Threats to Groundwater from the Mountain Valley Pipeline and Atlantic Coast Pipeline in Virginia

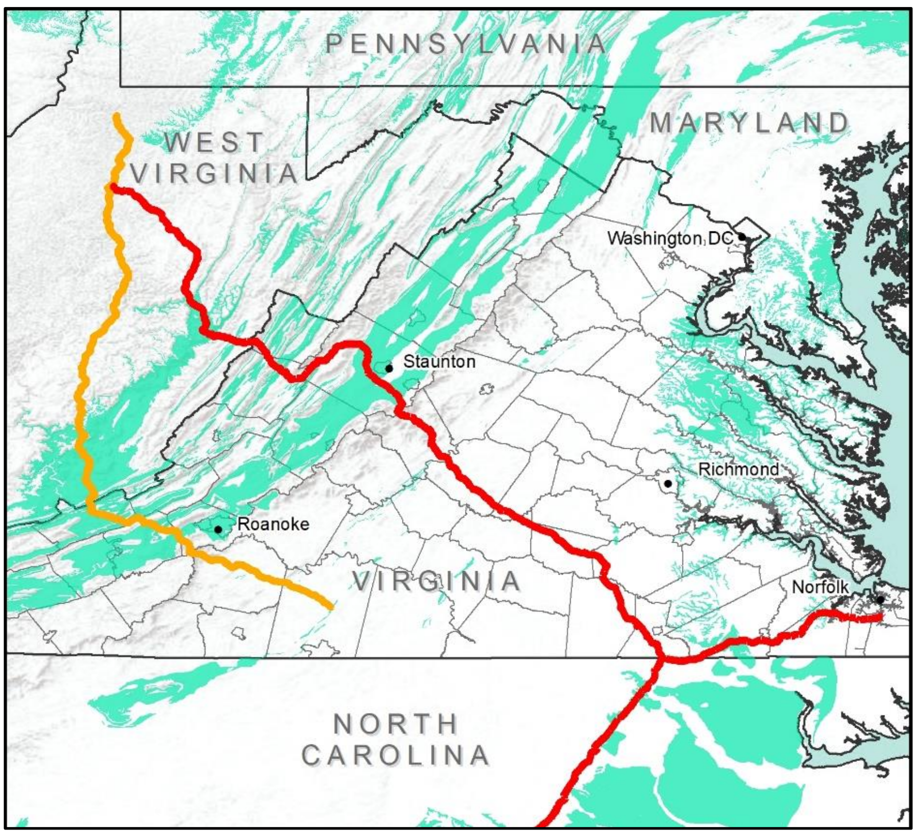

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

ABBREVIATIONS

ACP	Atlantic Coast Pipeline
DPMC	Dominion Pipeline Monitoring Coalition
EVGMA	Eastern Virginia Groundwater Management Area
EVGMAC	Eastern Virginia Groundwater Management Advisory Committee
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
MVP	Mountain Valley Pipeline
USDA	United States Department of Agriculture
VDEQ	Virginia Department of Environmental Quality
VOEHS	Virginia Office of Environmental Health and Safety
WVDEP	West Virginia Department of Environmental Protection

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1. SUMMARY AND RECOMMENDATIONS

Generalized risks

- Pipeline construction and operation present serious threats to underground sources of drinking water via soil compaction and excavation, surface spills of diesel and other petrochemicals, blasting and trenching, alterations of topography, exposed geology, hydrostatic testing, sinkhole filling and development, and drilling. These risks have been linked to drinking water contamination in incidents that occurred during construction of other pipelines.
- Baseline testing plans for both water quantity and quality, for both the ACP and MVP, are inadequate to protect drinking water sources, and do not match best management practices. The distances are arbitrary from an environmental transport point of view, do not seem to be benchmarked in any literature, and do not account for the speed or direction a potential contaminant could travel over land from the construction corridor. The current water testing protocols employed by both MVP and ACP developers do not include some potential sources of contamination from pipeline activity

Risks in non-karst areas

- The majority of the pipeline routes would cross non-karst areas, yet most analysis and protection measures for groundwater resources have only focused on karst areas; therefore, a summary of non-karst groundwater threats is crucial for the majority of residents along the ACP and MVP routes.
- A 150-foot testing area in non-karst areas is arbitrary and leaves many vulnerable drinking water sources without any baseline testing or protections. ***To ensure protection of groundwater resources in non-karst areas, testing of private water wells should be expanded beyond the current 150-foot limit.***
- The ACP crosses 70 miles of the EVGMA within Suffolk, Chesapeake, and Southampton counties, which is an area where groundwater demand already exceeds supply, and as such the security of groundwater quality and quantity in this area is of extreme importance.

Risks in karst areas

- As proposed, the MVP and ACP would cross just over 100 miles of karst terrain in Virginia.
- Karst aquifers are especially vulnerable to pollution at the ground surface because caves and other subterranean entrances can provide direct access for pollutants to quickly reach water tables, wells, and springs. Underground water in karst areas can move quickly over long distances, as far as five miles or more, sometimes in directions contrary to surface topography. ***To ensure protection of groundwater resources in karst areas, testing of private water wells and springs should be expanded beyond the current distance limits.***
- Many springs and groundwater recharge areas within known karst regions potentially crossed by the ACP and MVP have not been mapped, and efforts to map geology over large areas are known to have omitted some karst areas that are close to the proposed pipelines. Because recharge zones of springs in karst areas are not always known or mapped, proper mitigation strategies cannot be implemented in karst areas. Due to the unpredictable nature of transport in karst systems, ***site-specific dye trace studies and hydrogeological studies should be used to determine the most protective distance for well and spring sampling.***

Baseline testing

- Baseline water quality testing by the ACP and MVP developers fall short of widely accepted best management practices and are inadequate: ***ACP developers should test for a full list of volatile and semi-volatile organic compounds, and both companies should add blasting agents and herbicides to their analytical lists.***
- MVP developers have not documented plans to conduct water quantity assessments at wells or springs along its path; these plans should be documented. ***Also, to fully assess groundwater quantity, developers of both the ACP and MVP should conduct sustained yield tests for wells.***

Data availability

- The difficulty in accessing quality information on well and springs by the general public highlights the importance of increased oversight by state regulatory agencies and for thorough field review prior to pipeline construction.

