Molly Joseph Ward
Secretary of Natural Resources

Clyde E. Cristman
Director

Joe Elton
Deputy Director of Operations

Rochelle Altholz
Deputy Director of Administration
and Finance

COMMONWEALTH of VIRGINIA

DEPARTMENT OF CONSERVATION AND RECREATION

600 East Main Street, 24th Floor
Richmond, Virginia 23219
(804)786-6124

April 17, 2015

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

Re: Dominion Atlantic Coast Pipeline, LLC
Docket No. PF15-6-000
VIRGINIA CAVE BOARD COMMENTS AND RECOMMENDATIONS ON THE PROPOSED DOMINION ATLANTIC COAST GAS PIPELINE

Dear Ms. Bose,

First enacted in 1966, the Virginia Cave Protection Act was established to protect the cave and karst resources of the Commonwealth of Virginia. As part of an amendment to the Act, The Virginia Cave Board was established in 1979 and charged with advising local, state, and federal governmental entities on matters concerning caves and karst lands throughout the Commonwealth. The Virginia Cave Board has the duty to make recommendations concerning any proposed rule, regulation or administrative policy that directly affects the use and conservation of caves in the Commonwealth.

Therefore, the Cave Board is writing to provide input and recommendations for protection of cave and karst resources in Virginia with respect to the proposed construction of two natural gas pipelines that have been planned to pass through Virginia. Please find detailed below our comments, concerns, and recommendations concerning one of these pipelines, the Dominion Atlantic Coast Pipeline.

Best regards,

Meredith Hall Weberg
Chair, Virginia Cave Board

Cc: Bob Bisha, Dominion Atlantic Coast Pipeline

1 Attachment

Distribution of karst regions in Virginia in relation to proposed gas pipeline routes

The two proposed pipelines are the Mountain Valley Pipeline and the Dominion Atlantic Coast Pipeline. The proposed routes as of April 1, 2015, are shown in Figure 1. The map in Figure 1 also shows the areas of different geology that host karst features.

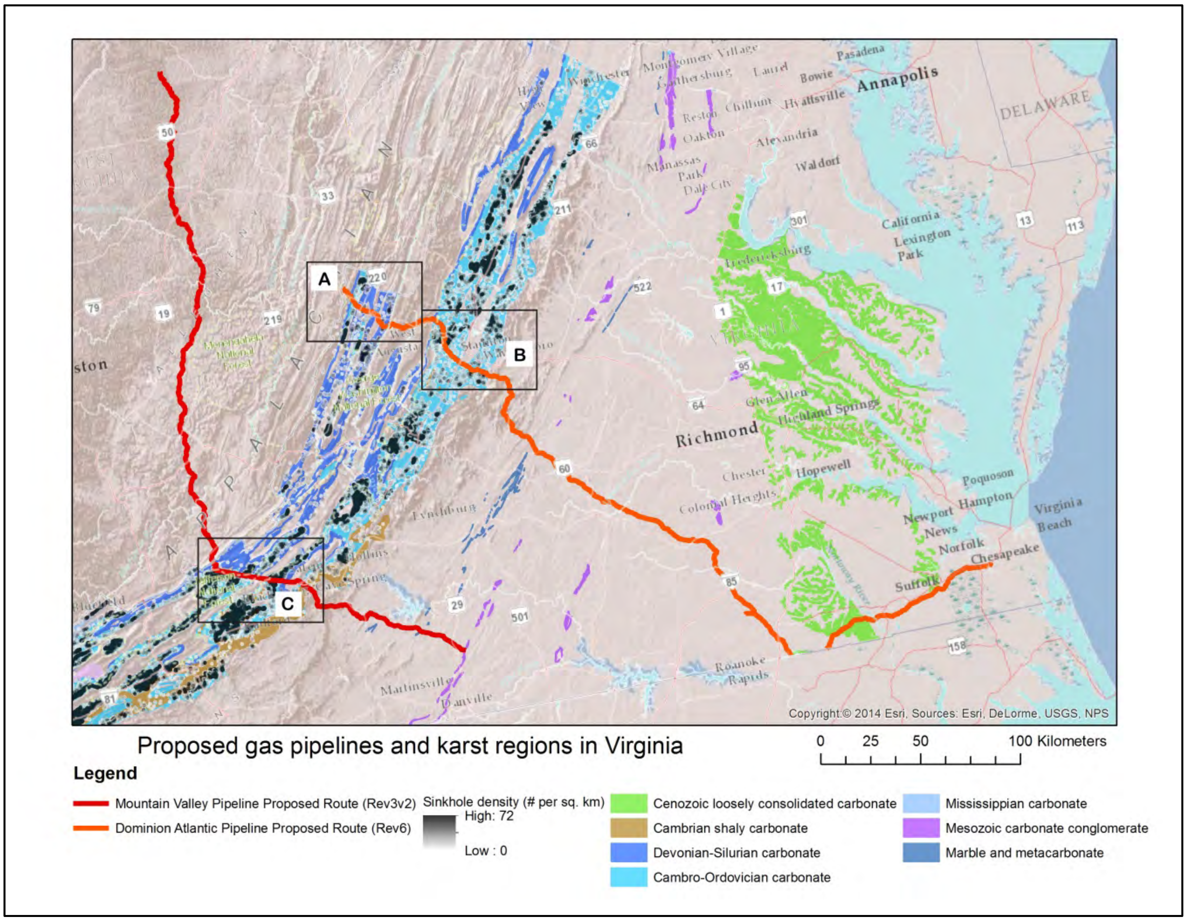


Figure 1.Map of karst regions in Virginia in relation to the proposed natural gas pipeline routes.

The areas of greatest potential impact to karst resources are located in the western portion of Virginia, within the Valley and Ridge physiographic province. The colored areas shown in the map of Figure 1 indicate regions underlain by soluble carbonate bedrock (primarily limestones and dolostones) that contain an abundance of karst features. The gray-to-black clusters of spots indicate the density of mapped closed depressions, or sinkholes, within a 1-square-kilometer region; the darker the cluster, the greater the density of sinkholes.

Dominion Atlantic Coast Pipeline

The proposed route of the Dominion Atlantic Coast pipeline is shown in orange in Figure 1. The two areas outlined in black (labeled A and B) are discussed in further detail below. These areas contain the greatest concentrations of karst features that could be impacted by this pipeline.

Highland County

In region A, the proposed Dominion Atlantic Coast Pipeline route passes through karst areas in Highland County, as shown in Figure 2. The proposed route passes through a zone of a high concentration of known sinkholes south of Monterey, shown in more detail in Figure 3 and Figure 4.

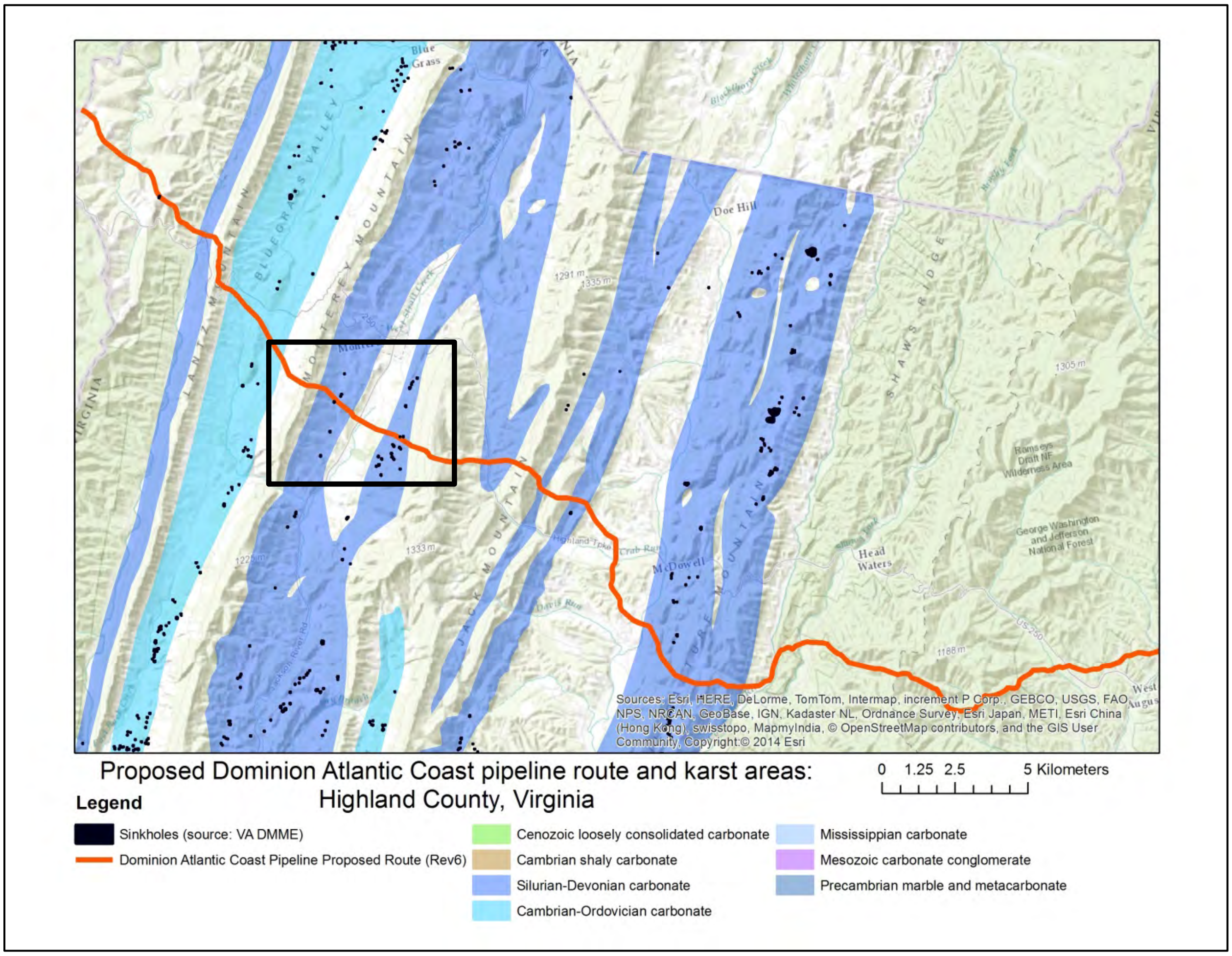


Figure 2. Route of proposed Dominion Atlantic Coast pipeline route through Highland County, regions with geologic potential for karst, and locations of known sinkholes. Area outlined in black is shown in greater detail in Figure 3 and Figure 4.

Highland County Cave Survey Karst Feature Map PR-4

The proposed pipeline route descends Monterey Mountain on an unnamed ridge west of Hannah Airfield. The karst is composed of Silurian-Devonian carbonates and the structure is the Monterey Syncline. The unnamed stream to the north of the route is a sinking/losing stream, as is the unnamed stream to the south of the route. All 14 streams originating on the east side of Monterey Mountain from Monterey in the north to Vanderpool to the south are sinking/losing streams. None of these sinking points have been dye traced to their spring resurgences. Most of these streams flow into an unnamed valley locally known as Sinking Creek Valley. Sinking Creek Valley is >2 miles long with the limestones continuing approximately another mile and a half to Vanderpool and then beyond (Figure 3).

There are five documented caves in this band of limestone between Monterey and Vanderpool. To the north of the proposed pipeline route is Sawmill Cave. To the south of the route is Sinking Creek Valley Cave, Meeks Cave, 9mm Pit, and Vanderpool Shaft. Sawmill Cave is less than a half-mile north of the proposed pipeline route. It is the sinking point for a small blind valley. It has been tentatively traced to Mackey Spring, approximately 3 miles to the south, when sawdust was pushed into the cave and it resurged at the spring. A formal dye trace should be conducted by competent professionals to confirm this connection.

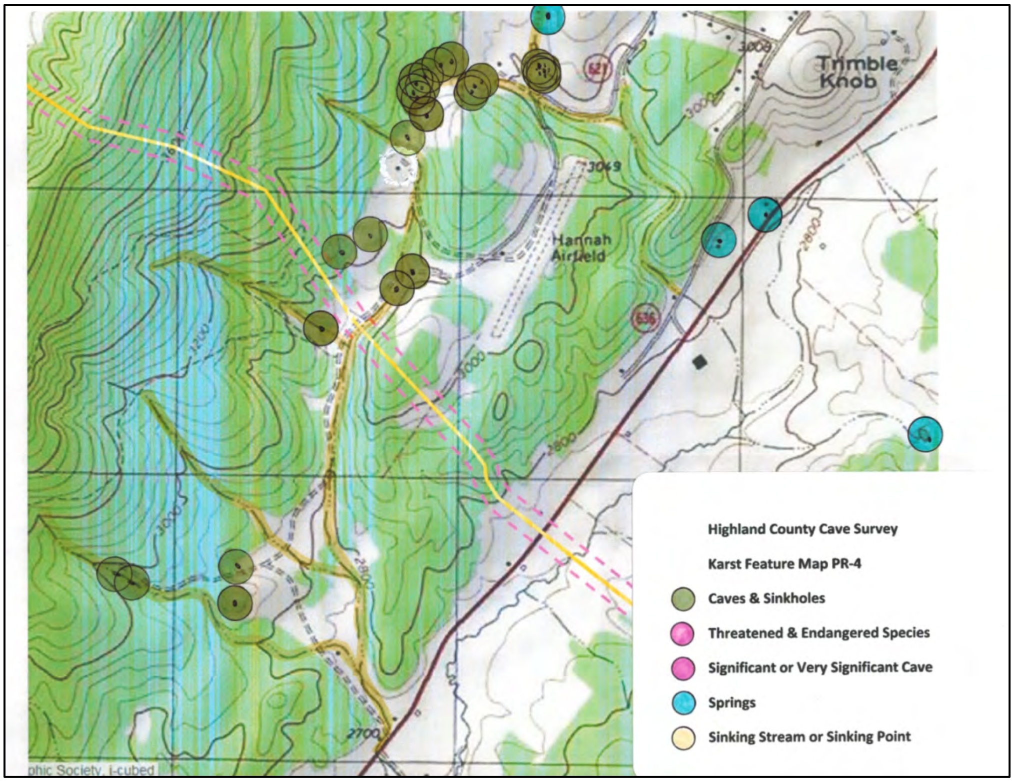


Figure 3. Highland County Map PR-4, showing the route of the proposed Dominion Atlantic Coast Pipeline and locations of known karst features near where the pipeline crosses west of State Route 220 and south of Monterey.

Sinking Creek Valley Cave is located approximately .25 miles south of the proposed pipeline route. This cave is a sinking point for the unnamed stream above it and has not been dye traced to its spring resurgence. This cave is an atmospheric karst feature that inhales or exhales air depending on the outside temperature and the barometric pressure at the time. This indicates this cave is connected by an air-filled conduit to another open karst feature that may or may not be documented. At the time of this cave's documentation indications were that this second entrance was higher than Sinking Creek Valley Cave.

Meeks Cave is approximately a mile south of the proposed pipeline corridor. This cave is in a sinkhole and not in a streambed. This cave also is an atmospheric karst feature and the karst feature it is connected to is unknown. At the time of its documentation indications were that the air was flowing to a lower entrance.

9mm Pit is located approximately 1.67 miles south of the proposed pipeline route. Its entrance is on the side of a hill and is not in a sinkhole or a sinking point.

Vanderpool Shaft is located approximately 1.81 miles south of the proposed pipeline corridor. This deep cave reaches the water table and has a water-filled passageway that appears to continue to the south. This cave has not been dye traced to its spring resurgence. This cave has not been inventoried for invertebrate fauna. It does contain *Plecotus townsendii*, Virginia Big-eared bat, which is on the Endangered Species List (Virginia, 2015) and the cave appears to have suitable Virginia Big-eared bat habitat characteristics.

A known Indiana bat, *Myotis sodalis*, roost tree is within 3-4 miles of the proposed pipeline corridor (see Attachment 1).

