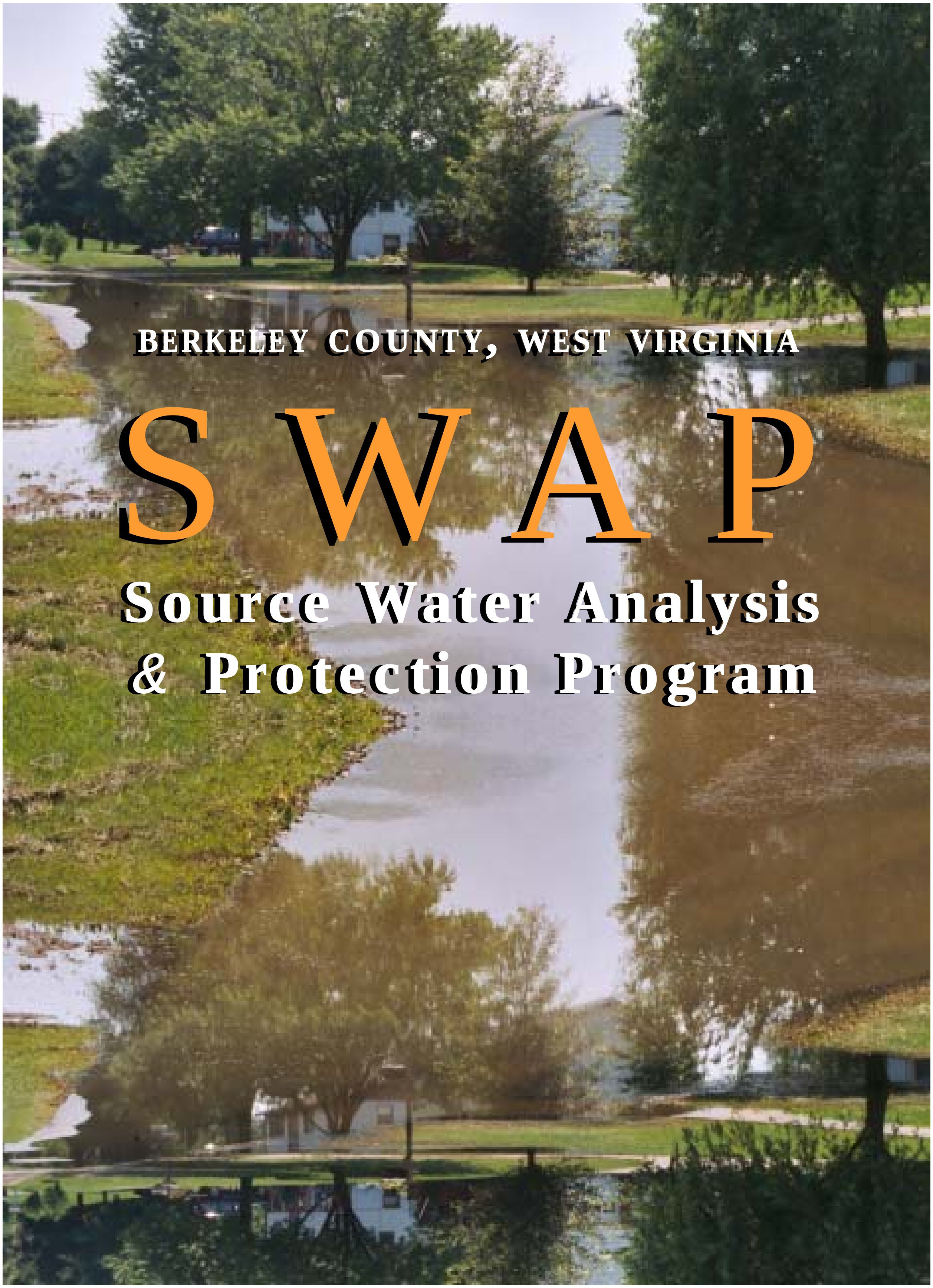

BERKELEY COUNTY, WEST VIRGINIA

SWAP

Source Water Analysis & Protection Program

Berkeley County, West Virginia

Source Water Assessment and Protection (**SWAP**) Project

March 2004

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EXECUTIVE SUMMARY

In recent years in Berkeley County, West Virginia, periods of severe drought have been followed by periods of excessive rainfall, resulting in flooding caused by stormwater runoff. During the same time, the population in Berkeley County has continued to increase dramatically, along with a sustained construction boom. Published reports have revealed well water contamination and septic system failures in certain areas. All of these factors have served to raise concerns about the present and future quality and quantity of drinking water in the county. To address these concerns, a diverse team of involved citizens; local, state, and federal officials; and university scientists began working together in mid-2001 to examine existing and potential threats to Berkeley County's source water and to make recommendations to mitigate those threats. This report is the culmination of the efforts of this Berkeley County Source Water Assessment and Protection (SWAP) Team and describes the vulnerability of the county's drinking water.

In this report, existing and potential water resources are described, along with methodologies for estimating total source water availability. Population projections and water demand forecasts have been prepared for all water user categories and are also included. Potential threats have been broken down into the following categories:

1. Wastewater,
2. Septic and Sewer Systems,
3. Septage (collected material from septic tanks),
4. Sludge (treated residue from wastewater treatment facilities),
5. Stormwater and Impervious Surfaces,
6. Other Pollutant Risks,
7. Agricultural Threats, and

8. Loss of Open Space.

Following each section, specific and attainable recommendations are provided.

The members of the SWAP project are convinced that source water protection should be an ongoing effort. Accordingly, we recommend that the Berkeley County Commission appoint a Water Resources Advisory Council to advise the Commissioners on matters regarding source water protection.