2. OVERVIEW

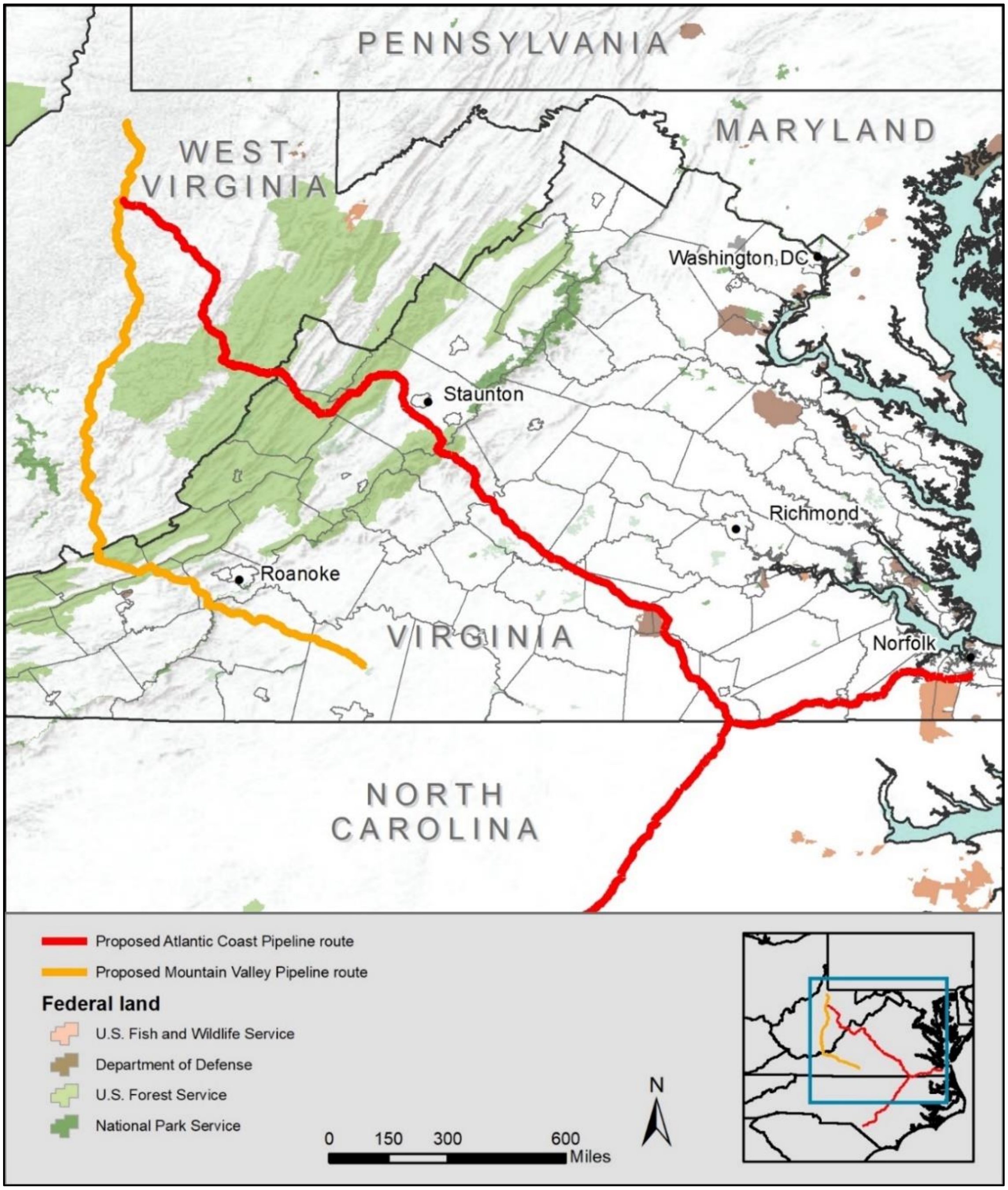
This report assesses threats and likely impacts to underground sources of drinking water in Virginia during the construction and operation of the Atlantic Coast Pipeline (ACP) and Mountain Valley Pipeline (MVP), two large natural gas pipelines that, as proposed, would cross 18 counties and two cities within Virginia (See Figure 1). ***Specifically, this report focuses on threats to private drinking water wells and springs.***

Groundwater pollution threats from pipelines have been confirmed by multiple regulatory and non-regulatory agencies. This report identifies risks to groundwater resources, examines the proposed mitigation measures expected to be performed by the pipeline companies, and provides suggestions for how to correct deficiencies in the proposed mitigation measures so that pipeline impacts to Virginia groundwater resources can be transparently understood, using the best available science.

Water well. Photo: M. Betcher

Groundwater resources, in the form of wells and springs, are a major source of drinking water for both public water supply customers and those with private water sources who do not have access to public water supply systems. In Virginia, approximately 2 million people rely on groundwater resources for drinking water. Groundwater is water found beneath the earth's surface. Depending on the location, it can be found at very shallow depths, moderate depth, or deep beneath the ground.

Figure 1: Proposed ACP and MVP routes



3. PIPELINE RISKS TO GROUNDWATER

3.1 Generalized risks

Pipelines are large-scale construction projects that threaten groundwater quality and quantity. The risks include activities both on the surface as well as those that disturb the underground geology. Both construction, as well as ongoing operation, can present risks to groundwater. The MVP and ACP will be buried seven-to-ten feet below the surface and will require the removal of vegetation, soil, and bedrock along the path through digging, blasting, and drilling. The construction rights-of-way will be 125 feet wide, and an extensive network of access roads and staging areas will be required. This disturbance to the surface and at water crossings has implications for both surface water and groundwater resources.

The potential impacts to groundwater have not yet been fully assessed or understood in Virginia. Numerous environmental risks associated with pipeline construction and operation present direct threats to groundwater resources. The risks include: reduced groundwater quality, reduced groundwater quantity (e.g., flow rates of wells), changed direction of groundwater flow, and even the loss of groundwater sources.

Pipeline construction and operation can harm groundwater in many ways:

- ***Surface spills*** of diesel and other petrochemicals from construction machinery or drilling fluids can be transported to groundwater. For example, a 2015 diesel spill at a pipeline construction staging area in West Virginia contaminated a public water supply spring about one-half mile away, requiring the water utility to purchase water for approximately 4,000 customers for a two-week period. (DPMC, 2015)
- ***Blasting and trenching*** could alter surface and groundwater flow due to an increase in fractures, which could result in a decrease in aquifer storage. In its analysis of the impacts of ACP construction on a federally-threatened cave isopod species, the U.S. Fish and Wildlife Service found that pipeline-related blasting and trenching "are expected to disrupt the subsurface water flow", and that this activity could have impacts up to a half-mile from the construction site (USFWS, 2017).
- ***Sinkhole filling*** due to placement of excavated materials from pipeline and road construction or erosion can have major impacts on groundwater recharge and cause increases in groundwater turbidity in karst areas (Kastning, 2016 and Williams, 2012).
- ***Sinkhole development*** due to pipeline construction in karst areas can pose a dangerous risk to people living near pipelines and open new conduits for transport of pollutants to groundwater. In Pennsylvania, construction of one pipeline and operation of another nearby are currently on hold, and families have been evacuated after many new sinkholes were created, up to 20 feet deep, in karst areas (Hurdle, 2018 and Maykuth, 2018).
- ***Drilling*** has the "potential to connect previously discrete underground waterways" (Hurdle, 2017, citing an interview with David Velinsky, Vice President of Science at the Academy of Natural Sciences of Drexel University). In Pennsylvania, pipeline drilling has been linked to drinking water contamination for 15 families (Phillips, 2017).
- ***Soil excavation*** and backfill may alter hydrologic characteristics and could impact time of travel of precipitation to groundwater and lead to increases in groundwater turbidity (Kastning, 2016).
- ***Soil compaction*** of access roads and construction in the pipeline corridor can impact water flow patterns and thus groundwater recharge and supply for wells and springs (Glass et al., 2016 and Williams, 2012).

- ***Topographic alterations*** required to place the pipelines—particularly in the steep terrain found along the western sections of the MVP and the ACP, which are already prone to landslides—could lead to additional landslides that would impact surface and groundwater flow patterns. In West Virginia, construction of Dominion's G-150 and TL-589 gas pipelines led to slope failure during and post-construction despite the application of industry-standard erosion and sediment control practices at thirteen locations along pipeline construction right-or-ways (WVDEP, 2014a).
- ***Exposed geology*** could erode and leach acid or metals to groundwater (Glass et al., 2016 and Williams, 2012).