Mackey Spring is located south of Vanderpool Gap. Virginia's Department of Game and Inland Fisheries (DGIF) has stated that Mackey Spring is extremely vital to a healthy upper Jackson River. It has been described as a "transformational water source to the river" (pers. comm., DGIF, 2015). The DGIF Cold Water Stream data base shows Mackey Spring transforming the Jackson River from a Class VI stream to a Class II stream.

The band of karst exposed in Sinking Creek Valley is the western limb of the Monterey Syncline trough which is covered in the center of the valley by shale and sandstone, and which reemerges on the western slope of Jack Mountain as another band of karst in the eastern limb. While these bands of karst recharge spring resurgences along the Jackson River, they also recharge the deeper aquifer containing the Town of Monterey's municipal wells. Well #1 and Well #3 are approximately 1.78 and 1.56 miles respectively from where the proposed pipeline corridor crosses this band of karst. The pumps are approximately 427 feet and 865 feet below the lowest point where the proposed pipeline corridor crosses this band of karst.

Highland County Cave Survey Karst Feature Map PR-5
The proposed pipeline route crosses Route 220, the Jackson River, and Jackson River Valley and ascends Jack Mountain on an unnamed ridge. The carbonates are Devonian-Silurian and the structure is the Monterey Syncline. The seven streams to the north of the proposed pipeline corridor are sinking/losing streams and the five streams to the south of the proposed pipeline corridor are sinking/losing streams. None of their sinking points have been documented and none have been traced to their spring resurgences (Figure 4).

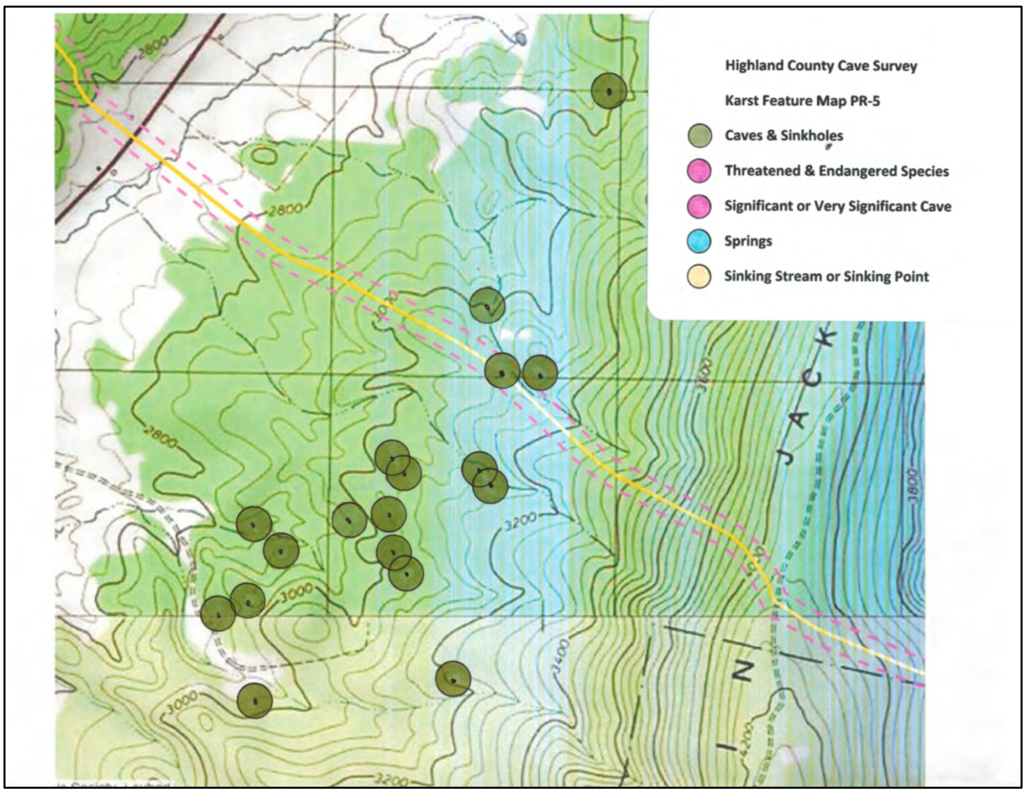


Figure 4. Highland County Map PR-5, showing the route of the proposed Dominion Atlantic Coast Pipeline and locations of known karst features near where the pipeline crosses east of State Route 220 and south of Monterey.

Needle's Eye Cave is .4 of a mile south of the route.

Eight known Indiana bat, *Myotis sodalis*, roost trees are within 3-4 miles of the proposed pipeline corridor (see Attachment 1).

The band of karst exposed on the western flank of Jack Mountain is the eastern limb of the Monterey Syncline trough which is covered in the center of the valley by shale and sandstone, and which reemerges on the eastern slope of Monterey Mountain as another band of karst in the western limb. While each of these bands of karst re-charge spring resurgences along the Jackson River, they also recharge the deeper aquifer containing the Town of Monterey's municipal wells. Well #1 and Well #3 are approximately 1.70 and 1.95 miles respectively from where the proposed pipeline corridor crosses this band of karst. The pumps are approximately 568 feet and 1006 feet below the lowest point where the proposed pipeline corridor crosses this band of karst.

Summary for Highland County

The proposed pipeline corridor has sinking/losing streams to its north and south. Indications are that an undetermined karst feature greater than 3 miles in length, stretching from Sawmill Cave (and possibly farther north and west) to Mackey Spring, lies under Sinking Creek Valley and the hills south of it. Nothing is yet known of the invertebrate fauna of this karst feature or its associated satellite karst features.

Habitat alteration due to sedimentation is potentially a threat that can be caused by construction of the proposed pipeline in this area of relatively steep slopes. Any major release of sediments or slope failure can potentially change conduit habitat, block recharge sites, or alter flow volume and velocity. Siltation can drastically modify gravel riffle and pool habitats and contaminated sediments can have detrimental effects on cave life (USDA, 2001). Due to the Jackson River being a Class II trout stream down gradient of the proposed pipeline, the discharge of hydrostatic test water must be prohibited within the Jackson River Valley and must be confined to holding ponds in a non-carbonate area. All sinking points down gradient of the proposed pipeline corridor must be identified and protected from potential engineering failures that could cause catastrophic releases of sediment, or possible slope failures. Their companion springs must be located and sampled for invertebrate fauna. The proposed pipeline corridor may be the recharge area for more than one spring. All possible springs must be identified and their recharge area protected.

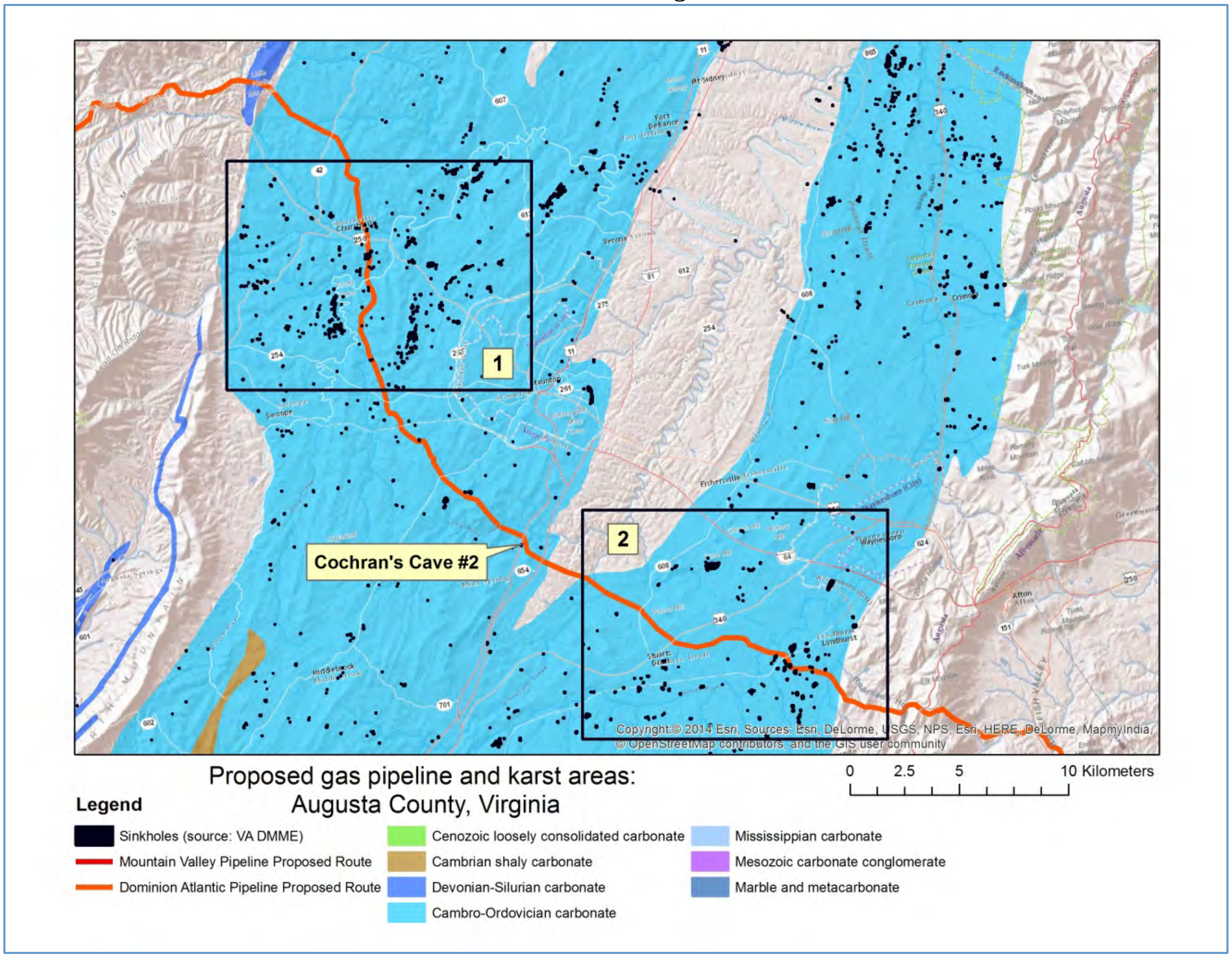
Several caves are known to exist in the vicinity of the pipeline route. Two of these caves have active air currents that inhale surface air from one entrance and exhale it from another. Methane from a leak on the east side of Monterey Mountain or in Sinking Creek Valley could be sucked into either of the two known caves that suck air or their unknown connection points and produce explosive atmospheres which would be detrimental to cavers. Potential methane entrapment within caves would present a significant hazard.

Approved surveys must be conducted for the presence of the Indiana and Northern Long-eared bats. All slopes of greater than 25% must be limited to open trenches of 500 feet or less. **The Cave Board recommends that Dominion Transmission Inc. maintain a 100-foot buffer around all karst features when blasting, drilling, digging, or trenching.** Any engineering failures in Sinking Creek Valley may cause irreparable damage to the underground karst drainage conduits and the health of the Upper Jackson River and the Town of Monterey's municipal wells. The sinking points in Sinking Creek Valley must be dye traced to their spring resurgences and the caves and resulting springs must be inventoried for invertebrate fauna. The spring recharge areas must be protected. All sinking points down gradient of the proposed pipeline corridor must be identified and protected from potential engineering failures. Extra time, money, and oversight must be put into any plan to cross this valley with a construction project of this magnitude. Even with the best "Best Management Practices," this segment of this route may be too risky and it is recommended the proposed pipeline corridor be re-routed around Sinking Creek Valley and Mackey Spring.

The concentration of known sinkholes in this region suggests intensive karst development is present in this portion of Highland County. **The Cave Board recommends application of heightened practices for environmental protection when constructing the pipeline through this area** (see section "**General recommendations on pipelines through karst regions**" below), **and local re-routing of the route to avoid passing directly over karst features. Particular attention needs to be paid to ensuring slope stability on steep slopes above karst valleys and within karst areas.**

Augusta County

In region B shown on Figure 1, the proposed Dominion Atlantic Coast Pipeline route passes through karst areas in Augusta County. These areas are shown in more detail in Figure 5. Two areas of high concentrations of known karst sinkholes are outlined and labeled 1 and 2, shown in greater detail.



ail in Figure 6 and Figure 7.

Figure 5. Route of proposed Dominion Atlantic Coast pipeline route through Augusta County, karst regions, and locations of known sinkholes.

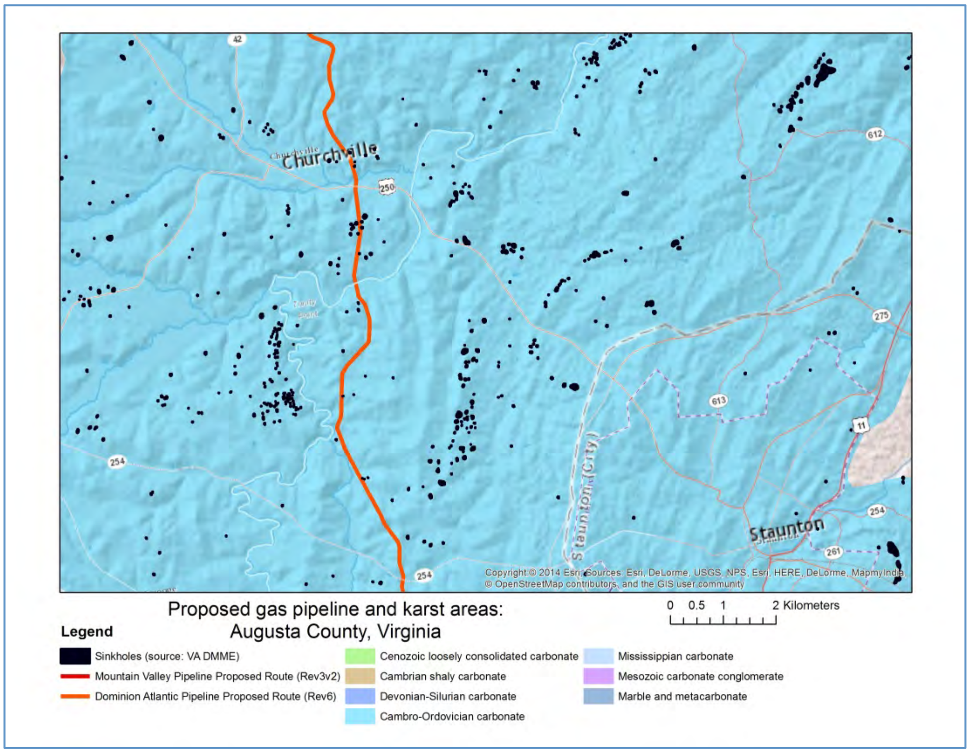


Figure 6. Sinkhole concentrations around Churchville, Va. in Augusta County.

