project Karst Specialist, who holds qualifications of a professional geologist having direct work experience with karst hydrology and geomorphic processes. The Karst Specialist team has over 70 years of combined direct field experience evaluating karst features in southern West Virginia and Southwest Virginia (the vicinity of the proposed MVP alignment).
Desk top analysis and field reconnaissance was focused on a 1/4-mile buffer from the proposed alignment (termed herein the secondary karst buffer), which incorporated the 150-foot lateral construction easement. The secondary karst buffer was expanded beyond ¼-mile where the likelihood of karst feature occurrence was deemed to be high. Certain carbonate bedrock formations in southern West Virginia and southwest Virginia are more prone to karstification than are others, and the desktop review and field reconnaissance were focused accordingly.

Desk top analysis included review of publicly available data sources, and data provided by the Virginia Speleological Survey (VSS) or West Virginia Speleological Survey (WVASS). Location information for many karst features was taken from information collected by volunteer amateur cavers, continuously compiled since the early 1940s. Many of these historically-documented karst features, originally mapped on 15-minute USGS topographic quadrangle maps, were transcribed onto more modern 7.5-minute topographic maps and location coordinates estimated. It is noted that information included in the desk top review that was provided by the VSS or WVASS are not associated with guarantees by these sources for accuracy or correctness of any information. Field verification was conducted (where property owner permission was granted) to verify a mapped karst feature and to identify previously undocumented karst features.

The KHA greatly expanded the knowledge base regarding local karst features. More than 12 new cave features were identified. Numerous previously undocumented springs and insurgences were identified and mapped. As well, locations of previously identified features were confirmed and updated. Equally important to identifying karst features, is documenting a lack of karst features in areas that previously had little to no historic karst review. Direct interaction with property owners, commenters, and state agencies during the KHA process facilitated karst feature identification and this additional knowledge will serve as an asset to future karst research efforts. Mountain Valley adjusted the proposed alignment in numerous locations to avoid karst features and mitigate associated hazards using the information gathered through the current and previous KHA efforts.

2.2 Coordination on Geologic Formation Names

The discussion of karst-related hazards presented below includes references to specific geologic formations, and to support that discussion the generalized stratigraphic column from McDowell and Schultz (1990) is presented below, to identify the major rock types in the karst area.
From McDowell and Schultz, 1990

Figure 5. Generalized columnar section for rocks in the Giles County area of Virginia and West Virginia.

Structural and Stratigraphic Framework, Giles County, Virginia and West Virginia · ES
For added clarity, we note that geologic formations comprising the local karst terrain are referred to by different names, particularly between practitioners in West Virginia versus Virginia. The geologic mapping work of McDowell and Schultz (1990) presented a useful correlation for formation names, as reproduced below (Table 1).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Correlation of Geologic Formations</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Virginia</td>
<td>Virginia</td>
</tr>
<tr>
<td>Formation 1</td>
<td>Correlation 1</td>
</tr>
<tr>
<td>Formation 2</td>
<td>Correlation 2</td>
</tr>
<tr>
<td>Formation 3</td>
<td>Correlation 3</td>
</tr>
</tbody>
</table>

...
### Table 1. Stratigraphic nomenclature used in this study and other studies in the Giles County area of Virginia and West Virginia