Lastly, SWAP team members believe that by increasing public awareness about source water and encouraging voluntary cooperation and participation by citizens, many of the threats to source water in Berkeley County can be reduced. Therefore, a Public Information and Education Program that also fosters water conservation is highly recommended.

Disclaimer Note: Some of the recommendations mentioned in this report will require additional sources of funding. This report recognizes this potential, but does not address means of acquiring these funds. Nor is it the intent of this report to place undue requirements upon utilities or other organizations to find additional funding sources.

INTRODUCTION

In 2001, the Environmental Finance Center (EFC) at the University of Maryland, along with other regional EFCs, received grants from the U.S. Environmental Protection Agency (EPA) designed to launch a series of source water protection pilot studies to help communities better protect their drinking water sources. Recognizing the promise of this program, the West Virginia Departments of Health and Human Services (DHHR) recommended Berkeley County as a community with both the opportunity and a need to engage in such an effort.

The DHHR asked the directors of the Berkeley County Public Service Water District (BCPSWD) if their district would participate with the EFC, along with stakeholders from federal, state, and community levels, to take ownership for protecting the quantity and quality of the county's source water. In the year 2000, the U.S. Geological Survey (USGS) sampled water from fifty wells in the county to the east of North Mountain for *E. coli, fecal coli,* and *total coli.*[1] Thirty-two of the fifty wells sampled had at least one of these three bacteria types. A similar USGS study undertaken in 1993 found fecal coliform bacteria present in 41 percent of the 46 wells sampled.[2,3]

Faced with rapid growth and the ensuing demand for more water, and a fragile topography with a high potential for groundwater contamination, the directors of the BCPSWD responded with a resounding yes. This affirmative was strongly seconded by the Berkeley County Commission

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[1] "Relation of Bacteria in Limestone Aquifers to Septic Systems in Berkeley County, West Virginia," USGS Water-Resources Investigations Report 00-4229, p. 2, 11. (*E. coli, fecal coli. & total coli.)* Hereinafter USGS 00-4229.