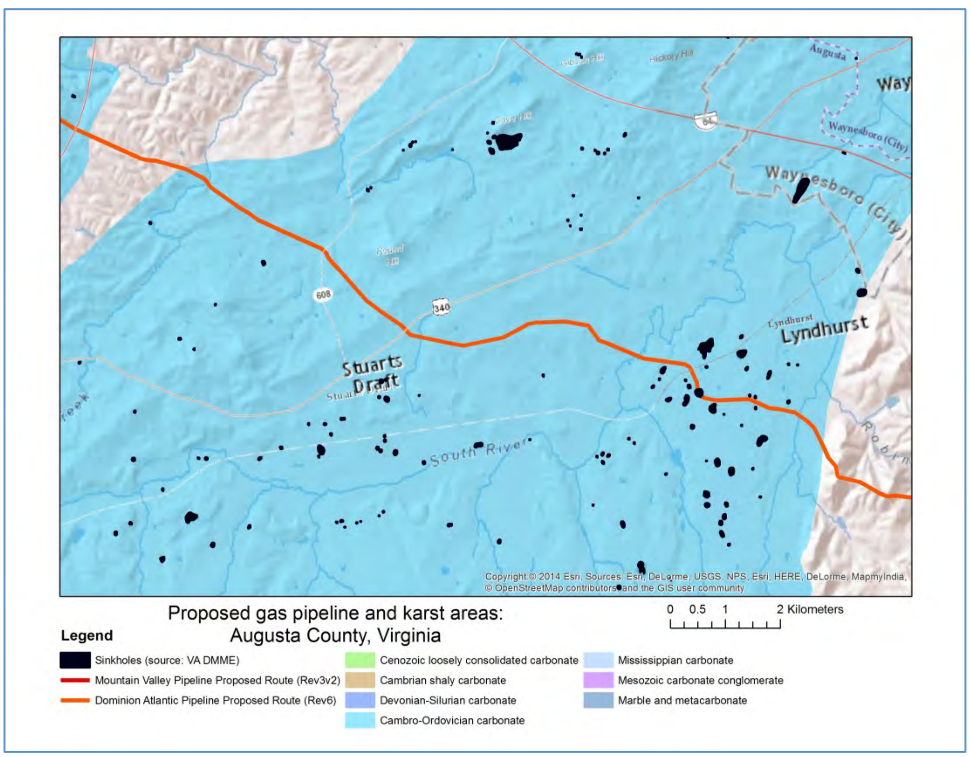


Figure 7. Sinkhole concentrations around Lyndhurst, Va. in Augusta County.

As documented in a letter from the Virginia Division of Conservation and Recreation (VA-DCR) (see Appendix I), the proposed Dominion Atlantic pipeline right-of-way (ROW) intersects only one significant cave, Cochran's Cave Number 2 in Augusta County (Figure 8). Cochran's Cave Number 2 is designated as significant under the Virginia Cave Protection Act of 1979. While considered significant in terms of hydrology, geology, and esthetics, the cave is also likely to be significant biologically. The cave lies just east of Route 11 beneath the current proposed pipeline alignment in Augusta County. The cave has a perennial stream upwelling near the back of the cave, and is within the range of the Madison Cave isopod (*Antrolana lira*), listed as threatened under the US Endangered Species Act. In addition, there is a high likelihood that several other globally rare, cave-adapted species are present in this cave. VA-DCR staff reports that the cave is scheduled for biological inventory in the coming year.

Ceiling heights of 70 feet are reported in the cave, bringing documented cave passage in close proximity to the base of the pipeline trench along the current proposed alignment. Therefore, the Cave Board strongly recommends local rerouting of the pipeline to avoid passing over or within the conservation area of Cochran's Cave Number 2.

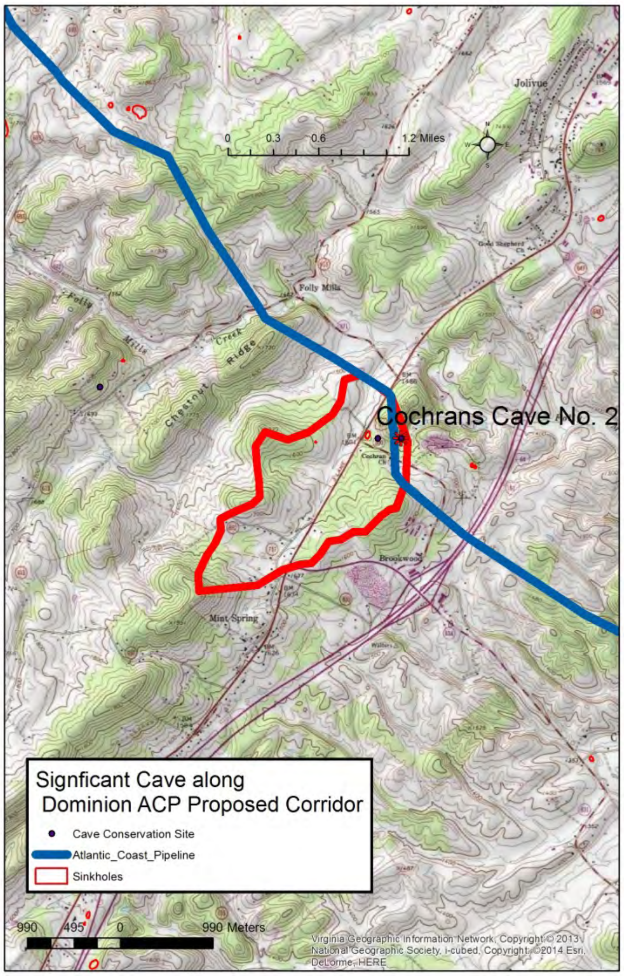


Figure 8. Location of Cochran's Cave No. 2 conservation area and proposed Dominion Atlantic Coast Pipeline route.

Many of the same issues apply to other routes, but given discrepancies between FERC's and Dominion's alternative route maps, as well as the lack of time, it is not possible to comment in any detail on all of the alternative routes. Our comments are not limited to the comments within this document, and all karst details have not been documented herein.

General recommendations on pipelines through karst regions

In addition to these specific concerns about impacts to documented resources, the Virginia Cave Board wishes to express some recommendations to address concerns regarding the potential impact of pipeline construction and operation on karst resources in general. Of particular relevance are:

1. CONDUCT A COMPREHENSIVE KARST FEATURE INVENTORY ALONG THE RIGHT-OF-WAY AND WITHIN A MINIMUM 1-MILE BUFFER ZONE (1/2 MILE ON EITHER SIDE) OF THE PIPELINE ROUTE

The Cave Board recommends that the project developer will, through a licensed professional experienced in conducting karst inventories, perform a comprehensive field inventory of all carbonate units. This karst inventory will include at a minimum: identification of karst features such as springs, sinkholes, signs of subsidence, sinking streams, cave entrances, and the limits of exposed surficial carbonate units. The scope of this inventory will be, at a minimum, all carbonate rock units within one mile of the project limits. A copy of the summary inventory report, along with a GIS-compatible, geospatially referenced data file containing all karst features identified, will be provided to the Virginia Cave Board for its review and comment. Karst drainage basins originating within and extending outside the area of influence of the pipeline route should be properly delineated and assessed for subsurface drainage pathways (see #4 below). The Cave Board recommends an adaptive management approach taken to the assessment of any proposed route.

2. DO NOT USE HORIZONTAL DIRECTIONAL DRILLING DURING PIPELINE CONSTRUCTION IN KARST AREAS

The use of horizontal directional drilling is known to be problematic in karst areas (e.g., Smith and Sinn, 2013), where loss of drilling fluid into voids can damage habitat and contaminate ground and surface water. The Cave Board recommends against the use of horizontal directional drilling in all areas of carbonate bedrock.

3. ENSURE STRUCTURAL INTEGRITY OF PIPELINE TO MITIGATE AGAINST POTENTIAL SURFACE COLLAPSE IN KARST AREAS

The potential for subsidence along the pipeline exists in karst areas, which could affect the structural integrity of the pipeline and induce leakage. The Cave Board recommends avoiding areas prone to subsidence as indicated by the presence of existing sinkholes within the pipeline right-of-way, and/or ensuring that the structural integrity of the pipeline is sufficient to bridge any voids that may form on the basis of comprehensive engineering studies. Subsidence prone areas would have been identified prior to pipeline construction by a comprehensive karst survey (see #1 above). A comprehensive plan for inspection and maintenance should be submitted and reviewed by a licensed engineer with experience working in karst regions.

4. DO NOT DISCHARGE FLUIDS INTO SINKHOLES OR OTHER KARST DEPRESSIONS OR SINKING STREAMS, INCLUDING PIPELINE HYDROSTATIC TEST WATER OR OTHER FLUIDS USED OR GENERATED DURING PIPELINE CONSTRUCTION OR OPERATION

The Cave Board recommends the prohibition of fluid discharge of any sort into sinkholes or onto the land surface in karst areas that may be generated during pipeline construction and maintenance. Discharge of hydrostatic test water to the land surface, including but not limited to sinkholes, has in the past induced the formation of sinkholes adjacent to pipeline right-of-ways, causing safety hazards and introducing sediment as well as any chemicals from the slug test water into the local ground water. If sinkholes receiving surface water drainage from the area of disturbance are identified from the karst feature survey, the Cave Board recommends that the designated sinkholes be dye-traced by competent professionals to resurgent springs and that the results of the traces be shared with the Cave Board and VA-DCR's Natural Heritage staff before the actual construction plans are finalized.

5. PREPARE A SPILL PREVENTION, CONTROL, AND COUNTERMEASURE (SPCC) PLAN SPECIFICALLY TAILORED TO KARST SYSTEMS
Spills of fuel and other chemicals may occur during project construction and maintenance activities. If such spills drain to sinkholes, caves, or sinking streams, they have the potential to contaminate groundwater and adversely affect subterranean habitat. The Cave Board recommends development of a Spill Prevention, Control, and Countermeasure (SPCC) plan that will include a comprehensive strategy for groundwater and surface water monitoring and remediation specifically tailored to address the complexity of karst systems. The Cave Board requests to be able to review and comment upon any drafts of the SPCC plan in order to assess its suitability for karst areas. VA-DCR must be notified in the event of any spill or discharge.

6. ESTABLISH A PROGRAM OF MONITORING OF KARST FEATURES POTENTIALLY AFFECTED BY THE PIPELINE CONSTRUCTION AND OPERATION
The Cave Board recommends adopting the Karst Monitoring Protocols and other guidance set out within Appendix L of the Multi-Species Habitat Conservation Plan for the Colombia NiSource natural gas pipeline: http://www.fws.gov/midwest/Endangered/permits/hcp/nisource/2013NOA/NiSourceHCPfinalJune2013.html.

7. CONDUCT GEOPHYSICAL SURVEYS ALONG THE PIPELINE ROUTE USING PROVEN TECHNIQUES
The Cave Board recommends conducting geophysical surveys along the proposed pipeline route passing through regions of carbonate rock in order to provide information on potential karst features hidden from view at the surface. Such surveys should employ methods shown to have been effective in karst areas, such as direct current electrical resistivity. The results of any geophysical surveys, including data generated and interpretive reports, should be shared with the Cave Board, VA-DCR, and the Virginia Department of Mines Minerals and Energy.

Compliance with Federal and State regulations

Streams flowing through karst are intimately connected with groundwater. Sinking streams in karst regions direct surface water flow directly into aquifers and provide little to no natural filtration to combat contamination in surface waters. Therefore, the Cave Board strongly recommends that FERC ensures that pipeline companies comply with all provisions of the Clean Water Act relevant to areas where the pipeline crosses through karst regions and to disallow any exemptions. At a minimum, the developer should be required to produce detailed storm water management and erosion and sediment control plans specifically tailored to the hydrological characteristics of karst terrains.

Offer to serve as a cooperator during the production of the EIS

The Virginia Cave Board offers to serve as a cooperating entity in the process of producing the Environmental Impact Statement (EIS).

Frequently Asked Questions on pipelines and karst

Due to the overwhelming public interest in the issues raised with building pipelines across karst areas, the Virginia Cave Board has compiled answers to a list of Frequently Asked Questions (FAQs) on the topic. These are provided as Appendix I to this letter.

REFERENCES:

Department of Game and Inland Fisheries (DGIF), 2015, an email dated February 18, 2015 from Paul Bugas (DGIF) to Rick Lambert (Highland County Cave Survey).

Fish and Wildlife Service (FWS), 2015, Letter dated January 23, 2015 to William A. Scarpinato, 5 pages

Keith, J. H. and Poulson, T. L., 1981. Broken-back syndrome in *Amblyopsis spelaea*, Donaldson-Twin Caves, Indiana. Cave Research Foundation 1979 Annual Report, 45-48.

Panno, S. V., Kelly, W. R., Weibel, C. P., Krapac, I. G., and Sargent, S. L., 1998, The effects of land use on water quality and agrichemical loading in the Fogelpole Cave groundwater basin, southwestern Illinois. Proceedings of the Illinois Groundwater Consortium Eighth Annual Conference, Research on agriculture chemicals in Illinois groundwater, 215-233.

Smith, T.J., and Sinn, G.C., 2013. Induced sinkhole formation associated with installation of a high-pressure natural gas pipeline, west-central Florida. In: Land L, Doctor D.H., Stephenson J.B., editors, Sinkholes and the Engineering and Environmental Impacts of Karst: Proceedings of the Thirteenth Multidisciplinary Conference, May 6-10, Carlsbad, New Mexico: NCKRI Symposium 2. Carlsbad (NM): National Cave and Karst Research Institute, p. 79-88. http://www.karstportal.org/node/11809

USDA Forest Service, Eastern Region, 2001, Conservation Assessment for Organ Cave snail (*Fontigens tartarea*), 9 pages, accessed online at: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_054191.pdf

Virginia Threatened/Endangered Cave Biota, 2015, Accessed online on March 8, 2015 at: http://www.acave.us/EndangerdVACaveBiota.htm

APPENDIX I

Memorandum

Subject: Dominion Transmission, Inc. Atlantic Cost Pipeline (Natural Gas): Potential impacts to cave and karst resources

Date: 02 March, 2015

To: The Virginia Cave Board

From: Wil Orndorff, Karst Protection Coordinator
Virginia Department of Conservation and Recreation

This memorandum is to alert the Virginia Cave Board of the potential for impacts to cave and karst resources by the construction and operation of the proposed Atlantic Coast Pipeline, a venture of Dominion Transmission, Inc. (Dominion Virginia Power). The current preferred alignment as submitted by Dominion to the Federal Energy Regulatory Commission crosses sensitive karst areas in Highland and Augusta counties, Virginia. The corridor intersects numerous documented cave and karst resources, including one state designated significant cave. Numerous smaller caves are documented by Virginia Speleological Survey along the project corridor.

A description of the designated significant cave follows. Conservation sites as used by the Virginia Department of Conservation and Recreation represent areas on the landscape where activities could reasonably be expected to impact a specific natural heritage resource or group of resources. Significant caves and rare cave fauna are considered natural heritage resources, so each such feature or occurrence is associated with a conservation site.

Significant Cave Conservation Site and karst intersected by the current proposed alignment:

Cochran's Cave #2 is designated as significant under the Virginia Cave Protection Act of 1979. While consider significant in terms of hydrology, geology, and esthetics, the cave is also likely to be significant biologically. Like many of Virginia's significant caves, biological investigations remain to be performed for Cochran's Cave #2. However, the cave is scheduled for biological inventory during spring of 2015 by the DCR Natural Heritage Program staff. Cochran's Cave #2 lies just east of US RT 11 beneath the current proposed pipeline alignment in Augusta County (see map provided as digital attachment.) The cave has a perennial stream upwelling near the back of the cave, and is within the range of the Madison Cave isopod (*Antrolana lira),* listed as threatened under the US Endangered Species Act. This species occurs in similar hydrogeological setting in several caves across its range. In addition, there is a high likelihood that other globally rare, cave-adapted species are present in the cave. Finally, ceiling heights of 70 feet are reported in the cave, bringing documented cave passage in close proximity to the base of the pipeline trench along the current proposed alignment. For these reasons, DCR Natural Heritage Program staff strongly recommends local rerouting of the pipeline to avoid passing over or within the conservation site for Cochran's Cave #2.

Although no significant caves are designated in the immediate area, the crossing of Bullpasture Mountain in Highland County should be investigated very carefully for karst hazards. Any caves identified within the project area should be fully investigated for biological significance and hydrological sensitivity.

<u>General concerns regarding gas line construction and operation in karst</u>

In addition to concerns about impacts to documented resources, I would like to bring the Cave Board's attention to some general considerations regarding the potential impact of pipeline construction and operation on karst resources. It is critical both for resource conservation and for the integrity of the pipeline that karst issues be recognized and dealt with in an appropriate manner. For some features, this will mean avoidance, while for others, appropriate engineering solutions. Of particular relevance are:

1) The use of directional drilling in karst areas, where loss of drilling fluid into voids can damage habitat and contaminate ground and surface water. For these reasons, direction drilling in karst is not recommended.