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MISSISSIPPIAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Match Chuck Series</td>
<td>Bluestone Group</td>
<td>Bluestone Formation</td>
<td>Bluestone Formation</td>
<td>Bluestone Formation</td>
<td>Bluestone Formation.</td>
</tr>
<tr>
<td>Hinton Group</td>
<td>Hinton Formation</td>
<td>(not exposed)</td>
<td>Hinton Formation</td>
<td>Stony Gap Sandstone Member</td>
<td>Hinton Formation</td>
</tr>
<tr>
<td>Bluefield Group</td>
<td>Bluefield Formation</td>
<td>“Casper” Limestone</td>
<td>Bluefield Formation</td>
<td>Bluefield Formation</td>
<td>Match Chuck Group</td>
</tr>
<tr>
<td>Greenbrier Series</td>
<td>“St. Genevieve” Limestone</td>
<td>Greenbrier Limestone</td>
<td>Greenbrier Limestone</td>
<td>Greenbrier Limestone</td>
<td>Bluefield Formation</td>
</tr>
<tr>
<td>Hillsdale Limestone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Little Valley Limestone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maccrady Series</td>
<td>Maccrady Formation</td>
<td>Maccrady Shale</td>
<td>Maccrady Shale</td>
<td>Maccrady Shale</td>
<td>Maccrady Shale</td>
</tr>
<tr>
<td>Pocono Series</td>
<td>Price Formation</td>
<td>Price Formation</td>
<td>Price Formation</td>
<td>Price Siltstone</td>
<td>Price Formation</td>
</tr>
<tr>
<td>Chemung Series</td>
<td>Parrot Formation</td>
<td>Chemung Formation</td>
<td>Chattanooga Shale</td>
<td>Chemung Formation</td>
<td>Chattanooga Shale</td>
</tr>
<tr>
<td>“Chemung” Formation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portage</td>
<td>Brallier Formation</td>
<td>Brallier Formation</td>
<td>Brallier Shale</td>
<td>Brallier Shale</td>
<td>Brallier Shale</td>
</tr>
<tr>
<td>Millboro Formation</td>
<td>Millboro Formation</td>
<td>Millboro Shale</td>
<td>Millboro Shale</td>
<td>Millboro Shale</td>
<td>Millboro Shale</td>
</tr>
<tr>
<td>Genezee-Hamilton-Marcellus Series</td>
<td>Huntsville Formation</td>
<td>Needmore Formation</td>
<td>Huntersville Chert</td>
<td>Huntersville Chert</td>
<td>Huntersville Chert</td>
</tr>
<tr>
<td>Licking Creek Formation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oriskany Series</td>
<td>Rocky Gap Sandstone</td>
<td>Healing Springs Sandstone</td>
<td>Rocky Gap Sandstone</td>
<td>Rocky Gap Sandstone</td>
<td>Rocky Gap Sandstone</td>
</tr>
<tr>
<td>Helderberg Series</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SILURIAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinton Series</td>
<td>Tonoloway Limestone</td>
<td>Tonoloway Formation</td>
<td>Tonoloway Limestone</td>
<td>Tonoloway Limestone</td>
<td>Tonoloway Limestone</td>
</tr>
<tr>
<td>“Keefer” Formation</td>
<td>Keefer Sandstone</td>
<td>Rose Hill Formation</td>
<td>Keefer Sandstone</td>
<td>Rose Hill Formation</td>
<td>Keefer Sandstone</td>
</tr>
<tr>
<td>Rose Hill Formation</td>
<td>Cacapon Formation</td>
<td>Clinch Sandstone</td>
<td>Clinch Sandstone</td>
<td>Clinch Sandstone</td>
<td>Clinch Sandstone</td>
</tr>
<tr>
<td>White Medina Series</td>
<td>Tuscarora Sandstone</td>
<td>Tuscarora Formation</td>
<td>Tuscarora Quartzite</td>
<td>Tuscarora Quartzite</td>
<td>Tuscarora Quartzite</td>