Simms Creek landslide associated with construction of Dominion's G-150 pipeline. Source: WVDEP, 2016

- ***Hydrostatic testing***, necessary to test the integrity of a pipeline before it is put online, requires substantial quantities of water. If sourced from an aquifer, quantity could suffer. If not disposed of properly, the large influx of water could lead to water contamination and sedimentation and erosion. In 2016, gas pipeline developer Stonewall Gathering, LLC was cited by WVDEP for allowing sedimentation of a receiving stream after water used for hydrostatic testing was not properly filtered before it was discharged to a stream (WVDEP, 2016).

3.2 ACP and MVP threats in non-karst areas

Much of the focus of groundwater protection for these pipelines has been in areas underlain with karst, because karst landscapes are especially sensitive. Given that the majority of the pipelines' lengths would cross non-karst areas (73% of the MVP and 83% of the ACP in Virginia), an understanding of the groundwater threats in non-karst areas is therefore important for the majority of residents along the ACP and MVP routes.

Both groundwater quantity and quality in non-karst areas could be impacted by construction and operation of the ACP and MVP. The ACP's Final Environmental Impact Statement (FEIS) prepared by the Federal Energy Regulatory Commission (FERC) acknowledges both threats, stating that surficial disturbances of the pipeline construction could impact infiltration and ultimately recharge of groundwater, and that groundwater quality could be impacted by hazardous material spills (FERC, 2017b). The FEIS claims that groundwater quantity would only be temporarily altered during pipeline construction activities; however, this analysis did not fully examine all the long-term risks to groundwater quantity from pipeline construction and operation.

Notably, the ACP crosses 70 miles of the Eastern Virginia Groundwater Management Area (EVGMA) within Suffolk, Chesapeake, and Southampton counties (FERC, 2017b). The EVGMA is a large area in the tidewater region of Virginia where groundwater supplies cannot meet current or future groundwater demand; therefore, use of groundwater in this region is more tightly controlled (EVGMAC, 2017). As such, the security of groundwater quality and quantity in this area is of extreme importance. Any potential impacts to this aquifer should be heavily scrutinized before, during, and after construction of the pipeline—especially given the potential scale of impacts from the ACP.

3.3 ACP and MVP threats to karst aquifers

Karst is a type of landform, generally underlain by limestone. Limestone can be dissolved by a weak carbonic acid found in water that has flowed into the subsurface. Erosion of the limestone over time can create extensive underground channels and massive cave systems, a geology that has been likened to "swiss cheese." These underground channels and cave systems in karst allow unhindered underground water flow, similar to streams and rivers, which can transport water long distances and in directions that differ significantly from surface drainage. Additionally, karst areas are a significant source of drinking water because of their abundance of water.

Pollution can threaten any aquifer, but karst aquifers are especially vulnerable to pollution from the surface. Caves and other entrances can provide direct access to the subsurface and allow pollutants to contaminate aquifers and quickly reach water tables, wells, and springs. Additionally, these underground systems may transfer water with pollutants long distances underground, and in directions that differ significantly from surface drainage. For example, dye tracing in Pocahontas County, West Virginia indicated that the distance between underground disappearance and reemergence routinely exceeded one mile and could be as far as five miles or more (Boettner et al., 2012, using data from WVDEP, 2010). Underground time of travel is highly variable and dependent on numerous variables. Because recharge zones of springs in karst areas are not always known or mapped, proper mitigation strategies cannot be implemented in karst areas.

As shown in Figure 2, the proposed routes for the MVP and the ACP both cross significant areas underlain by karst geology. As described above, potential impacts to groundwater resources are exacerbated in these areas. Together, the ACP and MVP would cross approximately 252 miles of karst terrain across three states: Virginia, West Virginia, and North Carolina (Table 1). The ACP would cross 183 miles of karst terrain, including 65 miles in Virginia. The MVP would cross 69 miles of karst terrain, 36 of which are in Virginia. As proposed, the MVP and ACP would cross just over 100 miles of karst terrain in Virginia.

As mentioned above, the MVP and ACP would be buried seven-to-ten feet below the surface, and vegetation, soil, and bedrock would be removed along the path. Groundwater in areas underlain with karst are particularly susceptible to these types of alterations to geology, and thus, this disturbance to the surface has potentially significant implications for groundwater resources. In addition to surface activities, blasting, drilling, and other mechanical construction could alter the existing underground flow network by opening new conduits from the surface to karst aquifers (Natural Resources Group, 2015a and 2015b). Further, contaminants can travel distances greater than five miles through underground caves and show up in unexpected areas (Boettner et al., 2012, using data from WVDEP, 2010).

Table 1: Pipeline mileage underlain by karst topography

Pipeline/State	Miles of pipeline underlain by karst topography
ACP	
Virginia	65
West Virginia	22
North Carolina	97
Total, ACP	**183**
MVP	
Virginia	36
West Virginia	34
North Carolina	0
Total, MVP	**69**
Total, Both pipelines	**252**

Source: Karst data from Weary (2008). Note: These distances were calculated using national karst data. Using more detailed, local karst data would likely increase these estimates.

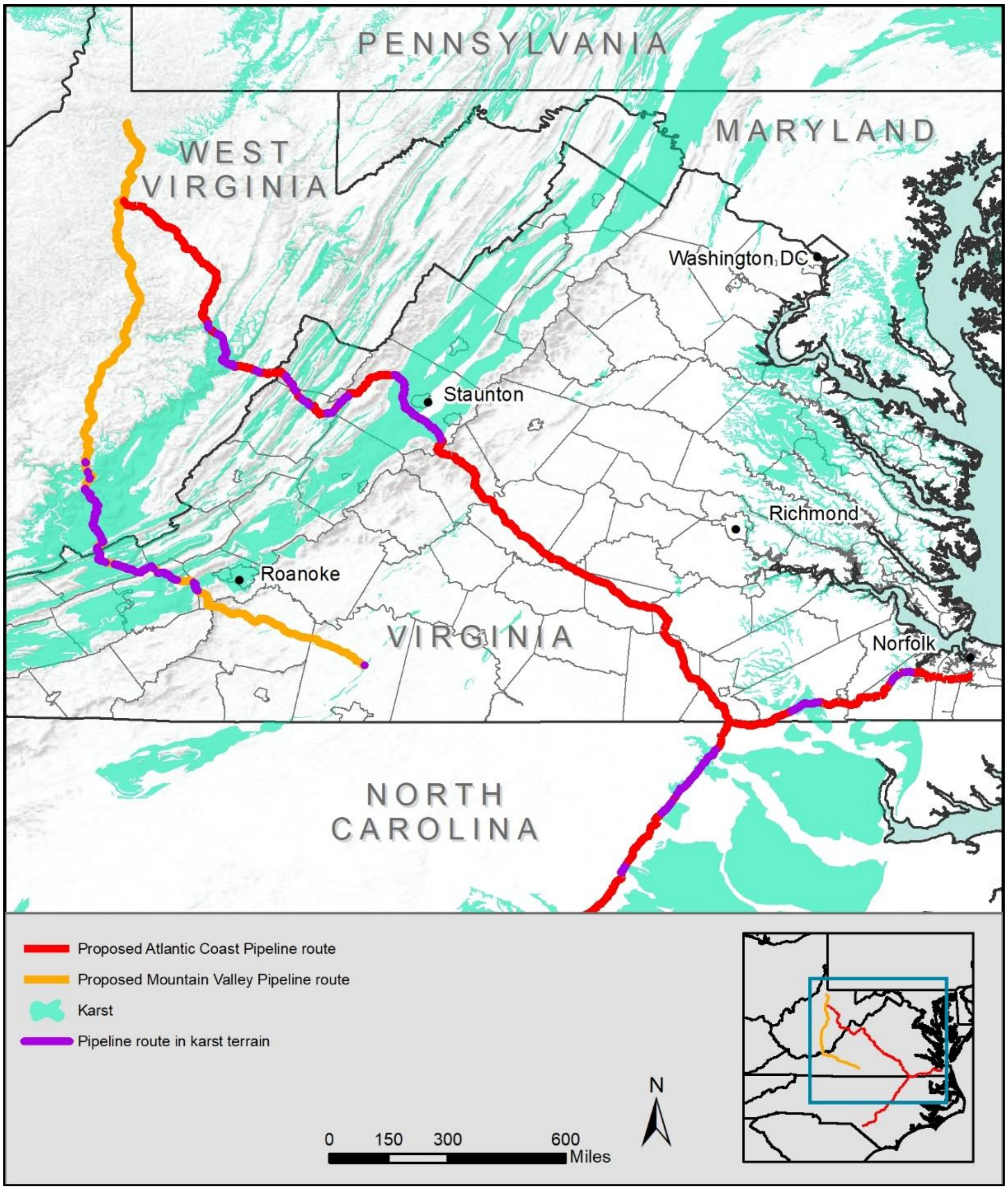
Sinkholes are common in karst areas and are especially sensitive to impacts from pipelines and other construction projects. Sinkholes provide direct conduits to groundwater and can quickly transport contaminants to underground aquifers. Additionally, sinkholes play an important role in groundwater recharge, and thus, accidental filling of sinkholes with spoil material from trench construction or due to deposition of eroded material can inhibit groundwater recharge. The hill and valley terrain crossed by the ACP and MVP is especially sensitive to sinkhole disturbance (Kastning, 2016).