2) The potential for subsidence along the pipeline, which could affect the structural integrity of the pipeline and induce leakage. Subsidence prone areas should be avoided if possible, and/or the the structural integrity of the pipeline must be documented as sufficient to bridge any voids that may form.

3) The potential for dissolution of methane into groundwater along the pipeline corridor. The extent to which this occurs is unknown, but the project's proponents should evaluate the potential for this to occur, particularly in areas where the pipeline will pass below the water table.

4) The impact to undocumented karst features encountered during survey and construction. The project's proponents should document and investigate any features of potential significance discovered during the course of the project, and the results of any such investigation be shared with the Cave Board.

5) The discharge of slug test water to sinkholes or the karst land surface. Discharge of slug test water to the land surface, including but not limited to sinkholes, has in the past induced the formation of sinkholes adjacent to pipeline ROWs, causing safety hazards and introducing sediment as well as any chemicals in the slug test water into the local ground water. Slug test water should not be discharged to sinkholes or to the land surface in karst areas.

6) Spills of fuel and other chemicals during project construction and maintenance activities. If such spills drain to sinkholes, caves, or sinking streams, they have the potential to contaminate groundwater and adversely impact subterranean habitat as well as drinking water supplies. Project proponents should include karst specific provisions in the spill prevention plan that provide the same level of protection to karst features as that afforded to surface waters.

APPENDIX II

Frequently Asked Questions (FAQ) About Natural Gas Transmission Pipelines Through Karst Terrains

By the Virginia Cave Board

The construction of new natural gas transmission pipelines through Virginia karst landscapes was recently proposed, and numerous questions and concerns have arisen regarding the potential risks that these pipelines may have upon human health, safety, and the karst environment. One of the core missions of the Virginia Cave Board is to provide information on matters relating to karst lands in Virginia, therefore the Board has developed answers to some potentially common questions on the topic.

Q. What exactly is karst?

Q. Where is karst located in Virginia?

Q. Are there currently any natural gas pipelines in Virginia located in karst terrain?

Q. Is locating natural gas transmission pipelines in karst inherently dangerous?

Q. Are there specific laws guiding the construction of natural gas pipelines in karst terrain?

Q. Is the strength of the bedrock a challenge for predicting the behavior of karst feature development?

Q. Is the limestone and dolomite dissolving away to form caverns and conduits?

Q. Have sinkholes ever formed during the installation of a high pressure natural gas pipeline?

Q. Sinkholes do form suddenly in our region, don't they? We read about road closures and building foundation failures. How could this have happened?

Q. Can soil being carried into sinkholes or caverns during the process of excavation negatively affect the karst environment?

Q. How can one predict where collapse of sediment into voids in the bedrock might occur?

Q. Can blasting have an effect upon karst aquifers and groundwater supplies?

Q. Can trenching negatively affect water wells and springs?

Q. Won't the pipeline trench, even if backfilled, become an artificial "conduit," diverting water away from its previous natural flow path through the subsurface?

Q. Can the on-going operation of natural gas transmission pipelines on karst affect water quality?

Q. Besides leaking natural gas, are there other potential water quality challenges from natural gas transmission pipelines located in karst terrain?

Q. Can a preliminary karst survey help reduce potential risks to the pipeline's integrity and safeguard water supplies, water quality, and the subsurface environment?

Q. How effective are natural gas pipeline inspections?

Q. Where can I learn more about karst?

Q. What exactly is karst?

A. The term "karst" refers to a landscape type, not unlike "desert," "marsh," "tundra," "steppe" or "montane." It was named for a province in Slovenia that was dominated by sinkholes, caverns, irregular "pinnacled" bedrock surfaces, and large springs. The term "karst" was later applied to other landscapes dominated by similar features. However, modern definitions usually apply the term to landscapes in which surface and groundwater flow systems occur within bedrock modified by chemical solution, regardless if there are sinkholes or other surface features historically associated with karst landscapes. Therefore, if surface and groundwater is flowing over and through soluble rocks, such as limestone, the presumption is that karst is present. The main difference in karst versus non-karst systems is:

1) Groundwater flow is non-uniform, and primarily through conduits formed by bedrock dissolution. As such, groundwater flow in karst is not as predictable as groundwater flow in unconsolidated sediment; therefore, many computer models of groundwater flow are not reliable;

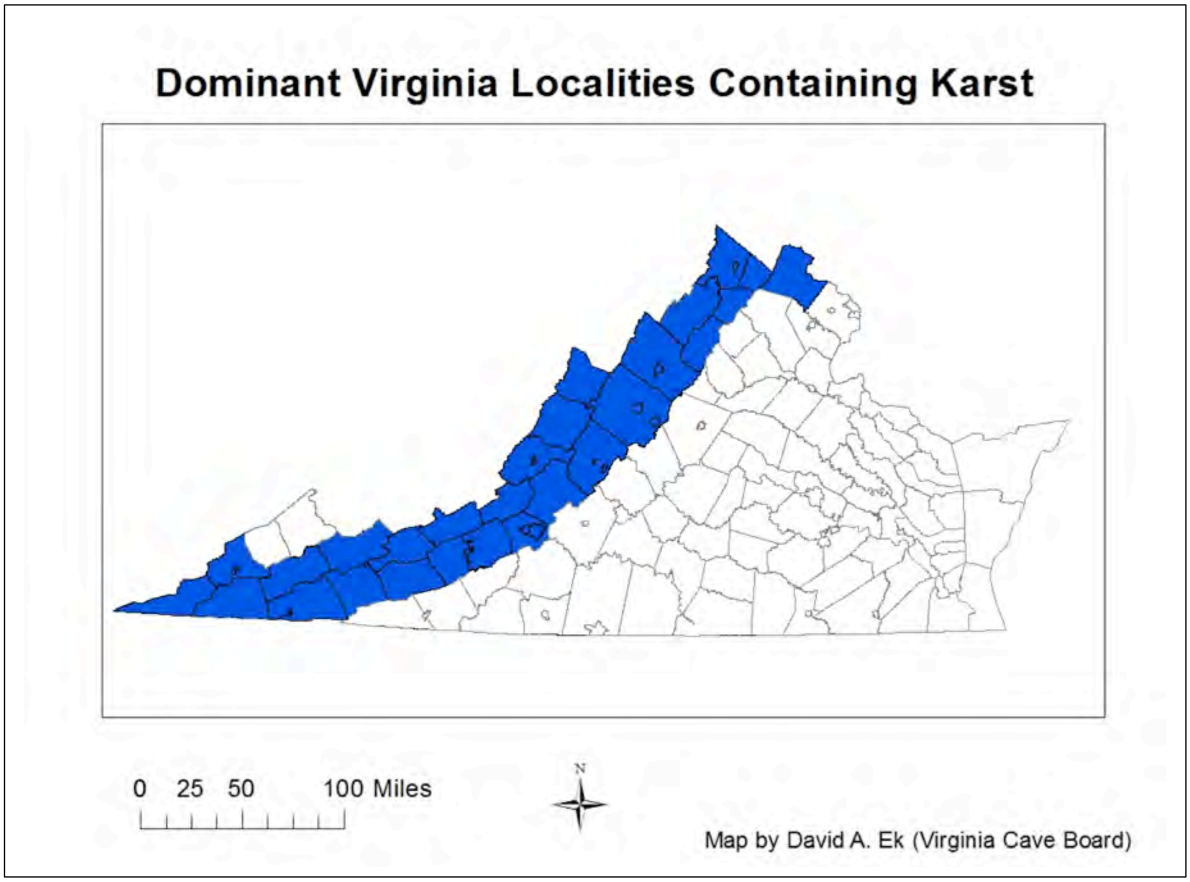
2) These conduits slowly change over time due to chemical solution and alteration of the bedrock and aquifer characteristics;

3) Groundwater can flow rapidly through solution channels, carrying pollutants and sediment with little or no filtration or treatment commonly associated with groundwater flow; therefore, the risk of contaminant transport is generally higher within karst terrain; and

4) Some aquatic and terrestrial organisms have adapted to the caves and conduits within karst systems, and their confinement to these systems has created a high degree of specific adaptation to these environments. These organisms' dependence upon this environment, coupled with their often low numbers, and their tendency to evolve into distinct species, has created a situation in which they are often highly susceptible to impact and environmental degradation.

Q. Where is karst located in Virginia?

A. It has been estimated that one-third of all of the United States east of the Mississippi River, and 18 percent of Virginia, contains karst. Karst can be located wherever there are soluble rock strata, and this includes sandstones that are cemented with calcite. While many areas of Virginia contain some karst, the dominant karst region within Virginia is the Valley and Ridge Physiographic Province located near the western portions of the state, bordering West Virginia and Kentucky. The following map provides an approximation of the major karst regions in Virginia.



Q. Are there currently any natural gas pipelines in Virginia located in karst terrain?

A. Yes, there are several companies that operate and maintain natural gas transmission pipelines located within Virginia karst terrains. Of the 27 Virginia counties that contain significant karst resources, 20 of them (74 percent) appear to have at least one natural gas transmission pipelines that traverses the county and is likely located on karst. These counties are: Alleghany; Augusta; Botetourt; Clarke; Frederick; Lee; Loudoun; Montgomery; Page; Pulaski; Roanoke; Rockbridge; Rockingham; Russell; Shenandoah; Smyth; Tazewell; Warren; Washington; and Wythe. The seven Virginia counties containing significant karst resources that do not currently contain any current natural gas transmission pipelines are: Bath; Bland; Craig; Giles; Highland; Scott; and Wise.

Q. Is locating natural gas transmission pipelines in karst inherently dangerous?

A. While natural gas pipelines are often the safest means of transporting natural gas, there are dangers associated with carrying pressurized flammable gas. According to the U.S. Department of Transportation's Pipeline and Hazardous Material Safety Administration (PHMSA), there were 1,270 "significant" "gas transmission" pipeline incidents from 1995 to 2014 in the United States, resulting in 42 fatalities and 174 injuries. For this same time period in Virginia, there were 58 incidents (from all types of pipelines, not just gas transmission), resulting in four fatalities and 28 injuries. The causes of these incidents ranged from pipe damage during excavations, pipe corrosion, flood damage, to weld failures. There is no cave or karst category, but cave or karst-related incidents appear to be an insignificant percentage of incidents.

The biggest safety threat associated with the on-going operations of a natural gas transmission pipeline in karst terrain is due to its potential ability to swiftly and widely transport pollutants through karst conduits, thereby potentially affecting a wider array of people and resources. Gas can move along a karst conduit faster than a person can walk. There have been instances in which teenagers have died from entering a cave a long distance from an unsuspecting gasoline spill. In these situations, the gasoline vapors traveled long distances through the cave and karst conduits before coming into contact with an ignition source or created a situation in which the unsuspected cave explorer became asphyxiated. There are incidents in which flammable vapors degassed and vented into crawlways and basements under existing homes and structures. These are rare incidents, but it is important to keep natural gas or other flammable gases out of cave and karst conduits and other confined locations. Corrosion is a ubiquitous concern for all pipelines; however, there are some situations that may lead to an increased risk for pipelines located in karst. Some rock layers contain pyrite, and pyrite can lead to the production of sulfuric acid, which would then accelerate limestone dissolution as well as pipeline corrosion. To reduce pipeline corrosion, some common industry practices include special sealants and the passing of a weak electrical current through the pipeline.

Q. Are there specific laws guiding the construction of natural gas pipelines in karst terrain?

A. Virginia does have a law specifically focused upon protecting caves (the Virginia Cave Protection Act, Code of Virginia Section 10.1-1000 to 1008); there is no corresponding law that specifically protects karst. In addition, there are regulations governing pipelines; however, these regulations provide no separate consideration for karst or karst impact.

It is important to understand, that caves and karst contain interrelated systems of physical, chemical and biologic processes. Virginia caves and karst not only provide pathways for water, they also support the economy, contain irreplaceable cultural resources, and provide critical habitat for rare and protected species. As such, there may be other laws that may be applicable to caves and karst, ranging from the Federal Cave Resources Protection Act, Endangered Species Act, Clean Water Act, and the Archeological Resources Protection Act, to name a few. From a project-to-project perspective, some of these laws may apply due to the specific resources and issues involved, not necessarily because of the presence or absence of sensitive karst resources. It should be noted that several of these environmental laws contain specific exemptions for targeted elements of the oil and gas industry.

Just as diverting or modifying water flowing into a karst system may interrupt the karst's natural flow regime, it may also disrupt or even seriously harm sensitive cave organisms. There are a variety of rare, threatened and endangered species that inhabit Virginia caves, some, such as the Lee County isopod, Madison Cave amphipod, Madison Cave isopod, and Holsinger's cave beetle, are restricted to caves and karst. Therefore, most cave and karst-related laws are due to the presence of protected species or artifacts that may be in caves and karst, and not due to the karst landscape *per se*.

Q. Is the strength of the bedrock a challenge for predicting the behavior of karst feature development?

A. It is true that the bedrock underlying the karst terrain of Virginia varies considerably, depending on how it was deposited and whether it underwent modification by solution action of acidic water in the distant past. However most of the rock within Virginia's karst regions is hundreds of millions of years old, and in general is structurally sound. In fact, most of the regional highway commissions consider ten-feet of solid limestone to be sufficient to support "critical structures" such as highway overpasses and viaducts. It should be noted that the famous Natural Bridge of Virginia's Rockbridge County is 50-feet thick, yet it carries U.S. Route 11 over an open void over 200 feet in height without collapsing.

But more importantly, it is often not the collapse of the bedrock that causes sudden, catastrophic formation of sinkholes in our region; rather; it is the collapse of sediment overlying the bedrock voids that commonly occurs. These are called "cover collapses." Cases in which a bedrock cavern roof suddenly gives way are rare in Virginia. Since the geographic setting, geologic history, climate and local environmental conditions vary widely from one karst region to the next, transferring the risk assigned to a karst setting in one part of the country and applying it to a Virginia karst setting may not be a valid assumption.

Although natural cave collapses are rare within Virginia, there are human-induced activities that can increase the likelihood of problems within a karst setting, this is one of the reasons that proper geophysical studies, site specific evaluations, and karst assessments prior to construction is important. Situations that would greatly increase this potential risk, especially within karst settings, are poorly designed on-site water and stormwater management, and diverting and impounding water. These poor practices can greatly increase the likelihood of unintended consequences, including the potential for sinkhole and cover collapse. This is why it is especially critical to have water and stormwater management designs and plans for projects within karst settings to be prepared by professionals who have demonstrated experience in karst stormwater management; and that developers should be held accountable for implementing these recommendations responsibly.

Q. Is the limestone and dolomite dissolving away to form caverns and conduits?

A. Yes, but the process of dissolution is imperceptibly slow. In our area, the limestone is dissolved by carbonic acid, which is the result of atmospheric and soil carbon dioxide mixing with percolating water. However, the actual rate of limestone dissolution underground is extremely slow. For instance, to dissolve an inch of limestone under natural conditions, may take many decades to several hundred years. In addition, the caves in our region are likely several millions of years old. Limestone and other carbonate rock and conduits and caves within karst terrain are not likely to catastrophically collapse merely from the placement of a pipeline, building or other structure on karst surfaces. It should be noted that since the founding of our country, there have perhaps been millions of people and hundreds of communities in the United States that have lived on karst- this is not a rare or unusual situation. Pipelines within karst terrain can be structurally stable, if properly designed, constructed and maintained.

Q. Have sinkholes ever formed during the installation of a high pressure natural gas pipeline?

A. Yes, they have, and in fact this occurred in a well-documented incident (click here for a reference: http://www.karstportal.org/node/11809) during the installation of a natural gas pipeline system in Florida. Unfortunately, this incident has been used as evidence by critics that all pipelines installed in karst are inherently unsafe and may induce sinkhole formation. However, the Florida incident occurred while the pipeline was under construction using a process called "Horizontal Directional Drilling" (HDD); and in the relatively soft and poorly consolidated limestone that occurs in that region. HDD requires enormous "tip pressure" to advance the borehole, and as a result of this it caused a "blow out" of the soft limestone and soil above it. It is for this and other reasons that the Virginia Cave Board does not recommend horizontal directional drilling within karst settings.