</tr>
<tr>
<td>System</td>
<td>Mercer, Monroe, and Giles Co., Va. and W. Va. (Herron, 1926, fig. 6)</td>
<td>Giles Co., Va. and W. Va. (Herron, 1926, fig. 6)</td>
<td>Southwestern Virginia (Miller and McElreath, 1977)</td>
<td>This report</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>Red River Series</td>
<td>Upper Muskingum Group</td>
<td>Lower Muskingum Group</td>
<td>Martinburg Formation</td>
<td>Janata Formation</td>
<td></td>
</tr>
<tr>
<td>Maysville Group</td>
<td>Muskingum Formation</td>
<td>Eglanton Limestone</td>
<td>Eglanton Formation</td>
<td>Martinburg Formation</td>
<td></td>
</tr>
<tr>
<td>Lower Group</td>
<td>Greasy Creek Group</td>
<td>Witten Limestone</td>
<td>Moccasin Formation</td>
<td>Janata Formation</td>
<td></td>
</tr>
<tr>
<td>Upper Group</td>
<td>Eglanton Limestone</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Lower Group</td>
<td></td>
</tr>
<tr>
<td>Lower Maysville Group</td>
<td>Green Limestone</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Upper Group</td>
<td></td>
</tr>
<tr>
<td>Upper Group</td>
<td>Witten Limestone</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Lower Group</td>
<td></td>
</tr>
<tr>
<td>Martinsburg Formation</td>
<td>Edinburg Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Middle Group</td>
<td></td>
</tr>
<tr>
<td>Eglanton Formation</td>
<td>Edinburg Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Upper Group</td>
<td></td>
</tr>
<tr>
<td>Moccasin Formation</td>
<td>Edinburg Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Lower Group</td>
<td></td>
</tr>
<tr>
<td>Eglanton Formation</td>
<td>Edinburg Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Middle Group</td>
<td></td>
</tr>
<tr>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Lower Group</td>
<td></td>
</tr>
<tr>
<td>Eglanton Formation</td>
<td>Edinburg Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Middle Group</td>
<td></td>
</tr>
<tr>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Lower Group</td>
<td></td>
</tr>
<tr>
<td>Eglanton Formation</td>
<td>Edinburg Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Middle Group</td>
<td></td>
</tr>
<tr>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Lower Group</td>
<td></td>
</tr>
<tr>
<td>Eglanton Formation</td>
<td>Edinburg Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Middle Group</td>
<td></td>
</tr>
<tr>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Lower Group</td>
<td></td>
</tr>
<tr>
<td>Eglanton Formation</td>
<td>Edinburg Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Middle Group</td>
<td></td>
</tr>
<tr>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Lower Group</td>
<td></td>
</tr>
<tr>
<td>Eglanton Formation</td>
<td>Edinburg Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Middle Group</td>
<td></td>
</tr>
<tr>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Stratton Limestone</td>
<td>Eglanton Formation</td>
<td>Lower Group</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1. Stratigraphic nomenclature used in this study and other studies in the Giles County area of Virginia and West Virginia—Continued**