Allogenic recharge is a process by which aquifers are recharged by headwater streams in mountainous terrain underlain by karst, such as the western extents of both the ACP and MVP. Pipeline impacts to mountain streams are likely to greatly impact allogenic recharge to lowland aquifers.

Pollution from construction or spills in karst areas is especially challenging to trace because the source area and flow paths are not always clear and because karst recharge areas and flow paths often do not follow surface watersheds. Further, underground flow paths may change from one season to another and may be affected by construction. When karst systems are exposed to changing runoff patterns, new solution channels may form or existing channels may be altered.

The ACP and MVP cross about 100 miles of documented karst terrain in Virginia alone (see Table 1), as well as other areas where the extent of karst is not well documented. For example, the MVP is proposed to cross at least two areas of karst terrain where many families rely on karst aquifers for drinking water in Giles and Montgomery counties. Underground transport channels of several miles have been identified by dye trace analysis near the Sinking Creek crossing in Montgomery County and the Mount Tabor Karst Sinkhole Plain in Montgomery County. In the latter area, dye trace studies have documented the interconnected nature of karst and caves, and the MVP would cross “two cave conservation areas, a natural area preserve and a major segment of the karst plain where scores of large, compound, sinkholes are present at the surface” (Kastning, 2016, p. 4).

Figure 2: Karst terrain crossed by the proposed ACP and MVP



Source: Karst data from Weary (2008).

Additionally, large-scale disturbances such as pipeline construction in the recharge zone of springs could cause those springs—which may be located a significant distance from the recharge zone—to become contaminated with sediment. Figure 3 depicts Mackey Spring in the Jackson River watershed in Highland County, which is clearly polluted with sediment due to disturbance in the karst recharge area several miles from the spring. The MVP and ACP would cross many similar areas, and the recharge zones of springs are not always known or mapped; thus, proper mitigation strategies cannot be implemented.

Figure 3: Mackey Spring, Highland County

Photo: Rick Webb.

4. BASELINE WATER SAMPLING

Baseline water sampling is water testing that is performed prior to disturbance from activities such as pipeline construction. Baseline sampling provides information on water quality and quantity conditions preceding any impacts that may occur during pipeline construction and operation. Sampling results are used as a point of comparison between the original and the altered, post-construction conditions. This section describes, in general, the importance of baseline water sampling, focusing on the specific goals of baseline water sampling necessary to adequately assess pre-construction groundwater quality and quantity at private drinking water wells as it pertains to pipeline construction. Section 5.1 discusses baseline water monitoring that is specifically required for the ACP and MVP.

4.1 Water quality

There are many potential sources of contamination during pipeline construction. These include sedimentation, hydrocarbons, metals, and blasting agents. Ideally, the suite of contaminants assessed should be comprehensive, assessing all potential impacts from pipeline development. The sampling should include analytes derived from natural sources such as metals; ions that are indicative of new transport routes; and chemicals associated with construction activities, such as petrochemicals from machinery. All samples should be collected by qualified environmental professionals and analyzed by a laboratory certified by the Virginia Department of Environmental Quality (VDEQ).

In addition to performing baseline sampling for the correct parameters, the sampling should also be performed in the right locations. The goal of baseline sampling is to document conditions prior to development, which will allow post-development impacts to be adequately examined and contaminant sources identified. Thus, all groundwater sources with any potential for impacts should be tested.

Finally, the timing of baseline sampling must be considered. Samples should be collected prior to construction; however, if too few samples are taken, they may not capture annual, seasonal, or other hydrologic variations (Glass et al., 2016).

4.2 Water quantity

Pipeline development may affect water quantity by altering local soils, geology, and the hydrogeological cycle in general. In terms of groundwater quantity, the rate of flow and also the duration of such a flow rate must be considered. Groundwater quantity and flow rates are important because groundwater is a finite resource, and loss of groundwater can impact water availability for private and public well owners who rely on groundwater for drinking water.

The most accurate method for assessing water quantity at water wells is a sustained yield test, which measures the amount of time an aquifer can maintain a flow rate. Defensibly documenting sustainable yield for a water well requires an aquifer pumping test.[1] Sustained yield tests normally involve the use of specialized equipment and knowledge under a prescribed methodology and demonstrate what can be produced by the well, not what is stored in a plumbing system. Most state, local, and county jurisdictions require that sustained yield tests be performed by licensed professionals. For example, the West Virginia Department of Environmental Protection (WVDEP) recently specified requirements for developers of water supply wells for oil and gas operations to conduct detailed aquifer tests, which includes a sustained yield test. These tests must be conducted by licensed groundwater professionals or water system installers and require 72 hours to properly complete.[2]

[1] This should not be confused with a well yield test, which does not accurately represent the true sustainable yield of the groundwater resource, and instead is a function of the well pump and plumbing.
[2] W.Va. Code of State Rules §35-8 9.1.a.4.

5. ACP'S AND MVP'S PROPOSED MITIGATION MEASURES

As discussed in Chapter 3, there are many risks to groundwater from pipeline construction. Some risks may be minimized or avoided, depending on the construction, mitigation, and restoration practices employed by the pipeline companies.

This section describes the measures proposed by the pipeline companies and/or required by regulatory agencies; we then provide commentary on the appropriateness and effectiveness of these propose mitigation measures for groundwater quality and quantity protection.

5.1 Baseline testing

The FERC orders issuing the certificates for the ACP and MVP state that the pipeline companies must complete field surveys and pre-construction water quality evaluations only for wells and springs within 150 feet of the construction workspace in non-karst terrain, and within 500 feet of the construction workspace in karst terrain (FERC, 2017c and 2017d).