Q. Sinkholes do form suddenly in our region, don't they? We read about road closures and building foundation failures. How could this have happened?

A. This certainly does happen, but usually not because the rock has collapsed. It more commonly occurs where soil and sediment that fills the pre-existing network of solution-enlarged voids and conduits in the bedrock begins to move downward. This can happen due to natural causes, such as periods of drought that lowers the water table, thus creating an air-filled void beneath the soil plug in a vertical chamber. In these situations, the water that was supporting the soil is gone; thereby allowing the soil to subside into the hollow below, forming a sinkhole on the surface. It can also occur when water that used to infiltrate in a dispersed manner has later been channelized into a concentrated area. As new sinkholes are created, it provides an effective conduit to transport sediment and other debris that falls into the sinkhole from the surrounding unstable land surface, and carry this material away by the water flowing through the karst conduit. This is how a catastrophic sinkhole can grow quickly engulfing objects on the surface and collapsing into itself. While these catastrophic sinkholes can be created by natural processes, more often they are due to human activity. Over-pumping of groundwater from shallow wells, quarry dewatering, and channeling of stormwater into narrow drainage paths, can all wash underlying soil and loose unconsolidated sediment away, thus leaving the surface structurally unstable and susceptible for the creation of additional sinkholes. Something as simple as improperly directing the water from roof drains and gutters away from the foundation of a structure can eventually cause a sinkhole to form along the footer or even below the slab.

Q. Can soil being carried into sinkholes or caverns during the process of excavation negatively affect the karst environment?

A. Yes, it can. That is why the preliminary karst survey is so important. The most vulnerable karst features are cave entrances and "open throat" sinkholes (i.e. sinkholes that have an opening into the subsurface bedrock). Soil, uncontrolled stormwater and pollutants absorbed into soil particles can flow into these openings and directly into the subsurface without the benefit of any filtration. Therefore, the preliminary survey identifies karst features so that the pipeline's route may be relocated accordingly. If they cannot be avoided, strict sediment and erosion control measures should be taken during construction and continue after construction until such time that the surrounding soil has stabilized. Every effort should be taken to direct soil and construction site runoff from these openings.

Q. How can one predict where collapse of sediment into voids in the bedrock might occur?

A. One cannot predict exactly where a sinkhole might form, but the pattern of existing sinkholes gives clues as to where the pre-existing structural features such as intersecting joints and fractures, faults, and folds in the bedrock, have allowed sinkholes to form with greater frequency and density over time. In addition, potential causative factors, such as ponded water or greater volumes of water being channeled into karst settings, would be particularly noted and inspected by knowledgeable professionals performing karst assessments. This is why preliminary surveys are so important. In addition, experienced karst geologists and soil scientists are aware that certain rock units tend to form cohesive, clay-rich soil layers that are prone to the development of so-called "covered karst" where these soils tend to bridge over underlying voids and hollows in the subsoil and bedrock. Known areas with this type of cohesive soil must be scrutinized very carefully during development, especially after the process of vegetation clearing (i.e. "stripping and grubbing") which destroys the entangled root mass holding the surface soil together.

Q. Can blasting have an effect upon karst aquifers and groundwater supplies?

A. Blasting is a common excavating tool, and it has wide applications, ranging from the breaking and fracturing of the maximum amount of material that may occur in a quarry operation, to the minor sculpting and finish work that you may see on a cliff above a highway. In many situations, trenching is the more common excavating tool for pipeline construction. When blasting is needed for pipeline construction, it is more common to use the lower-impact "finishing" end of the blasting spectrum.

Water in karst aquifers primarily moves along solution channels; therefore, flow is highly dependent upon the direction and characteristics of these conduits. This is also true for fracture flow aquifers in non-karst settings. The impact from blasting can alter and disrupt these solution channels, thereby causing the water to flow along different conduits. This creates situations in which the water flows in different directions, or that water quality and quantity is altered. If these water quality or hydrologic changes occur, it is highly improbable that the previous groundwater conditions can be restored.

Blasting may affect localized depth to groundwater, recharge characteristics and water quality. Many of these potential effects are similar for karst versus non-karst settings. It should however be noted that since karst groundwater flow is highly dependent upon localized structural characteristics, any disturbance, such as blasting, that can affect localized structural characteristics have therefore a greater chance of altering groundwater flow in surficial karst aquifers. If these impacts do not directly affect deeper wells, they may still affect the well's recharge characteristics.

There are many factors that contribute to the potential for blasting to affect karst resources; some of these are a function of the on-site karst characteristics, while others are factors of the blasting. Blasting parameters that may contribute to karst impacts are usually the same that would affect non-karst groundwater resources, such as: specific objective, proximity, intensity, use of cover material, duration and timing of charges, drilling characteristics, geologic considerations, handling and storage, and blasting material used.

Depending upon the explosive charge used, blasting can release a wide variety of soluble chemicals, such as nitrates, nitrites, perchlorates, and semi-volatile organic compounds, to name a few. These products can enter the local surface waters or groundwater and therefore contribute to water pollution.

Other potential complications with blasting include the incomplete combustion of explosive material, improper selection of explosive product, the "leaking" of chemical charges into surrounding cracks and fractures prior to detonation, increased turbidity within wells and karst conduits, geochemical reactions caused by the exposure of fresh geologic surfaces, airborne gas and particles, and improper transportation and storage. These all can be minimized by a properly written and implemented blasting plan.

Q. Can trenching negatively affect water wells and springs?

A. Trenching is a much more common form of excavation for pipeline construction than blasting. In most cases, the rock can be excavated using trenching equipment (i.e., rock saws) and hoe rams, which exert much less force and do not generally have enough power to collapse the strong regional bedrock. In addition, the trench can be inspected after rock removal to check if the more obvious karst conduits have been intercepted or disturbed. If intersected conduits are observed, they should be mitigated. It should be noted that just because a trench did not intersect any existing conduits, does not mean that the karst's groundwater flow characteristics have not been altered.

While trenching has the potential to create less impact to natural water flow through karst systems than blasting, trenching still can create karst impacts and these are not easily predicted. Ground disturbance of any kind in karst terrain can lead to complications, and trenching involves a lot of ground disturbance.

In addition, an excavated trench can lead to either diverted or ponded water, which can modify natural pathways, and can create ponding of water that could lead to accelerated sinkhole development. Professional karst assessment, proper construction techniques, the use of best management practices, and follow-up monitoring can greatly lessen the chance of negative effects from trenching, but it cannot be eliminated.

Q. Won't the pipeline trench, even if backfilled, become an artificial "conduit," diverting water away from its previous natural flow path through the subsurface?

A. Design steps should be taken to minimize this from happening. On slopes, water breaks should be installed on the surface to direct water away from flowing down the pipeline alignment. Within the trench itself, clay dams and collars are often installed and are intended to prevent the pipe's outer edge from acting like a continuous conduit for water flow. The dams and collars interrupt the water flow and promote the percolation of water vertically into the subsurface; however, the ponding of water behind the dams and collars can create unintended consequences by interrupting natural flow-paths and the acceleration of sinkhole development in karst areas.

Q. Can the on-going operation of natural gas transmission pipelines on karst affect water quality?

A. The presence or absence of karst does not add or diminish the likelihood of negative impacts to waters as a result of natural gas transmission pipelines. However, should a problem occur, say a leaking contaminant, then this contaminant, may travel further and quicker within a karst environment compared with many non-karst systems. This may create situations in which the impact is more widespread and may affect the karst environment and cause greater project management complications.

While pipelines are generally considered the safest means of transporting natural gas, problems can and do occur. One problem that can occur is leaks. Karst is especially susceptible to problems associated with leaking liquid chemicals, so there is a fundamental difference between pipelines carrying liquid products from those carrying gas products. Since natural gas (methane) is lighter than air, many problems associated with pipelines leaking liquid products are significantly reduced. However, natural gas pipelines are typically under a lot of pressure, and as such, minor or incipient leaks are common and therefore, may or may not be detected, reported, or mitigated.

If a natural gas pipeline leaks within a ventilated location, the methane is dissipated to the air and will likely not have any direct impact to karst, unless there is a cave entrance located immediately upslope of the leak. Many large caves "breathe" by either expelling air or drawing in air due to pressure and temperature differences between the cave's atmosphere and the localized surface atmosphere. Therefore, there may be rare instances in which methane leaking into the air immediately downhill from a cave is drawn into the cave environment. While this occurrence is likely very rare, should it actually occur, it could result in a potentially hazardous situation with the possibility of explosion. Every effort should be made to mitigate against the possibility of natural gas leaking into enclosed karst cavities or other closed spaces.

If the leak should occur from a section of the pipeline in contact with groundwater, then the water may pick up and transport the methane either in the dissolved state or as entrapped gas. Eventually within the water's flow-path, the entrapped gas or a portion of the dissolved methane will be vented to the air. Perhaps the biggest hazard in this situation is dependent upon where this venting occurs. If the venting occurs within a cave passage that has poor air circulation, then the methane concentration can build up to levels that could cause flammable and explosion hazards if the gas should come into contact with an ignition source. This risk may be reduced by:

- proper engineering and or design within higher-risk or sensitive areas (such as caves or karst);
- pipeline inspections (to detect leaks) and prompt reporting of suspected leaks;
- reducing the occurrence of pipelines being in contact with groundwater;
- an understanding of groundwater flow in the pipeline's vicinity;
- identifying and inventorying potential locations and situations in which gas may accumulate in down-gradient locations of the pipeline, and potential ignition sources;
- ensuring proper ventilation of managed facilities in areas of higher risk; and
- notifying the Virginia Department of Natural Heritage of any known leaks or spills within karst environments.

Q. Besides leaking natural gas, are there other potential water quality challenges from natural gas transmission pipelines located in karst terrain?

A. While pipeline construction poses a wide variety of potential threats to karst waters, few if any of these are specific to karst. In addition, most of these potential impacts are not even specific to pipeline construction, but are also valid for most any construction projects ranging from the construction of schools, and roads, to individual homes. For the discussion of karst impacts, it is instructive to categorize them according to risk, and threat. Risk refers to the likelihood of a situation happening, while threat refers to the harm that would result if that situation actually occurs. For instance, the risk of nuclear plant melt-down is extremely low, since it would have an extremely low probability of occurring. However, the threat of such a situation would be extremely high, since the damage from a nuclear catastrophe is extreme. Applying these categories to pipeline construction in karst areas, the risk to groundwater from pipeline construction is the same for karst and non-karst settings; however, since the possibility to quickly transport spills and contaminants to a higher degree in karst than in non-karst settings, the threat in karst landscapes is higher.

Constructing any structure creates a lot of short-term localized ground disturbance. If not properly managed, these disturbances can affect surrounding environments. This is true for karst and non-karst settings. This is the reason that Virginia has strict erosion and sediment-control regulations.

Besides the quantity of ground disturbance, new construction often requires equipment use, which therefore introduces gasoline, diesel, antifreeze, and oil into the project site. In addition, construction and repair of pipelines may include the use of on-site solvents, epoxy and other sealants used to waterproof pipe joints.

Once the pipeline is constructed, on-site equipment will occasionally be needed to perform inspections, for repair and maintenance, to conduct occasional replacements, and to perform routine vegetation management. Part of vegetation management may include the spraying of herbicides. Herbicide and other chemical usage in karst settings has a greater potential to affect off-site locations through unintended transport through solution conduits.

Q. Can a preliminary karst survey help reduce potential risks to the pipeline's integrity and safeguard water supplies, water quality, and the subsurface environment?

A. Yes, it can. Preliminary karst surveys should take into account a number of factors: the known locations of caves, sinkholes and springs, the type of carbonate rock and the structural geology of the area through which the pipeline is planned; documentation of bedrock deformation, including faults, folds and other structural features; and mapped water flow patterns that have been determined by existing studies of the local and regional hydrology. This survey should be augmented by careful karst mapping to obtain an idea of where there may be a dense concentration of karst features that may indicate significant karst development that would have the potential to influence planned facilities and construction activities. Changes in pipeline routing should be based on the findings of the survey and subsequent analysis. However it is important to emphasize that the preliminary survey is only the first step. It must be followed up with continuous observation and monitoring during the construction phase of the project. A comprehensive and robust inspection and evaluation program is also recommended throughout the life of the pipeline's operation.

Q. How effective are natural gas pipeline inspections?

A. Inspections are a critical component of a pipeline's safety management program. However, it is not enough simply to state or require monitoring, since there is a multitude of monitoring techniques that have been employed and each has their own advantages and disadvantages, as well as specific applicability. A few examples of natural gas pipeline monitoring techniques include the following: gas sampling, acoustic sensors, broad-band absorption, Lidar surveys, backscatter imaging, thermal imaging, soil monitoring, and dynamic monitoring. A good paper summarizing the advantages and disadvantages of many of these techniques is "Technology status report on natural gas leak detection in pipelines", by Yudaya Sivathanu; prepared for the U.S. Department of Energy, National Energy Technology Laboratory, Morgantown, WV. The web address of this document is listed in the "Where Can I Learn More about Karst" section.

Q. Where can I learn more about karst?

A. There are many excellent references on karst and related matters. The following are a few examples:

<u>Karst-Specific References Regarding Sinkholes and "Living on Karst":</u>

A Reference Guide for Landowners in Limestone Regions (the Virginia Speleological Survey)
    http://www.virginiacaves.org/lok/page1.htm
Commonwealth of Virginia Hazard Mitigation Plan (Section 3.14 deals with Karst Topography)
    http://www.vaemergency.gov/em-community/recovery/haz-mit-plans
Living on Karst (Cave Conservancy of the Virginias)
    http://www.caveconservancyofvirginia.org/livingonkarst/livingonkarst.htm
Living with Karst (American Geosciences Institute)
    http://www.americangeosciences.org/sites/default/files/karst.pdf
Sinkholes- The USGS Water Science School
    http://water.usgs.gov/edu/sinkholes.html
Sinkholes- Virginia Division of Geology and Mineral Resources
    http:www.dmme.virginia.gov/DGMR/pdf/sinkholes.pdf
Sinkholes and Karst Terrain
    http://www.dmme.virginia.gov/DGMR/sinkholes.shtml
Sinkhole Formation Assoc. with Installation of a High-pressure Natural Gas Pipeline, West-central FL
    http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1116&context=sinkhole_2013

General Information on Karst:

Cave Conservancy of the Virginias
    http://www.caveconservancyofvirginia.org
Karst Water Institute
    http://karstwaters.org
National Cave and Karst Research Institute
    http://www.nckri.org
National Speleological Society
    http://caves.org
Virginia Cave Board
    http://www.dcr.virginia.gov/natural_heritage/cavehome.shtml
Virginia Natural Heritage Karst Program- Virginia Department of Conservation and Recreation
    http://www.dcr.virginia.gov/natural_heritage/karsthome.shtml
Virginia Speleological Survey
    http://virginiacaves.org

Pipeline Safety Information:

Pipeline Safety Trust
    http://pstrust.org
Technology status report- natural gas Leak detection in pipelines
    http://www.netl.doe.gov/File%20Library/Research/Oil-Gas/Natural%20Gas/scanner_technology_0104.pdf
U.S. Department of Transportation Pipeline and Hazardous Material Safety Administration
    http://www.phmsa.dot.gov

ATTACHMENT 1

Migration of Female Indiana Bats *(Myotis sodalis*) from Winter Hibernacula to Summer Maternity Roosts

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PROJECT SUMMARY:

In April 2005 thirteen female Indiana bats *(Myotis sodalis*) were fitted with radio transmitters while still in their winter hibernacula in Bath County VA. They were released and followed closely with both ground and aerial telemetry to track them to their unknown summer maternity roost sites. Radio tracking was conducted on a daily basis from the day of their release until their signal disappeared. All bats but one could be followed for up to three weeks and their flight paths were recorded mostly traveling north or south. Five roost trees were found along natural corridors of creeks and ridges and one was still occupied at the end of the study. Several of the bats were observed to travel large distances in a short amount of time. Future research will be needed in order to determine more specifically how far the bats migrate to form maternity colonies.