From McDowell and Schultz, 1990
2.3 Karst Features Identified

Karst features located within the secondary karst buffer (minimum ¼-mile) and construction easement (minimum 150-feet) of the proposed MVP alignment are summarized in Table 2. The karst features presented in the summary table were mapped or otherwise recorded through desktop review. Features that were further characterized through field observation are specifically noted in Table 2. A description of the feature, potential impact to avoid or mitigate, and recommendations are included in Table 2. Note the color-code system for karst features (e.g., white is negligible risk; red is notable risk, etc.). The karst features identified in Table 2 are also shown in the corresponding Map Set provided in Appendix A. Note that the karst features listed in the specific route table includes a cross-reference to the map sheet. Each karst feature listed on Table 2 is associated with a unique identifier number for cross reference to route maps (see Map Sheets in Appendix A).

2.4 Karst Feature Mitigation

Refer to the MVP Karst Mitigation Plan for a detailed discussion on karst hazard mitigation where an identified feature cannot be reasonably avoided within a proposed construction easement, or where an unidentified feature is encountered during construction.
2.5 Bibliography


Karst regions derived from 1968 geological map of West Virginia. 1:250,000. West Virginia Geological and Economic Survey (WVGES).


RSPSD (2014) Red Sulphur Public Service District Board Members Statement to the Monroe County Commissioners. http://static1.squarespace.com/static/552f00fee4b00d8610d2a67a/t/55315c72e4b06c86f2510aee/1429298290847/RSPSD-to-Monroe-County-Commission.pdf


2.6 Figures 1 Through 3
Table 2 – Karst Features and Hazards Analysis
<table>
<thead>
<tr>
<th>Mile Post</th>
<th>Sector</th>
<th>Feature Identification</th>
<th>Height Above River (feet)</th>
<th>Description</th>
<th>Note(s)</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.00</td>
<td>1 of 3</td>
<td>Contact - Sarah Inneman</td>
<td>Yes</td>
<td>Small spring approximately 200 feet east (northeast) of proposed alignment.</td>
<td>See Note (1) at bottom of table</td>
<td>Monroe</td>
</tr>
<tr>
<td>12.50</td>
<td>2 of 3</td>
<td>Contact - Sarah Inneman</td>
<td>Yes</td>
<td>Small spring approximately 200 feet east (northeast) of proposed alignment.</td>
<td>See Note (1) at bottom of table</td>
<td>Monroe</td>
</tr>
<tr>
<td>13.60</td>
<td>2 of 3</td>
<td>Spring</td>
<td>Yes</td>
<td>Small spring approximately 200 feet east (northeast) of proposed alignment.</td>
<td>See Note (1) at bottom of table</td>
<td>Monroe</td>
</tr>
</tbody>
</table>

**Note:**
- The table above lists potential impacts to natural features that may require mitigation. Each note at the bottom of the table provides additional information on the specific location and potential mitigation strategies.
- The alignment is designed to avoid significant water features and natural openings to minimize environmental impacts.
- The construction activities may require the installation of temporary fencing and other measures to protect the natural features.
- The mitigation strategies may include the installation of culverts, temporary barriers, and other protective measures to ensure the safety and protection of the natural features.

**References:**
- Monroe County Department of Public Works and Engineering
- New York State Department of Transportation
- Environmental Impact Statement

**Additional Information:**
- The alignment is designed to minimize the impact on the natural environment and protect the integrity of the surrounding ecosystems.
- The project is subject to regulatory review and approval from the appropriate authorities.
- The construction activities may require the implementation of additional measures to ensure the safety and protection of the natural features.

**Contact Information:**
- For more information, please contact the Monroe County Department of Public Works and Engineering at (315) 765-0300.
<table>
<thead>
<tr>
<th>Mile Post</th>
<th>County</th>
<th>Study Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>208.85</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>209.00</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>209.10</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>209.30</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>209.95</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>210.54</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>210.62</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>211.00</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>211.39</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>211.67</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>212.43</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>214.98</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>215.01</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>215.24</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>215.59</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>215.60</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>215.91</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>216.22</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>216.89</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>217.03</td>
<td>Giles</td>
<td>Yes</td>
</tr>
<tr>
<td>217.13</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>217.24</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>218.09</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>218.65</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>219.31</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>221.24</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>221.32</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>224.15</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>224.26</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>224.42</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>225.65</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>225.81</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>226.52</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>226.53</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>226.64</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>226.65</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>227.24</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>227.32</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>227.65</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>228.09</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>228.31</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>229.35</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>230.65</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>230.81</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>231.24</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>233.25</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>234.15</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>235.42</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>235.65</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>237.24</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>237.32</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>237.65</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>238.09</td>
<td>Craig</td>
<td>Yes</td>
</tr>
<tr>
<td>Site</td>
<td>Date</td>
<td>Feature Identification</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>------------------------</td>
</tr>
<tr>
<td>218.15</td>
<td>20 of 15</td>
<td>Cave and spring entrance</td>
</tr>
<tr>
<td>219.28</td>
<td>20 of 15</td>
<td>Caves</td>
</tr>
<tr>
<td>220.72</td>
<td>27 of 17</td>
<td>Contact of Paleozoic and Cretaceous, Saugeen Moraine and till</td>
</tr>
<tr>
<td>221.56</td>
<td>27 of 17</td>
<td>Caves, spring entrance</td>
</tr>
<tr>
<td>222.39</td>
<td>27 of 17</td>
<td>Cave</td>
</tr>
<tr>
<td>223.43</td>
<td>26 of 17</td>
<td>Spring</td>
</tr>
<tr>
<td>224.50</td>
<td>28 of 17</td>
<td>Spring entrance</td>
</tr>
<tr>
<td>225.67</td>
<td>28 of 17</td>
<td>Spring</td>
</tr>
<tr>
<td>226.82</td>
<td>30 of 17</td>
<td>Sinkhole</td>
</tr>
<tr>
<td>228.05</td>
<td>31 of 17</td>
<td>Sinkhole</td>
</tr>
<tr>
<td>229.34</td>
<td>32 of 17</td>
<td>Sinkhole</td>
</tr>
<tr>
<td>230.62</td>
<td>32 of 17</td>
<td>Sinkhole</td>
</tr>
<tr>
<td>231.72</td>
<td>32 of 17</td>
<td>Sinkhole</td>
</tr>
<tr>
<td>232.62</td>
<td>32 of 17</td>
<td>Sinkhole</td>
</tr>
<tr>
<td>233.58</td>
<td>32 of 17</td>
<td>Sinkhole</td>
</tr>
<tr>
<td>234.83</td>
<td>32 of 17</td>
<td>Sinkhole</td>
</tr>
</tbody>
</table>
Appendix A