The water quality certifications issued by the Commonwealth of Virginia added an additional requirement in karst areas, requiring the pipeline companies to: (1) conduct a survey to identify wells, cisterns, springs, and surface waters within 1,000 feet of the project centerline in areas known to have karst topography; and (2) conduct one round of water quality sampling to evaluate wells and springs used for human consumption and located 500 to 1,000 feet from the project centerline in karst terrain (VDEQ, 2017a and 2017b). These requirements are summarized in Table 2. However, these distances are arbitrary from an environmental transport point of view and do not appear to be benchmarked in any literature, or otherwise shown to be protective of nearby groundwater resources.

Table 2: Groundwater survey and testing requirement summary

Distance from pipeline	Non-karst areas	Karst areas	Agency
< 150 feet	Survey and sample wells and springs	Survey and sample wells and springs	FERC
150 - 500 feet	None	Survey and sample wells and springs	FERC
500 – 1,000 feet	None	Survey wells, cisterns, springs and surface waters; one sample for wells and springs used for human consumption	VDEQ

In 2016, the Virginia Office of Environmental Health and Safety (VOEHS) recommended a thorough survey of all private water wells and springs, as well as septic systems, within 1,000 feet of MVP—at a minimum (Roadcap, 2016). In October 2017, VOEHS issued weaker recommendations that were nearly identical to the requirements from VDEQ (VDH, 2017). These new recommendations removed the recommendation to survey all features within 1,000 feet of a pipeline, and instead only suggested this action was necessary in karst areas.

The 150-foot distance for well testing in non-karst areas does not account for the speed or direction a potential contaminant could travel over land from the construction corridor. Especially in steep terrain, a hazardous material spill on the surface—petrochemicals from machinery in staging areas or drilling fluids near stream crossings where horizontal directional drilling is utilized, for example—could travel quickly from the construction corridor to a well located more than 150 feet away before any containment or diversion could be employed.

To ensure protection of groundwater resources, testing of private water wells and springs should be expanded beyond the current distance limits. Given the variability in local conditions (e.g., geology, water table depth, slope, soil permeability), a wider testing zone for both karst and non-karst areas is essential to ensure that groundwater resources that are in potential contamination pathways are better protected. Appropriate testing distances should be determined by examining site-specific geology and groundwater flow patterns. Performing baseline testing on additional wells would also help pipeline companies reduce their potential liability, should contamination be documented before construction begins.

The ACP developers plan to collect quarterly samples one year prior to construction. The MVP developers plan to only collect two samples: one six months prior to construction and one three months prior to construction. This baseline sampling done by the companies would only be done with the landowner's permission.

5.1.1 ***Water quality***

Proposed water testing in the pathway of the proposed pipelines is inadequate.

The current water testing protocols employed by both MVP and ACP developers, as laid out in their plans (MVP, 2015 and Natural Resource Group, 2015b) and in water quality sampling reports provided to landowners by each company, confirm that their tests do not include some potential sources of contamination from pipeline activity (ACP, 2017 and MVP, 2017).

Notably, agents used in blasting bedrock and herbicides used to maintain rights-of-way are not included in plans submitted by either company. The ACP sampling list does not fully assess impacts to groundwater from organic compounds; the list only includes oil and grease and total phenolic compounds rather than a full assessment of all volatile and semi-volatile organic compounds, which is necessary to fully understand sources and routes of contamination. ACP does not include nitrate in its analytical list. Monitoring for nitrate prior to pipeline development will help to determine if nitrate contamination is pre-existing and to help evaluate if future construction disturbances introduce new communication pathways between nitrogen sources and drinking water resources. MVP's list of metals should be expanded to provide a more detailed view of baseline conditions so that impacts can be more fully understood.

Table 3 compares contaminants to be sampled by the MVP and ACP developers against a recommended set of testing parameters most likely to be affected by natural gas pipeline development (Code of Federal Regulations § 40-450.21; USEPA, 1999a; USEPA, 1999b; USEPA, 2005; WVDEP, 2014b). Cells in the table are highlighted orange where sampling planned by the pipeline developers are insufficient when compared to regulatory agency guidance.

Baseline water quality testing by the ACP and MVP developers falls short of widely accepted best management practices and are inadequate: ACP developers should test for a full list of volatile and semi-volatile organic compounds, and both companies should add blasting agents and herbicides to their analytical lists.

5.1.2 *Water quantity*

Water quantity monitoring standards are unclear.

The ACP's construction and restoration plans include measures to aid in the protection of groundwater quantity. Trench plugs, interceptor dikes, and regrading of the surface to its original contours will be used to reduce the risk that groundwater flow paths are permanently altered. If groundwater flow paths are not maintained or returned to pre-construction conditions, groundwater quantity may be altered (e.g., wetlands and shallow aquifers could be dewatered).

ACP's FERC filing mentions water quantity monitoring, but is not clear how this will be accomplished. Review of a well water sampling report provided to a private landowner indicates that a flow measurement was collected, but the method is not described (ACP, 2017 and MVP, 2017).

MVP developers have not documented plans to conduct water quantity assessments at wells or springs along its path; these plans should be documented. Also, to fully assess groundwater quantity, developers of both the ACP and MVP should conduct sustained yield tests for wells.

Table 3: Baseline water quality testing parameters

Category	Best practices	Mountain Valley Pipeline	Atlantic Coast Pipeline
General chemistry	pH, conductivity, temperature, turbidity, hardness, alkalinity, total suspended solids, total dissolved solids	pH, conductivity, temperature, turbidity, hardness, alkalinity, total suspended solids, total dissolved solids, dissolved oxygen	pH, conductivity, temperature, alkalinity, acidity, total suspended solids, total dissolved solids
Organic compounds	Total analytical list of semi-volatile organic compounds and volatile organic compounds	Total analytical list of semi-volatile organic compounds and volatile organic compounds	Oil and grease, phenolic compounds
Ions	Chloride, sulfate	Chloride, sulfate	Chloride, sulfate
Nutrients	Nitrate	Nitrate	
Biologicals	Total and fecal coliform	Total and fecal coliform	Fecal coliform
Metals	Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, potassium, selenium	Calcium, magnesium, sodium, potassium, iron, manganese	Aluminum, antimony, arsenic, beryllium, cadmium, calcium, chromium, copper, iron, manganese, lead, nickel, selenium, silver, thallium, zinc
Other	Explosives, herbicides, glycols and drilling agents in the proximity of stream crossings where horizontal directional drilling will be utilized		Cyanide

Note: Analytes highlighted in orange are those that are insufficient in developers plans when compared to regulatory agency guidance.

5.2 Karst mitigation

The karst mitigation plans for both pipelines are inadequate.

The Karst Mitigation Plan submitted for the MVP states that sinkholes will be stabilized (Draper Arden Associates, 2016). However, the method of stabilization is not described, but stabilizing may include filling. Filling of sinkholes often impedes groundwater recharge and is only a short-term fix (Kastning, 2016).

Many karstic features—such as recharge areas, springs, and sinkholes—along the proposed routes of the ACP and MVP are not well documented (Richards, 1997). This lack of thorough mapping and knowledge of underground transport routes makes it impossible for the pipeline companies to fully ascertain the risks to groundwater in karst areas, and thus implementation of adequate protections is challenging.

Allogenic recharge and its impacts are not described in the MVP documents provided to FERC; this is a major omission due to the number of homes supplied by these aquifers (Kastning, 2016). Allogenic recharge is noted in FERC's documentation for the ACP, but specific measures to account for allogenic recharge issues and contamination are not discussed.