Methods

On April 11 eight female Indiana bats were pulled from Clarks Cave in Bath County (Figure 1) and fitted with individual radio transmitters (frequency 151.xxx, Holohil Systems, Ltd., Carp, Ontario, Canada). All bats remained in the cave until dusk, at which time they were checked to make sure of proper transmitter function and released one at a time. This procedure was repeated on April 14 at Star Chapel Cave in Bath County with five additional female Indiana bats. The thirteen bats were tracked from their release date until their transmitter battery died or their signal was lost. Tracking was performed by both ground and aerial crews. Ground crews operated daily from local high points and covered several counties including Bath, Highland, Augusta, Allegheny, Rockbridge and Botetourt counties in Virginia and Pocahontas and Pendleton counties in West Virginia. Two separate aerial crews operated both day and night on intermittent days and covered an area similar to the ground crew. They also searched over additional regions south of Covington VA and further west in West Virginia. The aerial crews flew 15 days for a total of 64.1 flight hours. The original search area was 50 km north-south and 25 km east-west surrounding the winter caves. This was later expanded by at least 15 km in all directions, including 80 km northwest towards Elkins, West Virginia.

A daily log was kept for each bat, detailing where, and at what time, its signal was heard. Direct GPS location of the bat was recorded if possible, if not, a bearing and location of observer was recorded. Locations obtained from the airplane at night were used to pinpoint search areas for the following day. If a steady signal was heard from an individual during the day an attempt was made to walk up to the roost tree. If a roost tree

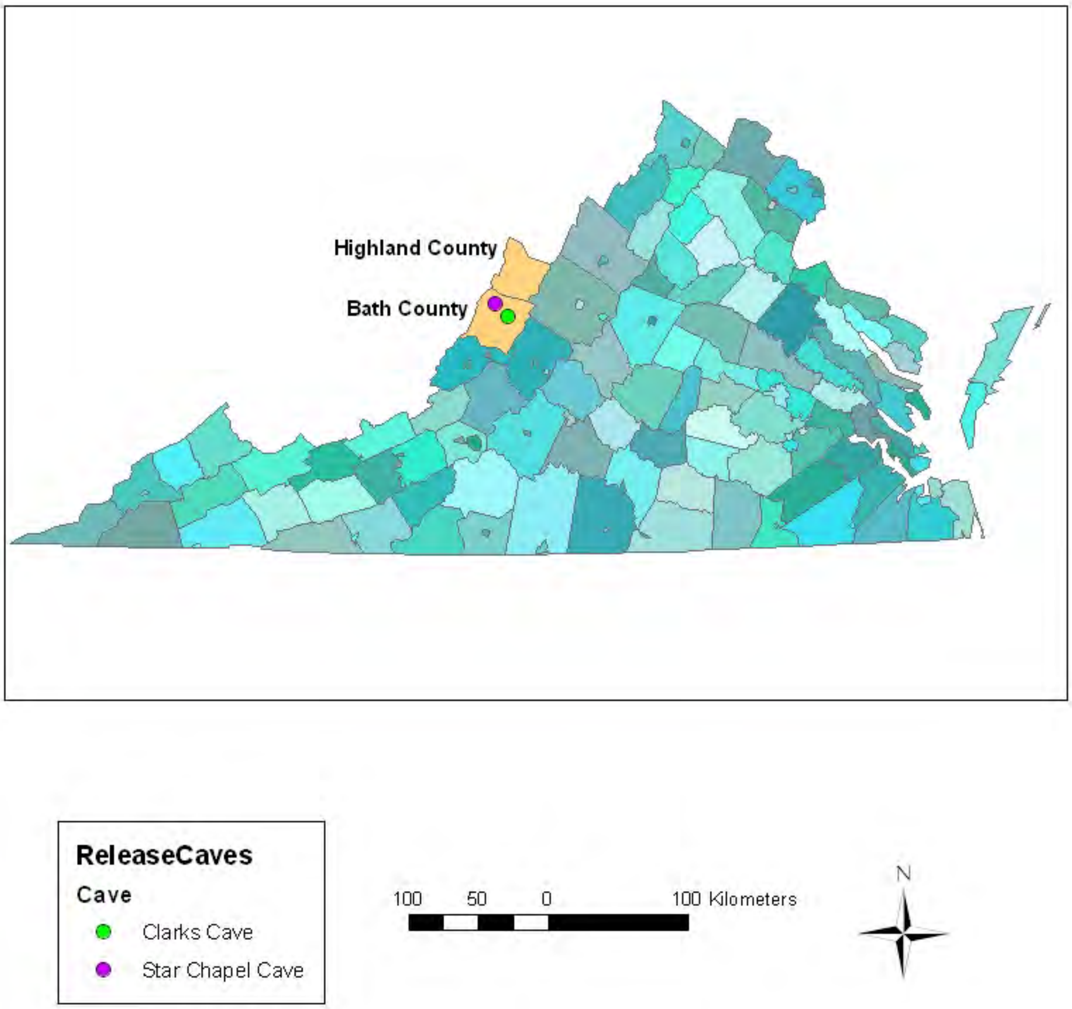

Figure 1. Highland and Bath Counties in Virginia with locations of winter caves.

was located, we took measurements including location, height, dbh, species (if able to be determined) and habitat. At one roost tree site we set up mist nets on three nights in June and July to survey what bat species were present. The mist nets were placed along the riparian corridor next to the roost tree, with two nets used the first night and three nets used the second and third nights in a total of 14.1 net hours. For each bat caught we recorded species, sex, age, reproductive status and weight.

The minimum and maximum temperatures at the nearest public airport (Hot Springs VA) were recorded daily.

Results

We recorded flight activity for twelve of the thirteen bats (See Appendix). One bat disappeared immediately following release and could not be located despite extensive searching. The tracking period for each bat ranged from 2 to 23 days. Based on daily locations and triangulation, we constructed flight paths for all bats, for those released April 11 (Figure 2) or April 14 (Figure 3). We calculated the farthest distance that each bat traveled from its winter cave as well as the longest distance it traveled between two subsequent tracked locations (Table 1). The number of locations obtained for each bat ranged from one to nine. The bats traveled from 4 to 80 km from their winter cave and tended to travel long distances when they moved. The direction of travel in general followed the direction of the ridges in the area, which run northeast-southwest.

Table 1. Extent of range and direction of movement for each bat.

Bat	# of Locations	Farthest Distance (km) from Cave	Farthest Distance (km) Traveled (# Days)	Direction Since Previous Location
679	2	4	4(1)	S, N
702	2	20	20(1)	NE, NW
719	1	7	7(0.5)	S
740	6	25	26(3)	NE, NW, NE, E, N, NE
761	3	80	76(4)	SW, S, NE
777	5	39	39(3)	N, SW, SE, N, W
801	0	0	0	X
821	6	23	29 (0.5)	SW, SE, N, W, W, N
839	9	32	32(2)	N, W, SE, NE, SE, N, SE, W
858	4	25	12(3)	SE, S, S, SE
877	9	21	18(0.5)	N, W, SE, SE, SE, NW, SE, N, NW
897	1	11	11(3)	W
915	4	57	34(2)	NE, E, E

One bat (821) had a transmitter that worked for three days but then began to emit a pulse twice the normal rate. Battery failure was an unlikely explanation because of the short time the collar had been active and because there had been no change in the signal prior to the double pulse. The signal was tracked to a willow tree along a stream in Highland County, but never moved from the tree. The signal was checked at various hours of day and night without exhibiting any change.

Daily minimum and maximum temperatures in Hot Springs were recorded from April 1 through May 3 (Figure 4) and compared to flight activity.

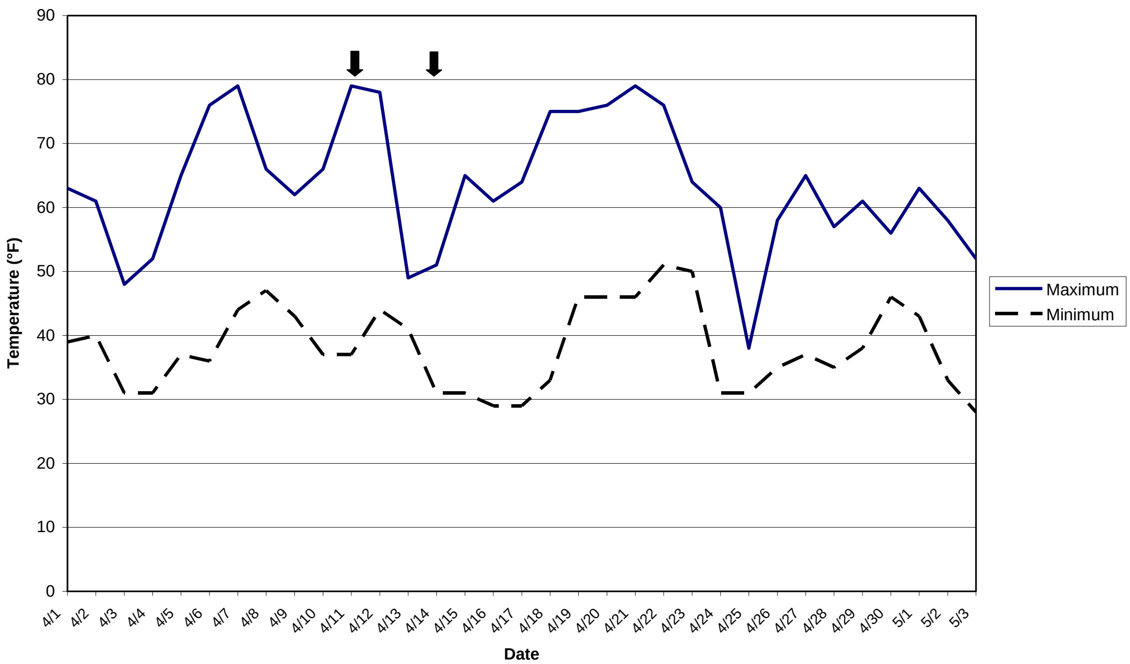

Figure 4. Minimum and maximum temperatures for Hot Springs, Virginia, from April 1 – May 3, 2005. Arrows indicate dates the bats were released.

Five of the bats (740, 777, 839, 877, 915) settled in roost trees and one remained in the same roost tree at the end of the study. The other four bats continued movements after spending 1-3 days in a single roost. We took measurements and habitat information for each tree (Table 2). These trees were checked periodically to determine if and when the occupant abandoned the tree.

Table 2. Roost trees used by bats 839, 877, 91, 740 and 777.

Tree	Bat	Easting	Northing	DBH (cm)	Height (m)	Aspect	Snag?	Species	Habitat
1	839	38° 19’ .511	79° 36’ .187	124	18	S	Y	Oak	Riparian
2	877	38° 05’ .464	79° 41’ .499	100	10	N	Y	Oak	Riparian
3	915	38° 18’ .595	79° 23’ .509	34	6	W	Y	Maple/ Hickory	Oak Forest
4	740	38° 19’ .583	79° 35’ .817	300			Y		Oak Forest
5	777	38° 20'.349	79° 36'.041	43	15	N	Y	Oak	Oak Forest

Around each roost tree we placed a 500 m, 1 km and 2 km buffer and calculated the percentage of four habitat types within each buffer (Figure 5). Three roost trees were in such close proximity that the average habitat composition was only calculated on the most centrally located tree. The sample size was small, but there were no obvious differences in habitat around each roost tree or between trees and the surrounding landscape. At the smallest scale there was additional crop land around the roost trees (crops in this coverage refers to pasture), but the variance around this value was high, again probably due to the small sample size. This coverage did not include other landscape variables (i.e. slope, aspect, and elevation) but forest type at the landscape level does not appear to influence roost selection.

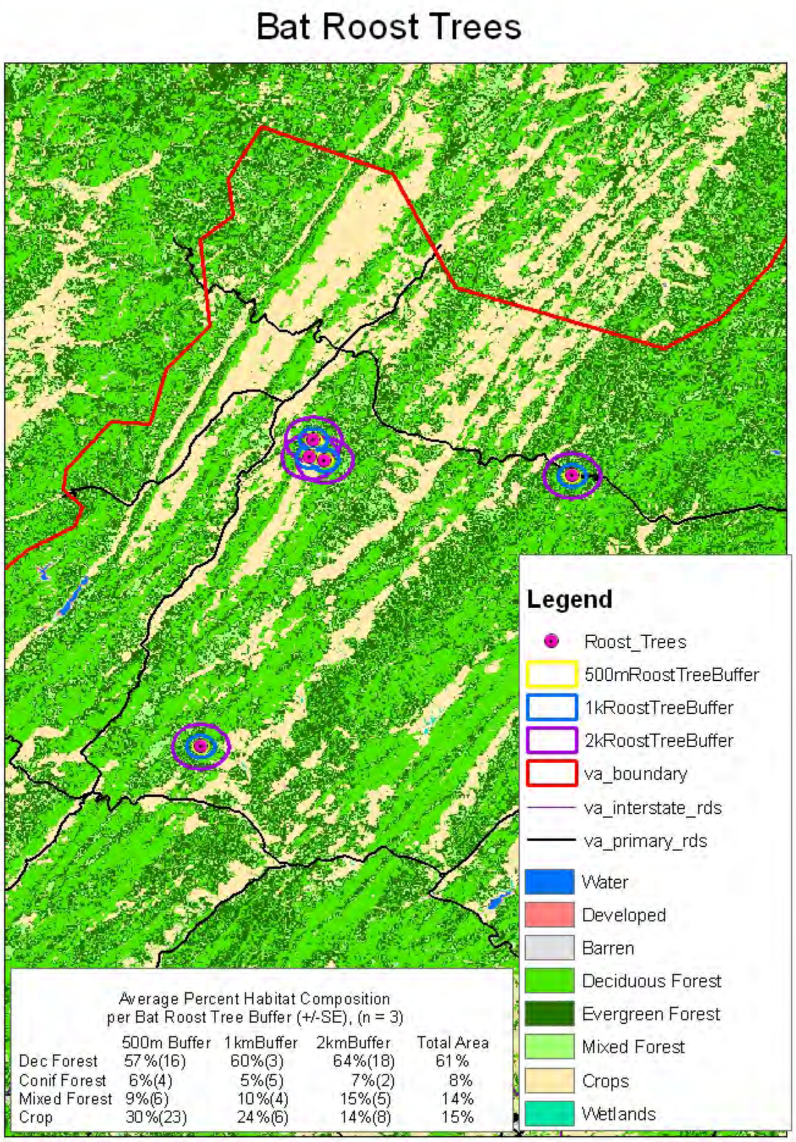

Figure 5. Habitat composition of 500 m, 1 km and 2 km buffers around five roost trees.

The tracking period for seven bats was cut short because their signals were crossed with other wildlife studies once they left the immediate vicinity of the winter caves. Signals from bats 702, 740, 777 and 839 were obstructed by radio-collared turkeys with the same frequencies in the Big Valley/Signal Knob region. Signals from bats 801, 858 and 897 were obstructed by radio-collared deer with the same frequencies in Kumbrabow State Forest, southwest of Elkins, West Virginia. These signals were picked up when the aerial crew expanded its search range into West Virginia in an attempt to locate missing bats.

We tracked one bat (877) as it ranged north 20 km, changed direction and flew 38 km south and then returned within 10 kilometers of its winter cave to settle in a roost tree. The bat was still in the roost tree when its signal stopped, presumably due to battery failure. Mist-nets were set up on three nights along the riparian corridor where the roost tree was located (Table 3). The net system spanned the full width of the stream along which we presumed the bats would fly. We arranged two nets so one net was above the other the first night and three nets high the other two nights. Despite these efforts, the height of the nets could not reach to the height of the canopy. Six bats in total were caught, all non-reproductive adults. We caught one male eastern pipistrelle (*Pipistrellus subflavus*) the first night, two northern myotis (*Myotis septentrionalis*) the second night and three northern myotis the third night. In addition we visually observed many bats of undetermined species flying around the nets.