Map Sheets (1-37) for Karst Hazards Assessment
Sinkhole, Sinkhole ~240' right.

Contact - Limestone, Begin limestone area (approx.).

Legend
- Cave Length, Depth
- Spring
- Swallet
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VGIN - 5ft
- Sinkholes VaDMME
- Select Sinkhole Watersheds
- Fault
- Lineament
- 150' Buffer, Primary Karst Review Zone
- 1330' Buffer, Secondary Karst Review Zone
- MVP October 2016 Proposed Route
- MVP October 2016 Proposed Route/Mapport
- MVP October 2016 Proposed Access Roads
- MVP October 2016 Proposed Permanent Easement
- MVP October 2016 Proposed Temporary Work Space
- MVP October 2016 Proposed Ancillary and AFW

Sheet 1 of 37

Mountain Valley Pipeline Project
Karst Features and Hazards Assessment
MVP October 2016 Proposed Route
09-30-16

Draper Aden Associates
Engineering, Surveying, Environmental Services

Contact: E.K. Rader and T.M. Gathright II


Caves: Douglas (1964); Holsinger (1975); Zokaites (1995), Va and WVa Speleological Surveys.


Appalachian Trail: https://www.appalachiantrail.org/about-the-trail/mapping-gis-data

Mountain Valley Pipeline Project

Copyright 2016. Draper Aden Associates. All rights reserved. The information in this document is the property of Draper Aden Associates, Inc. The recipient is granted permission to use this information exclusively for the purpose of planning. No part of this material may be reproduced, transmitted, or distributed in any form or by any means, electronic, mechanical, or other, without written permission of Draper Aden Associates. The recipient is permitted to provide a copy of this document to those persons directly involved in the planning process. Any determination of topography or contours, or any depiction of physical improvements, property lines or boundaries is for general information only and shall not be used for the design, modification, or construction of improvements to real property or for flood plain determination.

Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.
Note, Several short sections of Tonoloway.
Contact - Dolomite, Begin dolomite area. Medium karstification potential.

Fault, Complex structural discontinuity due to ancient thrust faulting (inactive Narrows thrust fault), possible preferential hydrology, voids.
Sinkhole, Several sinkholes in region.

Contact - Limestone, End dolomite, Begin limestone. High karst feature potential.

Cave, Uhoist Cave. Small cave approx 370’ right.

Sinkhole, Sinkhole complex 1000’ right.

Legend

- Sinkhole
- Spring
- Cave Length, Depth
- Sinkhole Watersheds
- Fault
- Primary Karst Review Zone
- Secondary Karst Review Zone
- Proposed Access Roads
- Proposed Temporary Work Space
- Proposed Ancillary and ATWS


Caves: Douglas (1964); Holsinger (1975); Zokaites (1995), Va and WVa Speleological Surveys.