Given the ability of potential contaminants to enter underground karst networks and reemerge great distances away, expanded protection of karst aquifers is necessary. ***Due to the unpredictable nature of transport in karst systems, site-specific dye trace studies and hydrogeological studies should be used to determine the most protective distance for well and spring sampling.*** This will help to ensure that karst groundwater resources that are in potential contamination pathways are better protected.

MVP plans to utilize karst experts as on-site inspectors during all phases of pipeline construction in karst terrain to monitor impacts to karst features and water resources are protected (WVDEP, 2017). However, this effort should not be relied on for complete avoidance of karst impacts. Proper planning and avoidance mechanisms should be implemented prior to the beginning of construction.

6. CASE STUDIES: GROUNDWATER IMPACTS

6.1 MVP case study: Lucki property, Roanoke County

Jacki Lucki owns a 17-acre parcel along the MVP route in Roanoke County between Milepost 243 and 244 (FERC, 2017a), near the community of Bent Mountain (See Figure 4). This is a non-karst area. The proposed pipeline route would parallel an unnamed tributary of Mill Creek of Bottom Creek. This low-relief property is located on the valley bottom, with wet soils and shallow depth to groundwater (USDA, 2017), and is likely the location of one of the many perched aquifers in this area noted by Dodds (2016). Shallow groundwater (including perched aquifers) are more vulnerable to contamination because of their proximity to the ground surface and the limited soil barrier to filter any surface contaminants.

The water well on this property does not appear to fall within the required 150-foot testing distance from the construction workspace, but it is an example of groundwater that is still at risk. The well is located approximately 300 feet from the construction workspace, and given the shallow depth to the water table (at least seasonally) in this valley, pipeline construction could impact well water quality and quantity.

To ensure protection of groundwater resources similar to this example, both pipeline developers should expand their surveying and testing beyond 150 feet in non-karst areas.

6.2 ACP case study: Limpert property, Bath County

The Limpert property lies in the Little Valley area of Bath County (See Figure 5). State geologic maps indicate the area is underlain by shale, and ACP documents originally did not identify any karst in Little Valley. But a site visit by a karst specialist with the Virginia Department of Conservation and Recreation indicated that the property is actually underlain by thin layers of limestone, which has resulted in definite karst features on the Limpert property and other adjacent properties in Little Valley. Sinking streams were observed on the Limpert property and sinkholes were observed in the vicinity of the pipeline on adjacent properties, and these are connected to numerous small springs within Little Valley (Orndorff, 2017). The karst specialist also notes that there is a possibility that the small-scale karst system within Little Valley could be connected to more significant karst features, specifically the nearby Bolar Spring, and recommends dye tracing to confirm this, which has begun. (Orndorff, 2017)

The Limpert family water well, as well as the numerous sinkholes and springs on this property and adjacent properties, falls between the 150-foot testing distance for non-karst areas and the 1,000-foot testing distance from the construction centerline in karst landforms. If the karst had not been identified by an individual investigation, this would have been considered a non-karst area. ***This exemplifies the arbitrary and inadequate nature of the 150-foot buffer, and why both pipeline developers should expand their surveying and testing.***

6.3 MVP case study: Franklin County

Figure 6 illustrates a section of the MVP route in very steep terrain of Franklin County and models the overland flow paths that would result from two hypothetical spills in this section of the pipeline. The first spill would put a rural farm pond at risk of contamination, and the second would threaten a private domestic water well. Given the steep terrain and the relatively short flow paths, it is clear that it would be highly unlikely that a spill could be contained or diverted before impacting these private water resources. Even more concerning is that these private water resources fall outside of the 150-foot testing distance that the pipeline companies utilize to ensure protection of private water resources. ***This is another example of the arbitrary and inadequate nature of the 150-foot buffer, and why both pipeline developers should expand their surveying and testing.***