Table 3. Mist-netting results along the riparian corridor near the roost tree of bat 877 in Bath County.

Date	# of Nets	Time Open	Time Closed	Net Hours	Species	Sex	Age	Repro	Weight (g)
15-Jun	2	2030	2200	3.0	Pipistrellus subflavus	M	Adult	Non	6.0
22-Jun	3	2050	2230	5.1	Myotis septentrionalis	F	Adult	Non	11.3
					M. septentrionalis	M	Adult	Non	6.8
18-Jul	3	2030	2230	6.0	M. septentrionalis	F	Adult	Non	8.3
					M. septentrionalis	F	Adult	Non	8.1
					M. septentrionalis	F	Adult	Non	7.4

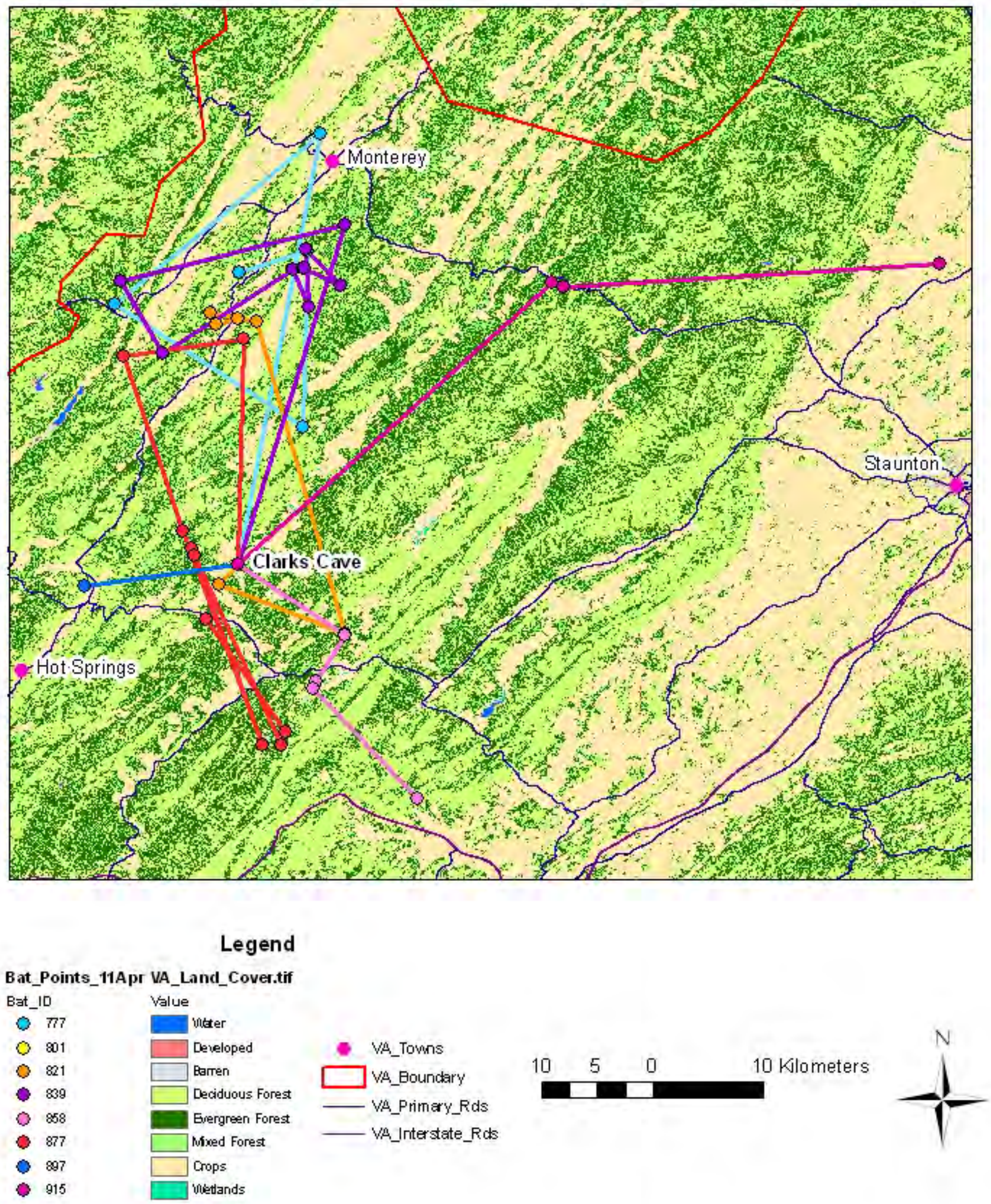

Figure 2. Flight paths for eight bats released April 11 from Clarks Cave, Bath County, Virginia.

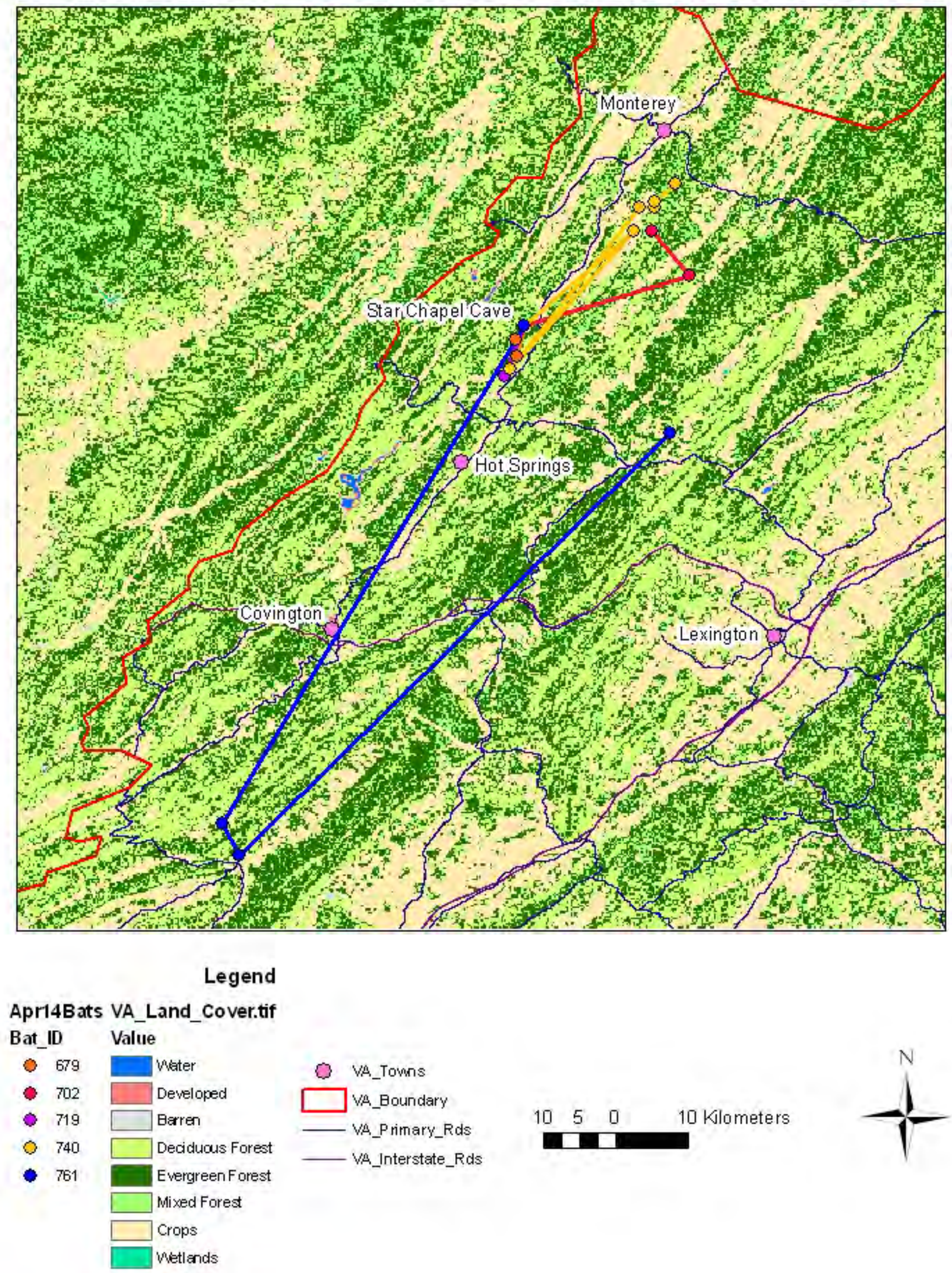

Figure 3. Flight paths for five bats released April 14 from Star Chapel Cave, Bath County, Virginia.

Conclusions

The major directions of travel were generally north and south, with only one bat flying east (i.e. into the Shenandoah Valley) and none flying west (i.e. over the higher mountain ridges into West Virginia) following release from the winter caves. The bats were located mostly in line with ridges, suggesting that they use these corridors as flyways to follow for easy transportation routes. When they do decide to move the bats can cover large distances in a short amount of time. For example, bat 761 moved 80 km south in four days and bat 777 moved 40 km north in two days. The small size of the transmitters necessitated “direct line of sight” to locate the animals, so that ground crews were only effective when near the animal or above the animal on a ridge. An aerial crew was a necessity in order to keep track of all individuals when they foraged at night and as the bats dispersed following release.

The five roost trees we found had similar characteristics. All were large snags and three were along the forest edge (creek or road) where they received significant sunlight during April. All roost sites were within oak-dominated forest types. The four bats that ultimately left their roost trees only stayed in them a few days before moving elsewhere. The overall movement pattern suggests flying to a nearby roost tree, resting for a few days and then flying a long distance before resting again.

Mist-netting was unsuccessful in capturing Indiana bats at the single long-term roost; however, this does not exclude the possibility that there were Indiana bats in the area. The riparian corridor along which the nets were set was wide, high and surrounded by open forest. We were ineffective in closing off the flight corridor due to the high canopy. It was easy for bats to avoid the nets while flying through the area. Many bats were observed visually on all three nights around the nets and flying along the creek corridor. From this it is difficult to conclude whether or not Indiana bats were present.

An unexpected complication was the weather. The week of April 4 was unusually warm in the area (as recorded at Hot Springs VA) for early spring (Figure 3). The daily temperature reached a maximum of 79°F on two days that week with only two days not exceeding 65°F. There was suspicion that many of the bats would leave the cave early before we would be able to catch them. However, immediately after the release from both caves there were several nights of unusually cold weather (Figure 3). The nightly temperature dropped to freezing immediately following the second release and on only two nights of the remaining tracking period stayed above 50°F. Previous studies have suggested that foraging behavior at night is curtailed below 50°F and completely stops below 41°F (Anthony et al. 1981, Taylor and Savva 1990, Wilkinson and Barclay 1997). The inability of bats to travel directly to maternity sites during the tracking period may be due to the low temperatures which curtailed movements.

Future recommendations

It was a frustrating activity to invest so much time, money, and manpower without identifying maternity sites for this species. The use of the planes was essential and we had the right aerial support for the project to be successful. The initial success was due to the plane being over the cave site at release. The subsequent loss of many bats occurred due to our inability to fly many nights due to weather and the lack of obvious movement on clear, but cold, nights. We would not recommend an immediate repeat of this exercise. We did learn that none of the bats appear to be moving in unison toward a single maternity roost or forest region. The bats appear to moving individually north and south from the winter caves. It might be more advantageous to mist-net along streams and other natural flyways in May when more consistent activity is evident. Any females netted at that time would be radio-collared and tracked. This would depend on a plane being available on short-notice, which is not the current state. It would be good to verify that bats radio-collared this spring returned to the winter caves this winter, as an indication that the tracking did not reduce survival of individuals. Any attempt to repeat the study should verify overlaps in frequencies, delay release until advance forecast indicate a warm period, and consider increased power over increased length of transmission to increase detection probability.

References

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Taylor RJ, Savva NM. 1990. Annual activity and weight cycles of bats in south-eastern Tasmania. Australian Wildlife Research 17: 181-188.

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APPENDIX

Bat 679

On April 14 the bat was captured in Star Chapel Cave during the day, fitted with a transmitter and released at dusk. It was heard the next two days 6 km south of the cave in the Rte. 220 valley. On April 17 the signal was lost and not found again despite search efforts.

DATE	TIME	EVENT	COORDINATES	
14-Apr	1515	transmitter attached		
	1930	removed from cave		
	2015	released from cave top		
15-Apr	1100	located by plane	38° 07' .826	79° 45' .836
	2200	located by plane	38° 09' .145	79° 45' .865
16-Apr	2200	located by plane		
17-Apr through 19-Apr		SEARCHED, NOT FOUND		
20-Apr through 26-Apr		NOT SEARCHED		

Bat 702

On April 14 the bat was captured in Star Chapel Cave during the day, fitted with a transmitter and released at dusk. The following day it was 19 km east in the Cowpasture River valley. By the afternoon of April 18 it was heard 9 km northwest near Sounding Knob. Subsequent tracking was most likely of a radio-collared turkey, as all locations were heard within Big Valley or near Sounding Knob and it was impossible to track the signal to a single location during the day.

DATE	TIME	EVENT	COORDINATES	
14-Apr	1515	transmitter attached		
	1930	removed from cave		
	2015	released from cave top		
15-Apr	1100	located by plane	38° 13' .903	79° 32' .879
16-Apr	2200	located by plane		
17-Apr	2200	located by plane		
18-Apr	1500	heard from Sounding Knob (ground)		
	2000	located by plane	38° 17' .203	79° 35' .728

		SIGNAL IS PROBABLY TURKEY		
19-Apr	1200	heard from Sounding Knob (ground)		
20-Apr	2200	located by plane	38° 22' .087	79° 36' .875
21-Apr	1200	heard from Sounding Knob (ground)		
22-Apr	2200	located by plane	38° 19' .361	79° 36' .444
23-Apr	1200	heard from Sounding Knob (ground)		
24-Apr	1200	heard in Big Valley (ground)		
25-Apr	all day	searched for in Big Valley (ground)		
26-Apr	all day	searched for in Big Valley (ground)		
27-Apr	2100	located by plane	38° 19' .404	79° 35' .668
28-Apr	1200	heard in Big Valley (ground)		
29-Apr through 2-May		NOT SEARCHED		
3-May	1200	heard in Big Valley (ground)		

Bat 719

On April 14 the bat was captured in Star Chapel Cave during the day, fitted with a transmitter and released at dusk. It was 7 km south of Warm Springs later that night. It was located again the following night but after April 16 the signal was not heard again despite search efforts.

DATE	TIME	EVENT	COORDINATES	
14-Apr	1515	transmitter attached		
	1930	removed from cave		
	2015	released from cave top		
	2200	located by plane	38° 06' .421	79° 46' .757
15-Apr	2200	located by plane		
16-Apr through 19-Apr		SEARCHED, NOT FOUND		
20-Apr through 26-Apr		NOT SEARCHED		

Bat 740

On April 14 the bat was captured in Star Chapel Cave during the day, fitted with a transmitter and released at dusk. The next night it moved 7 km south towards Warm Springs into Muddy Run. All tracking for the next four days placed the signal in Big Valley or around Sounding Knob. On April 20 a roost tree was found during the day 30 km northeast on the east ridge encompassing Big Valley and that night it was in the same vicinity. Subsequent tracking was most likely of a radio-collared turkey, as all locations were heard within Big Valley or near Sounding Knob and it was impossible to track the signal to a single location during the day.