Appalachian Trail: https://www.appalachiantrail.org/about-the-trail/mapping-gis-data


Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Karst Features and Hazards Assessment
MVP October 2016 Proposed Route
Sheet 16 of 37
09-30-16

Legend
- Cave Length: Depth
- Spring
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VGIN-58
- Sinkholes VaDMME
- Selected Sinkhole Watersheds
- Fault
- Lineament
- 150' Buffer, Primary Karst Review Zone
- 130' Buffer, Secondary Karst Review Zone
- MVP October 2016 Proposed Route
- MVP October 2016 Proposed Access Roads
- MVP October 2016 Proposed Permanent Easement
- MVP October 2016 Proposed Temporary Work Space
- MVP October 2016 Proposed Ancillary and ATWS
- MVP October 2016 Proposed Access Roads

Contact - Limestone, End of limestone area

Swallet, Sinking stream ~430' right. Dye traced to Doe Creek Spring on New River by DCR.
Pighole Cave, Mountain Valley Pipeline Project

Legend
- Cave Length: Depth
- Spring
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VGIN-50
- Sinkholes VaDMME
- Select Sinkhole Waterheds
- Fault
- Lineament
- 1,000' Buffer, Primary Karst Review Zone
- 1,300' Buffer, Secondary Karst Review Zone
- MVP-October 2016 Proposed Route
- MVP-October 2016 Proposed Permanent Easement
- MVP-October 2016 Proposed Temporary Work Space
- MVP-October 2016 Proposed Access Roads

Cave, Echols Cave ~150' above access road.

Contact - Dolomite, End limestone, Begin dolomite. Moderate karst feature potential.

Sinkhole, Sinkhole ~660' right.

Sinkhole, Sinkhole ~150' right. Additional sinkholes in vicinity farther away.

Additional sinkholes in vicinity farther away.

Legend: Cave Extent - Dolomite, End limestone, Begin dolomite. Moderate karst feature potential.
Appalachian Trail: https://www.appalachiantrail.org/about-the-trail/mapping-gis-data

Contact - Dolomite, End limestone, Begin dolomite. Moderate karst feature potential.

Sinkhole, Sinkhole ~660' right.

Sinkhole, Sinkhole ~150' right. Additional sinkholes in vicinity farther away.

Additional sinkholes in vicinity farther away.
Karst Features and Hazards Assessment
MVP October 2016 Proposed Route
Sheet 19 of 37
09-30-16

Legend

- Cave Length, Depth
- Spring
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Other Sinkholes (VA DMME)
- Sinkholes VaDMME
- Select Sinkhole Watersheds
- Fault
- Lineament
- 150' Buffer, Primary Karst Review Zone
- 1307 Buffer, Secondary Karst Review Zone
- MVP October 2016 Proposed Route
- MVP October 2016 Proposed Permanent Easement
- MVP October 2016 Proposed Temporary Workspace
- MVP October 2016 Proposed Ancillary and AFWS

Sinkhole, Sinkhole ~80' to right. Contact - Limestone, End dolomite. Begin limestone. High karst feature potential with significant cave and karst feature development.

Sinkhole, Several sinkholes to left, ~170'.

Sinkhole, Sinkhole ~200' left. Second sinkhole at ~350'.

Cave, Tawneys and Smokehole Cave Systems and related springs, (upstream). Hydrologic system drains Clover Hollow.

Smokehole Cave, Tawneys and Smokehole Cave Systems and related springs. (upstream). Hydrologic system drains Clover Hollow.
Sinkhole, Several sinkholes in vicinity of access road.

Spring, Alignment cuts above a large spring ~10' left.

Sinkhole, Several sinkholes to left.
Sinkhole, Several sinkholes in vicinity of access road.

Spring, Large spring 360' right.

Cave, Canoe Cave, ~950' right.

Sinkhole, ~440' right.

Sinkhole, ~50' right.

Sinkhole, Sinkhole containing farm debris, 240' right.

Sinkhole, Several sinkholes in vicinity of access road.
Cave, Stream insurgence in open throat sinkhole, ~140' left.

Sinkhole, Shallow sinkhole ~230' left.