Figure 4: Lucki property, Roanoke County

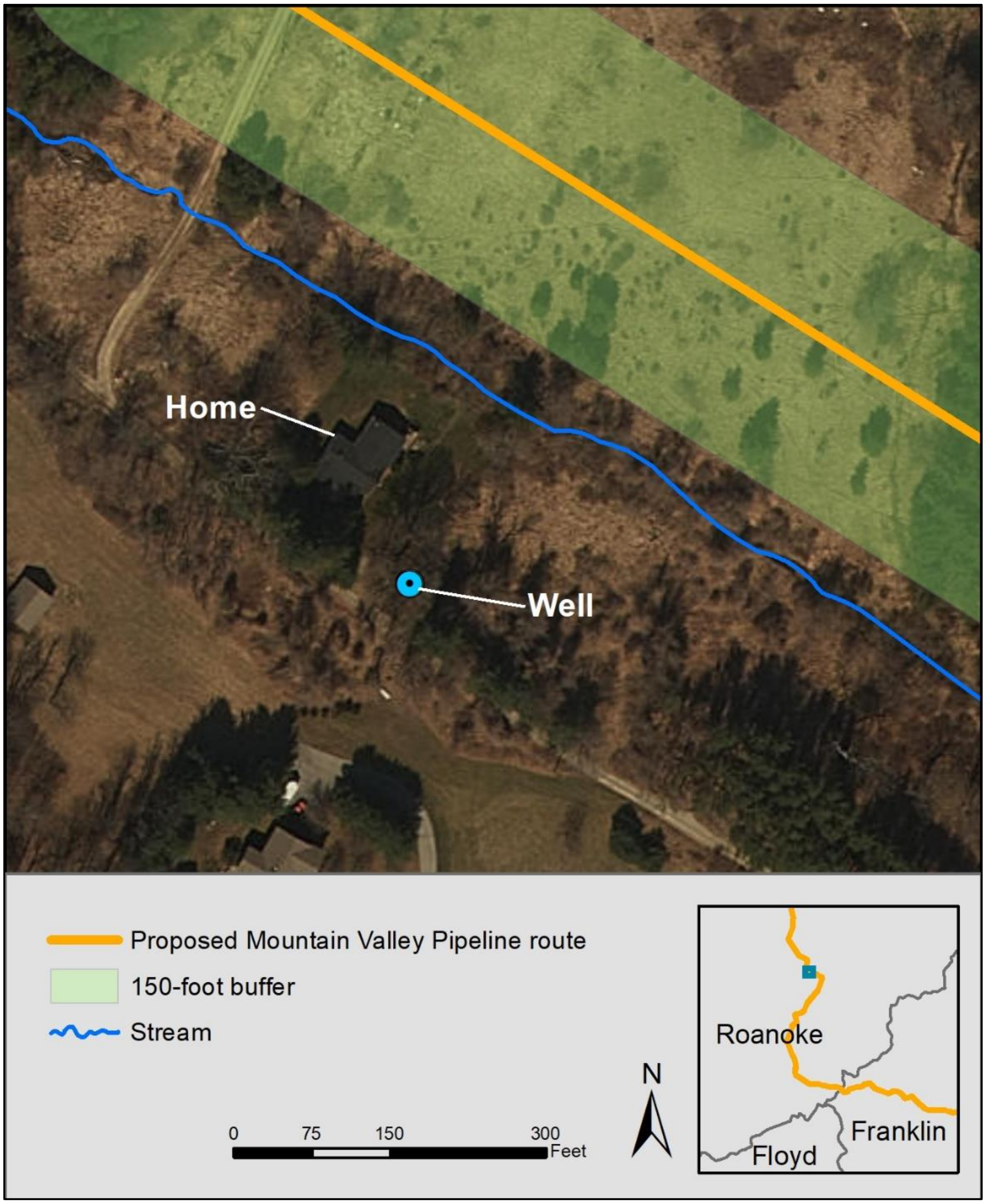


Figure 5: Limpert property, Bath County

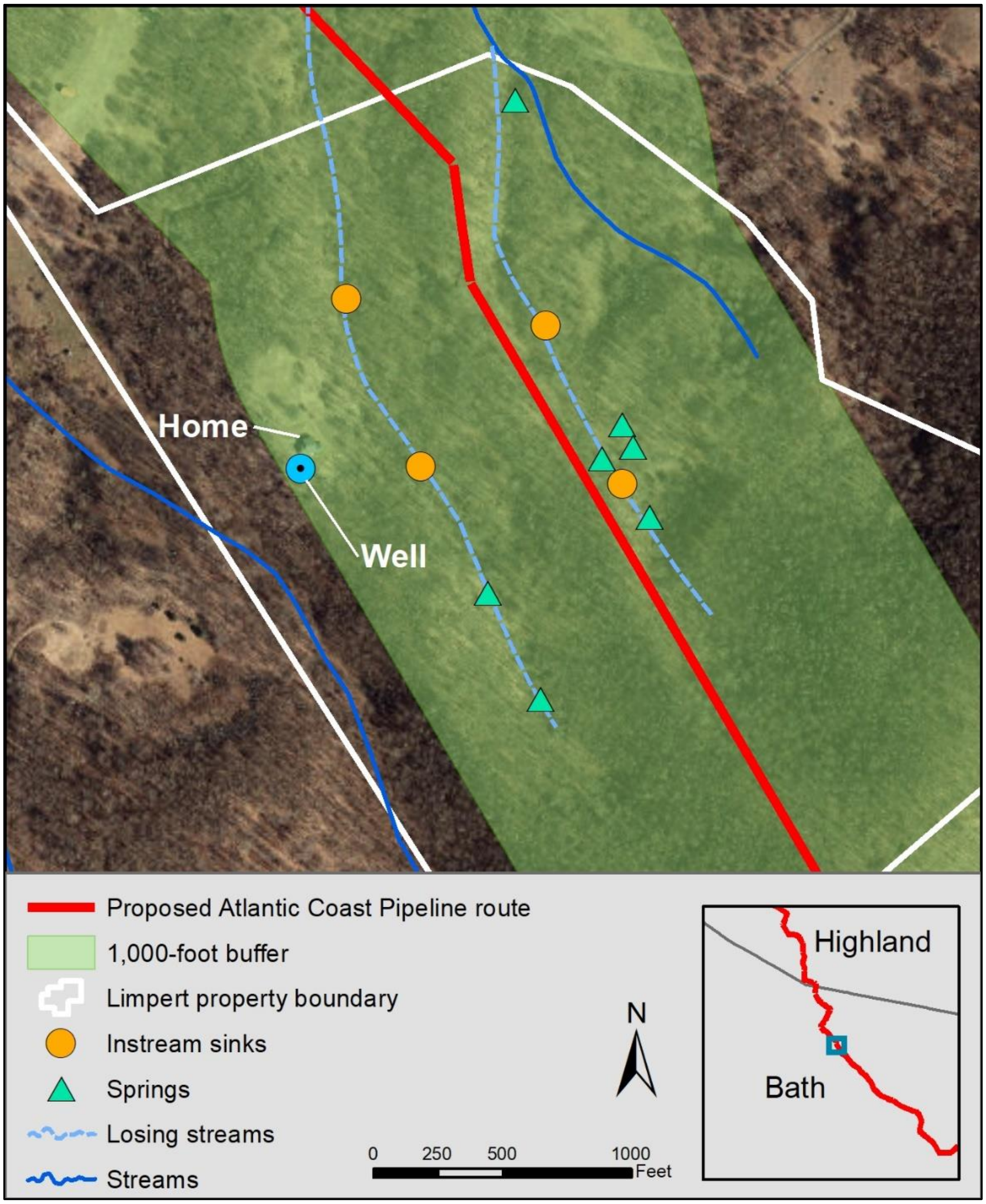
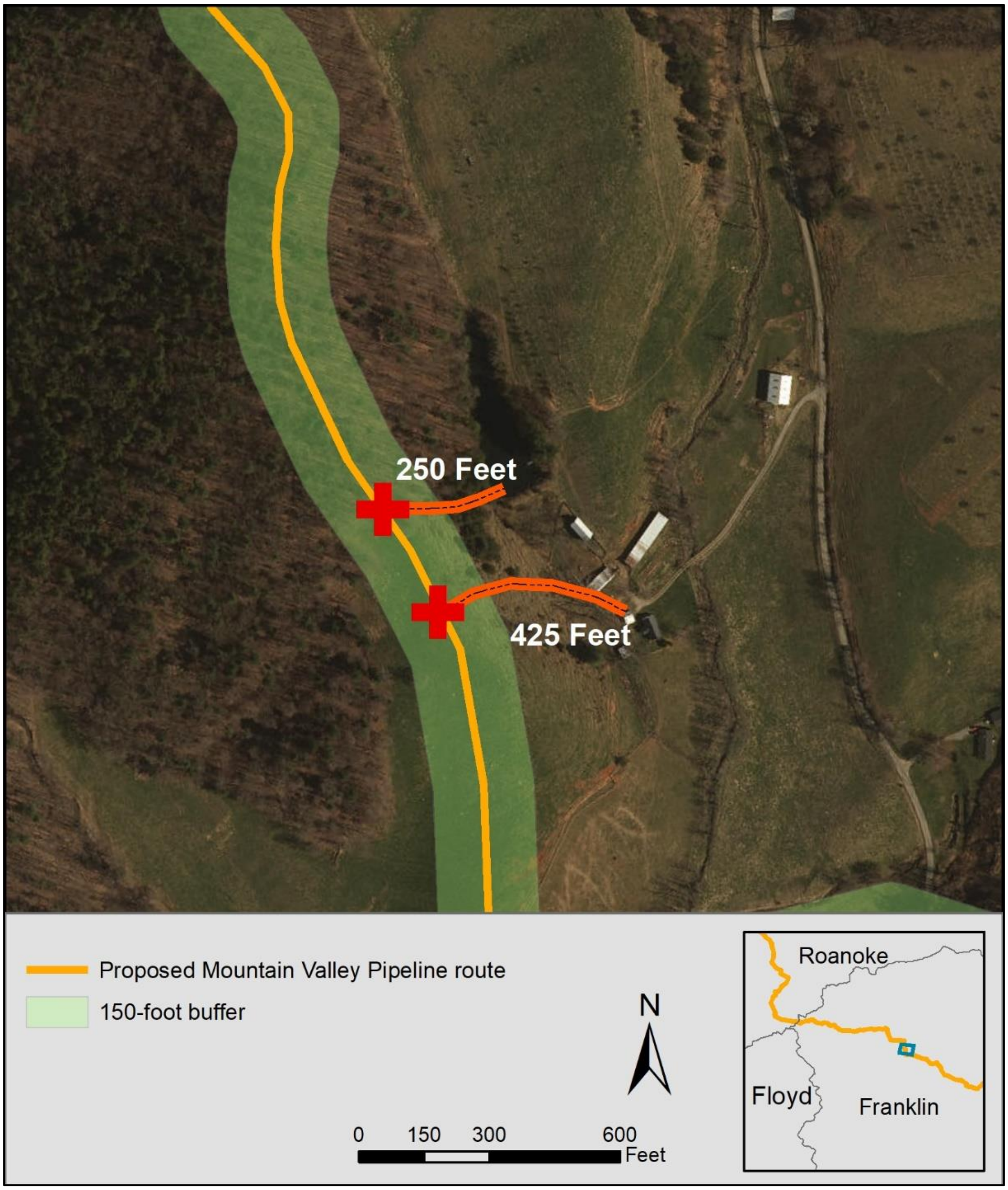