DATE	TIME	EVENT	COORDINATES	
14-Apr	1515	transmitter attached		
	1930	removed from cave		
	2015	released from cave top		
15-Apr	1100	located by plane	38° 17' .252	79° 37' .058
	2200	located by plane	38° 06' .950	79° 46' .294
16-Apr	2200	located by plane		
17-Apr	2200	located by plane		
18-Apr	2000	located by plane	38° 18' .952	79° 36' .672
19-Apr	1200	heard from Sounding Knob (ground)		
	2000	located by plane	38° 18' .921	79° 35' .499
20-Apr	1300	found in roost tree	38° 19' 35"	79° 35' 49"
	2200	located by plane	38° 20' .709	79° 33' .961
21-Apr	1200	heard from Sounding Knob (ground)		
22-Apr		NOT SEARCHED		
23-Apr		NOT SEARCHED		
		SIGNAL IS PROBABLY TURKEY		
24-Apr	1400	heard in Big Valley (ground)		
25-Apr	1600	heard in Big Valley (ground)		
26-Apr	1200	heard in Big Valley (ground)		
27-Apr	2100	located by plane	38° 19' .956	79° 36' .261
28-Apr	all day	searched for in Big Valley (ground)		
29-Apr through		NOT SEARCHED		

2-May		
3-May	1200	heard in Big Valley (ground)

Bat 761

On April 14 the bat was captured in Star Chapel Cave during the day, fitted with a transmitter and released at dusk. It was not heard again for three days until it was located the night of April 18 25 km southwest of Covington on Bald Mountain, or almost 80 km from the cave. The next night it had moved 8 km south toward New Castle but the following night it was found 22 km from the cave in Mill Creek, a change of over 80 km. After this the signal was lost and not found again.

DATE	TIME	EVENT	COORDINATES	
14-Apr	1515	transmitter attached		
	1930	removed from cave		
	2015	released from cave top		
15-Apr through 17-Apr		SEARCHED, NOT FOUND		
18-Apr	2000	located by plane	37° 33' .094	80° 07' .847
19-Apr	2000	located by plane	37° 30' .721	80° 06' .601
20-Apr	2200	located by plane	38° 02' .102	79° 34' .379
21-Apr		SEARCHED, NOT FOUND		
22-Apr through 3-May		NOT SEARCHED		

Bat 777

On April 11 the bat was captured in Clarks Cave during the day, fitted with a transmitter and released at dusk. Two days later it was heard from the top of Monterey Mountain in Highland County in the direction of Big Valley. The following afternoon it was located by aerial telemetry on top of Monterey Mountain 40 km north of Clarks Cave. That night it moved 26 km south into the Back Creek drainage and the next night it had moved 27 km southeast, closer to Clarks Cave. Two days later (April 17) it was heard in Big Valley south of Sounding Knob and the following day the bat was found in a roost tree below Sounding Knob. That night it was heard by aerial telemetry in the vicinity of the roost tree. Subsequent tracking was most likely of a radio-collared turkey, as all locations were heard within Big Valley and it was impossible to track the signal to a single location during the day.

DATE	TIME	EVENT	COORDINATES	
11-Apr	1200	transmitter attached		
	1900	removed from cave		
	2100	released from cave top		
	2200	heard in vicinity by plane		
12-Apr		SEARCHED, NOT FOUND		
13-Apr	2205	heard from Monterey Mountain		
14-Apr	1500	located by plane	38°26'.072	79° 35'.365
	2200	located by plane	38° 17' .790	79° 45' .410
15-Apr	2200	located by plane	38° 11'.776	79° 36'.209
16-Apr		NOT SEARCHED		
17-Apr	1900	detected in Sounding Knob (ground)		
18-Apr	1630	found in roost tree	38° 20'.349	79° 36'.041
	2000	located by plane	38° 19'.292	79° 39'.338
		SIGNAL IS PROBABLY TURKEY		
19-Apr	1200	detected in Sounding Knob (ground)		
20-Apr	1400	detected in Sounding Knob (ground)		
21-Apr	1200	detected in Sounding Knob (ground)		
22-Apr		NOT SEARCHED		
23-Apr	1700	not in roost tree		
24-Apr	1400	detected in Sounding Knob (ground)		
25-Apr	1200	detected in Sounding Knob (ground)		
26-Apr	1200	detected off Rte. 220 (ground)		
27-Apr	2100	located by plane		
28-Apr		detected off Rte. 220 (ground)		
29-Apr		NOT SEARCHED		
30-Apr		NOT SEARCHED		
1-May		detected off Rte. 220 (ground)		

2-May	NOT SEARCHED
3-May	detected off Rte. 220 (aerial)
4-May	detected off Rte. 220 (ground)

Bat 801

On April 11 the bat was captured in Clarks Cave during the day, fitted with a transmitter and released at dusk. The signal was not heard again after the release despite search efforts until May 3, where it was heard in Kumbrabow State Forest, WV and later identified as a deer.

DATE	TIME	EVENT	COORDINATES
11-Apr	1200	transmitter attached	
	1900	removed from cave	
	2100	released from cave top	
	2200	heard in vicinity by plane	
12-Apr through 19-Apr		SEARCHED, NOT FOUND	
20-Apr through 2-May		NOT SEARCHED	
3-May		signal heard in Kumbrabow State Forest, WV (ground)	
		SIGNAL IS DEER	

Bat 821

On April 11 the bat was captured in Clarks Cave during the day, fitted with a transmitter and released at dusk. Two days later it was 2 km southwest of the cave. The next afternoon it was 10 km southeast near Mill Creek. Several hours later that night it had moved 31 km north into Big Valley below Sounding Knob, although it is possible this signal was coming from a collared turkey. The next day (April 15) the signal was heard by aerial telemetry in the vicinity of Big Valley but with a pulse twice as fast as normal, suggesting a mortality or collar malfunction. It was heard two days later in a tree located at the junction of Rte. 220 and Rd. 606 in Highland County just outside Big Valley. The signal remained in the tree the remainder of the tracking period and did not move during the day or night.

DATE	TIME	EVENT	COORDINATES
11-Apr	1200	transmitter attached	
	1900	removed from cave	
	2100	released from cave top	
	2200	heard in vicinity by plane	
12-Apr		SEARCHED, NOT FOUND	

13-Apr	2230	located by plane	38° 04'.056	79° 40'.332
14-Apr	1500	located by plane	38° 01'.670	79° 34'.205
	2200	located by plane	38° 16'.945	79° 38'.463
15-Apr	1100	located by plane (signal pulse double time)	38° 17'.361	79° 40'.710
		POSSIBLE COLLAR MALFUNCTION		
	2200	located by plane	38° 16'.766	79° 40'.439
16-Apr	2200	located by plane		
17-Apr	1700	signal tracked to possible tree off Rte. 220 (ground)		
18-Apr	1600	found in roost tree	38° 17'.067	79° 39'.387
19-Apr	1400	found in same roost tree		
	2100	found in same roost tree		
20-Apr	1600	found in same roost tree		
	2000	found in same roost tree		
21-Apr	1600	found in same roost tree		
22-Apr	1600	found in same roost tree		
23-Apr	1600	found in same roost tree		
24-Apr	1600	found in same roost tree		
25-Apr	1600	found in same roost tree		
26-Apr	1600	found in same roost tree		
27-Apr through 2-May		NOT SEARCHED		
3-May	1500	found in same roost tree		
	2200	found in same roost tree		

Bat 839

On April 11 the bat was captured in Clarks Cave during the day, fitted with a transmitter and released at dusk. The following day it was triangulated 30 km north on the ridge north of Sounding Knob, the same region it was also heard the next night. On April 14 it was heard during the day 16 km southwest of

Sounding Knob in Back Creek. That night it had moved another 5 km south onto Back Creek Mountain. For the next ten days the signal was heard as originating from Big Valley or the ridges surrounding Big Valley. On April 25 the bat was found in a roost tree in Big Valley. Two days later it was heard in a similar location at night, although at this point it is possible that the signal was from a radio-collared turkey. After April 27 the signal was not heard again despite search efforts.

DATE	TIME	EVENT	COORDINATES	
11-Apr	1200	transmitter attached		
	1900	removed from cave		
	2100	released from cave top		
	2200	heard in vicinity by plane		
12-Apr	1430	heard off Rte. 250 (ground)		
	1608	heard from Sounding Knob (ground)		
	1658	heard from Monterey Mountain (ground)		
13-Apr	1500	heard from Sounding Knob (ground)		
	2200	located by plane	38° 21'.670	79° 34'.204
14-Apr	1500	located by plane	38° 18' .870	79° 45'.138
	2200	located by plane	38° 15' .384	79° 43'.080
15-Apr	1100	located by plane	38° 19' .457	79° 36'.747
16-Apr	2000	located by plane		
17-Apr	1900	heard from Sounding Knob (ground)		
18-Apr	1500	heard from Sounding Knob (ground)		
	2000	located by plane	38° 17' .655	79° 35'.912
19-Apr	2000	located by plane	38° 20' .446	79° 36'.078
20-Apr	2200	located by plane	38° 18' .686	79° 34'.379
21-Apr	1200	heard from Sounding Knob (ground)		
22-Apr	1300	located by plane	38° 19' .523	79° 36'.191
23-Apr	1200	heard from Sounding Knob (ground)		
24-Apr	1500	heard in Big Valley (ground)		
25-Apr	1100	located day roost	38° 19' .511	79° 36'.187
26-Apr		NOT SEARCHED		
		SIGNAL IS PROBABLY TURKEY		
27-Apr	2100	located by plane	38° 19' .447	79° 36'.693

28-Apr		SEARCHED, NOT FOUND
29-Apr through 2-May		NOT SEARCHED
3-May		SEARCHED, NOT FOUND

Bat 858

On April 11 the bat was captured in Clarks Cave during the day, fitted with a transmitter and released at dusk. The signal was located two days later 12 km southeast near Mill Creek. The next two nights it was heard in the same region around Mill Creek. By April 18 it had moved 14 km south toward Interstate 64. It was heard again the next night and then not searched for in the next eight days. The signal reappeared on April 28 in Kumbrabow State Forest, WV and later identified as a deer.

DATE	TIME	EVENT	COORDINATES	
11-Apr	1200	transmitter attached		
	1900	removed from cave		
	2100	released from cave top		
	2200	heard in vicinity by plane		
12-Apr		SEARCHED, NOT FOUND		
13-Apr	2230	located by plane	38° 01'.620	79° 34'.204
14-Apr	2200	located by plane	37° 59'.388	79° 35'.613
15-Apr	2200	located by plane	37° 59'.028	79° 35'.748
16-Apr		SEARCHED, NOT FOUND		
17-Apr	2200	located by plane		
18-Apr	2000	located by plane	37° 53'.663	79° 30'.653
19-Apr	2000	located by plane		
20-Apr through 27-Apr		NOT SEARCHED		
28-Apr	1100	signal heard in Kumbrabow State Forest, WV (aerial)	38° 40'.869	80° 03'.649
29-Apr	1200	signal heard in Kumbrabow State Forest, WV (ground)		
30-Apr		NOT SEARCHED		

1-May	1200	signal heard in Kumbrabow State Forest, WV (ground)
2-May	1200	signal heard in Kumbrabow State Forest, WV (ground)
3-May	1200	signal heard in Kumbrabow State Forest, WV (ground)
		SIGNAL IS DEER

Bat 877

On April 11 the bat was captured in Clarks Cave during the day, fitted with a transmitter and released at dusk. The following day it was heard within the vicinity of the cave and the night of April 13 it moved 20 km north into the south end of Big Valley. The next day it moved 5 km west toward Back Creek Mountain and that night it was heard 4 km west of the cave in Dry Run. On April 15 it was 20 km south of its night position, but that night it had again moved back into the same Dry Run region. Two days later a roost tree was found on US Forest Service property in the Dry Run drainage. For the next four days it was found in the same roost tree, and those nights it was south of the roost tree from 5 -15 km away. The roost tree was checked periodically between April 22 and May 2 without a change in the signal. On the nights of May 3 and 4 we sat near the roost tree for two hours at dusk to see if it would emerge from the tree and heard no change. After this the signal was lost presumably to battery failure.

DATE	TIME	EVENT	COORDINATES	
11-Apr	1200	transmitter attached		
	1900	removed from cave		
	2100	released from cave top		
	2200	heard in vicinity by plane		
12-Apr	1500	located by ground telemetry		
13-Apr	1700	located by plane		
	2230	located by plane	38° 16'.062	79° 39'.141
14-Apr	1500	located by plane	38° 15'.248	79° 45'.002
	2200	located by plane	38° 06'.695	79° 42'.104
15-Apr	1100	located by plane	37° 56'.215	79° 38'.229
	2200	located by plane	38° 05'.819	79° 41'.673
16-Apr		NOT SEARCHED		
17-Apr	1100	found in roost tree	38° 05'.464	79° 41'.499
18-Apr	1100	found in same roost tree		
	2000	located by plane	37° 56'.217	79° 37'.258
19-Apr	1240	found in same roost tree		
	2000	located by plane	37° 56'.869	79° 37'.072
20-Apr	1600	found in same roost tree		

	2100	located by plane	38° 02'.420	79° 40'.954
21-Apr	1400	found in same roost tree		
22-Apr		NOT SEARCHED		
23-Apr		NOT SEARCHED		
24-Apr	1700	found in same roost tree		
25-Apr	1000	found in same roost tree		
26-Apr	1000	found in same roost tree		
27-Apr through 2-May		NOT SEARCHED		
3-May	2000	sat on signal 2 hours, no movement		
4-May	1930	sat on signal 2 hours, no movement		

Bat 897

On April 11 the bat was captured in Clarks Cave during the day, fitted with a transmitter and released at dusk. It was not heard again for three days until it was found 10 km west near Warm Springs. The signal was lost again and not heard until April 28 in Kumbrabow State Forest, WV and later identified as a deer.

DATE	TIME	EVENT	COORDINATES	
11-Apr	1200	transmitter attached		
	1900	removed from cave		
	2100	released from cave top		
	2200	heard in vicinity by plane		
12-Apr		SEARCHED, NOT FOUND		
13-Apr		SEARCHED, NOT FOUND		
14-Apr	1500	located by plane	38° 04' .000	79° 46' .900
15-Apr through 19-Apr		SEARCHED, NOT FOUND		
20-Apr through 27-Apr		NOT SEARCHED		
28-Apr	1100	signal heard in Kumbrabow State Forest, WV (aerial)	38° 40' .079	80° 04' .063

29-Apr	1200	signal heard in Kumbrabow State Forest, WV (ground)
30-Apr		NOT SEARCHED
1-May	1200	signal heard in Kumbrabow State Forest, WV (ground)
2-May	1200	signal heard in Kumbrabow State Forest, WV (ground)
3-May	1200	signal heard in Kumbrabow State Forest, WV (ground)
		SIGNAL IS DEER

Bat 915

On April 11 the bat was captured in Clarks Cave during the day, fitted with a transmitter and released at dusk. Two days later it was heard on Shenandoah Mountain in Highland County 34 km away. It was found in the same location the next day and on April 15 a roost tree was found on the west slope of Shenandoah Mountain. The bat remained in the roost tree until the night of April 18, when it disappeared. The signal was not heard again despite search efforts.

DATE	TIME	EVENT	COORDINATES	
11-Apr	1200	transmitter attached		
	1900	removed from cave		
	2100	released from cave top		
	2200	heard in vicinity by plane		
12-Apr		SEARCHED, NOT FOUND		
13-Apr	1500	heard on Shenandoah Mountain (ground)		
	2240	located by plane	38° 18' .841	79° 24' .128
14-Apr	1600	heard on Shenandoah Mountain (ground)		
	2200	located by plane	38° 18' .841	79° 24' .128
15-Apr	1300	found in roost tree	38° 18' .595	79° 23' .509
	2200	located by plane	38° 19' .752	79° 05' .171
16-Apr	1200	found in same roost tree		
17-Apr	1100	found in same roost tree		
18-Apr	1700	found in same roost tree		
	2000	not heard in same roost tree (aerial)		
19-Apr		SEARCHED, NOT FOUND		
20-Apr		NOT SEARCHED		

through 23-Apr	
24-Apr	SEARCHED, NOT FOUND
25-Apr	NOT SEARCHED
26-Apr	NOT SEARCHED