Contact, End limestone area.
Legend

- Cave Length: Depth
- Spring
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VaDMME
- Sinkholes VaDMME
- Select Sinkhole Watersheds
- Fault
- Lineament
- 150' Buffer, Primary Karst Review Zone
- 1307' Buffer, Secondary Karst Review Zone
- MVP October 2016 Proposed Route
- MVP October 2016 Proposed Route
- MVP October 2016 Proposed Access Roads
- MVP October 2016 Proposed Permanent Easement
- MVP October 2016 Proposed Temporary Work Space
- MVP October 2016 Proposed Trenching and AFEs

Note: DCR Dye Traces indicate flow from Dry Branch, ~3000 feet to the northeast of MP-226.4, to Old Mill Cave Spring, Dam Spring, and Hancock Spring ~6000 feet southwest of the alignment.

Sinkhole, Sinkholes ~95' left.
Sinkhole, Sinkholes ~240' left.
Sinkhole, Several sinkholes ~240' left, along lineament.
Sinkhole, Sinkholes ~145' left, along lineament.
Sinkhole, Sinkholes ~150' right, along lineament.
Sinkhole, Sinkholes ~165' right, along lineament, additional sinkholes in vicinity of access road.
Sinkhole, Sinkhole ~165' right, along lineament, additional sinkholes in vicinity of access road.
Sinkhole, Sinkhole ~165' right, along lineament.
Sinkhole, Sinkholes in vicinity of access road.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkhole ~165' right.
Sinkhole, Sinkholes ~145' left, along lineament, additional sinkholes in vicinity of access road.

Sinkhole, ~160' right, along lineament, additional sinkholes in vicinity of access road.

Sinkhole, ~145' left, along lineament, additional sinkholes in vicinity of access road.

Spring, Water for livestock, ~2000' right.

Spring, Johnsons Cave Spring, Water probably from hollow to east.

Johnson Cave Spring, ~100', 10'.

Sinkhole, Losing stream, wet weather insurgence.

Sinkhole, Sinkhole lineament to west.

Cave, Johnsons Cave; Carries a small stream.

Spring, Johnsons Cave Spring; Carries a small stream.

Contour Disclaimer: "Any determination of topography or contours, or any depiction of physical improvements, property lines or boundaries is for general information only and shall not be used for the design, modification, or construction of improvements to real property or for flood plain determination."

Mountain Valley Pipeline Project
Karst Features and Hazards Assessment
MVP October 2016 Proposed Route
Sheet 32 of 37
09-30-16

Legend
- Cave, Contour
- Spring
- Swallet
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VGIN-5ft
- Sinkholes VaDMME
- Select Sinkhole Waterheds
- Fault
- Lineament
- 150' Buffer, Primary Karst Review Zone
- 1300' Buffer, Secondary Karst Review Zone
- MVP October 2016 Proposed Route
- MVP October 2016 Proposed Route/Mapport
- MVP October 2016 Proposed Access Roads
- MVP October 2016 Proposed Permanent Easement
- MVP October 2016 Proposed Temporary Work Space
- MVP October 2016 Proposed Ancillary and AWES


Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.
Contact, End limestone area.

Insurgence, Stream sinks.
Mountain Valley Pipeline Project

Karst Features and Hazards Assessment
MVP October 2016 Proposed Route

Sheet 34 of 37
09-30-16

Legend

- Cave Length, Depth
- Spring
- Swallet
- Sinkhole
- Quarry/Mine
- Known Cave Extent
- Sinkholes VA/GIN
- Sinkholes VA/DMME
- Select Sinkhole Watersheds
- Fault
- Lineament
- 150' Buffer, Primary Karst Review Zone
- 1307 Buffer, Secondary Karst Review Zone
- MVP October 2016 Proposed Route
- MVP October 2016 Proposed Access Roads
- MVP October 2016 Proposed Permanent Easement
- MVP October 2016 Proposed Temporary Work Space
- MVP October 2016 Proposed Ancillary and ATWS

Note: The information contained in this map is intended to provide a general overview of the potential karst hazards associated with the proposed route. The data used in the preparation of this map may not be complete or accurate. The information is subject to change and should not be used for specific engineering, legal, or regulatory purposes. For more detailed information, please refer to the original sources listed in the legend.