Figure 6: Franklin County: flow paths from pipeline corridor to potential private water sources

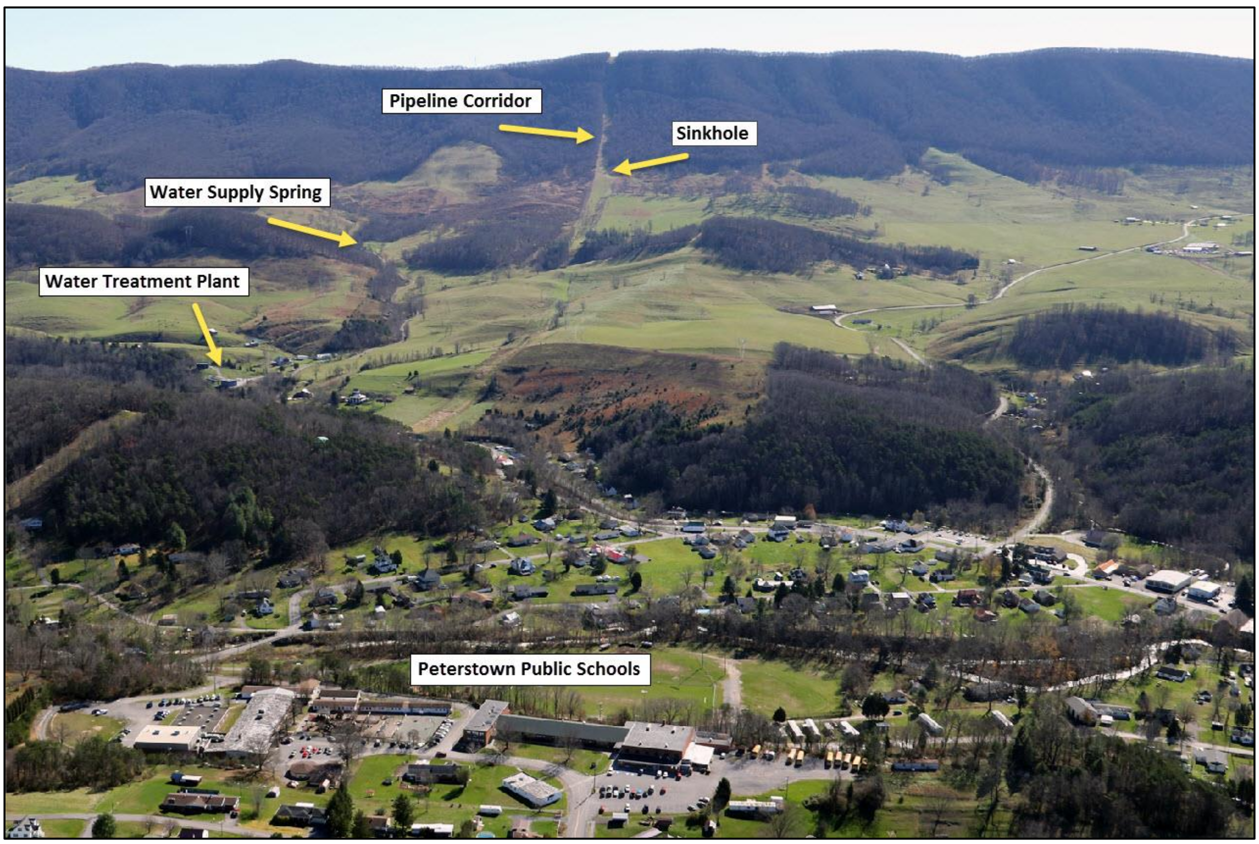


6.4 Groundwater contamination case study: Columbia Gas of Virginia pipeline project

The 12-inch diameter Columbia Gas of Virginia pipeline crosses Peter's Mountain in Giles County (Figure 7). Red Sulphur Spring Public Service District's water supply—which supplies nearby Peterstown, West Virginia—was contaminated in 2015 by diesel fuel spilled at a pipeline construction staging area near a sinkhole, causing the water supply system to be offline for over two weeks (Adams, 2015). This required the water utility to purchase water to supply the system's approximately 4,000 customers. The spill area was only about one-half mile from the system's primary supply spring (DPMC, 2015).

The proposed MVP route would cross Peter's Mountain only five miles northeast of the Columbia Gas of Virginia pipeline, and much of the landscape projected to be crossed by both the MVP and ACP is characterized by an abundance of springs—many of which originate in karst formations similar to the conditions in the vicinity of Peter's Mountain. Many of these springs act as drinking water sources for people living near the projected pipeline routes.

Figure 7: Sensitive features near the Columbia Gas of Virginia pipeline



Source: DPMC.

7. DATA AVAILABILITY CONCERNS

Sound data relevant to groundwater resources is difficult to obtain, and in many cases, it may not exist. The authors of this report had difficulty finding usable data for private residential water resources in the vicinity of the proposed ACP and MVP routes. While information from county or state agencies may be available, access to that information is difficult to obtain for broad areas. Additionally, locations of wells drilled prior to approximately 2015 may not be accurate, because the State of Virginia did not start collecting latitude/longitude data before then. The extent to which the MVP and ACP developers have collected information on water wells and springs in the vicinity of their pipeline routes is unknown.

While some efforts to map major karst features have been well documented (Weary, 2008; Dicken et al., 2008), many springs and groundwater recharge areas within known karst regions potentially crossed by the ACP and MVP have not been mapped (Richards, 1997). Additionally, efforts to map geology over large areas are known to have omitted some karst areas that are close to the proposed pipelines (Orndorff, 2017). This highlights the importance of detailed field assessments of geology and groundwater near the paths of the proposed pipelines to ensure protection of groundwater quality and quantity.

The difficulty in accessing quality information on wells and springs by the general public highlights the importance of increased oversight by state regulatory agencies such as VDEQ or the Virginia Department of Health to ensure that groundwater quality and quantity are protected, should the ACP and/or the MVP be built.

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GLOSSARY

Aquifer: The zone beneath the water table, saturated with groundwater, is called an aquifer. Water can flow through aquifers over considerable distances. Groundwater in an aquifer can be readily transmitted to springs and water wells.

Groundwater quality: Soil acts as a filter, removing large particles from water as it passes through. As water moves through soil, other contaminants can also be captured before they reach groundwater.

Perched aquifer: A specific type of aquifer that sits relatively near the ground surface and above another aquifer because water infiltrating subsurface is trapped or 'perched' atop an impenetrable layer of soil or bedrock.

Recharge rate: Groundwater is periodically replenished at a rate that will vary by location. This replenishment is known as "recharge" and may come from precipitation, whereby a portion of all precipitation that reaches the Earth's surface infiltrates into the ground. Some groundwater sources are recharged by rivers or streams.

Water table: Some of the water coming from precipitation or from surface water will remain in an unsaturated layer of soil and rock near the surface, and some will reach a deeper zone saturated with water and become groundwater. The level at which the soil becomes saturated is called the water table. Groundwater is located beneath the water table.