Sources:
- USGS NALP Series, Monroe Co. 10/27/2014; Giles Co. 10/02/2014; Montgomery Co. 10/25/2014
- Appalachian Trail: https://www.appalachiantrail.org/about-the-trail/mapping-gis-data
- Gaps: 34.23, 23.00
- Very small sinkholes (<6' across)
- Very small stream sinks
- Insurgence, Very small steam sink, ~140' right
- Sinkhole, Area of very small sinkholes (<6' across) likely indicating a cutter and pinnacle bedrock surface
- Sinkhole, Sinkhole adjacent, left
- Sinkhole, Sinkhole ~160' left
- Contact, Begin Elbrook Dolomite (approx)

Map credits:
- Tom Marshall, Draper Aden Associates
- Volonakis Group
- C. A. Frye
- Dave Lott
- C. E. Hall

Scale: 1:4,800
NAD 1983 UTM 17N

Dimensions: 612.0x792.0
Sinkhole, Two sinkholes ~65' right.

Contact, End Elbrook, Begin Rome

Sample Sinkhole Watersheds

Fault Lineament

150' Buffer, Primary Karst Review Zone

1320' Buffer, Secondary Karst Review Zone

MVP October 2016 Proposed Route

MVP October 2016 Proposed Permanent Right-of-Way, Stage 1

MVP October 2016 Proposed Activity and 500'

Sinkhole, Two sinkholes ~65' right.

Legend

Mountain Valley Pipeline Project

VGIN 1:4,800


Caves: Douglas (1964); Holsinger (1975); Zokaites (1995), Va and WVa Speleological Surveys.


Appalachian Trail: https://www.appalachiantrail.org/about-the-trail/mapping-gis-data

Karst Features and Hazards Assessment

MVP October 2016 Proposed Route

Legend

Mountain Valley Pipeline Project

VGIN

Sinkhole

Spring

Cave (Length, Depth)

Known Cave Extent

Sinkholes VGIN-5ft

Sinkholes VaDMME

Select Sinkhole Watersheds

Fault Lineament

150' Buffer, Primary Karst Review Zone

1320' Buffer, Secondary Karst Review Zone

MVP October 2016 Proposed Route

MVP October 2016 Proposed Permanent Right-of-Way, Stage 1

MVP October 2016 Proposed Activity and 500'

MVP October 2016 Proposed Ancillary and ATWS

VGIN Contour Disclaimer: "Any determination of topography or contours, or any depiction of physical improvements, property lines or boundaries is for general information only and shall not be used for the design, modification, or construction of improvements to real property or for flood plain determination."


Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

MVP October 2016 Proposed Route Milepost

MVP October 2016 Proposed Access Roads

MVP October 2016 Proposed Permanent Easement

MVP October 2016 Proposed Temporary Work Space

MVP October 2016 Proposed Ancillary and ATWS
Mountain Valley Pipeline Project

Karst Features and Hazards Assessment
MVP October 2016 Proposed Route

Sheet 36 of 37
09-30-16

Legend

- Cave Length: Depth
- Spring
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VaDMME
- Sinkholes VaGON - USGS
- Select Sinkhole Watersheds
- Fault
- Lineament

1,500' Buffer, Primary Karst Review Zone
1,300' Buffer, Secondary Karst Review Zone
MVP October 2016 Proposed Route
MVP October 2016 Proposed Route/Report
MVP October 2016 Proposed Access Roads
MVP October 2016 Proposed Permanent Easement
MVP October 2016 Proposed Temporary Work Space
MVP October 2016 Proposed Ancillary and AFWS


Caves: Douglas (1964); Holsinger (1975); Zokaites (1995), Va and WVa Speleological Surveys.


Contact, End Rome (approx), very marginal karst formation.