[2] "Geohydrology, Ground-Water Availability, and Ground-Water Quality of Berkeley County, West Virginia, with Emphasis on the Carbonate-Rock Area," USGS Water Resources Investigations Report 93-4073. Hereinafter USGS 93-4073.

[3] *Note:* These studies were not designed to assess the water quality in the county as a whole, rather were targeted to areas of septic systems. No conclusions are drawn from the relationship of septic density and well contamination.

when briefed on the proposed project. The EFC was then able to help launch the project in Berkeley County, and it has since become a highly successful community-driven initiative that has been used by the EFC as a model for other communities.

SWAP—Phase I

With the endorsement of the County Commission, the Berkeley County Source Water Analysis and Protection Program (SWAP) got underway in July 2001.The first part of the project was devoted to data collection. Professionals from federal, state, and local government, as well as Canaan Valley Institute (CVI) and the EFC, made major contributions during this phase, which lasted 12 months. The SWAP Project team collected and organized a substantial amount of scientific data from previous studies, which had not previously been brought together and summarized in a meaningful manner.

Karst Topography

The SWAP team also gathered a large amount of existing data about the delicate karst terrain that underlies large portions of heavily developed land in the county. Karst is a land surface resulting from limestone, dolomite, gypsum beds, and other rocks formed by dissolution and characterized by closed depressions, sinkholes, caves, and underground drainage. Approximately 40 percent of Berkeley County is underlain by limestone rock, which is subject to becoming karst topography.

Carbon dioxide in groundwater forms a weak acid that dissolves calcite, which is a component of limestone and dolomite rock. Acidic groundwater moving through fractures and other spaces within the rock gradually alters small openings, creating large passages and networks of interconnected conduits. Most flow and passage enlargement takes place at or just below the water table—the level below where the ground is saturated with water. The dissolving of bedrock is characterized by both small features (e.g., fractures and fissures) and large features (e.g., caves, sinkholes, and underground streams). Except in these openings, however, the limestone is very dense and mostly impermeable. This explains why water may be very abundant at one site but flows only at a trickle in a well a short distance away.

In Berkeley County, the largest portion of the karst area extends from the Virginia line to the Potomac River in a northeasterly direction around Interstate 81 and is bounded to the west by North Mountain. The other substantial area of karst in the county borders on Jefferson County. A small oblong pocket of karst also exists in Back Creek Valley. (See Map 1 in Appendix F.)

Karst regions require special care because contaminants can flow easily through sinkholes, thus polluting groundwater. The majority of Berkeley County's drinking water supply—from private wells and from the public water system—comes from groundwater within this karst system. Stormwater runoff that carries petrochemicals, domestic and industrial chemicals, trash, fertilizers, pesticides, herbicides, animal decay products, as well as sewage disposal, provide substantial risk of contamination to the groundwater. In high-growth communities like Berkeley County, construction activities can destabilize the delicate equilibrium between the surface and underground components of karst, causing altered drainage patterns and sinkhole collapse. The clearing and stabilization of land for buildings and roads is a particularly serious threat to groundwater.[4]

SWAP—Phase II

Following the initial phase of data collection, the SWAP effort sought stakeholder involvement to 1) describe the status of Berkeley County's drinking water and potential threats; and 2) prepare recommendations for action to the County Commissioners. To accomplish this, SWAP Co-chairs Lavonne Paden, Planning Commission member, and William L. Stubblefield, Public Service Water District board member, encouraged a broad cross-section of the population, including private citizens, represen-

[4] "Living with Karst. A Fragile Foundation." American Geological Institute, 2001.

tatives from local organizations and county government, and several members from academia, to participate in this phase.

The goals of the SWAP project team were to

1. identify threats to the quantity and quality of water in the Berkeley County watershed, and
2. assess the impact of these threats, and make attainable recommendations to the County Commission.

The second phase of SWAP considered local resources and threats to Berkeley County's water supply from four sources:

1. transportation and hazardous materials (HAZMAT) activities,
2. sewer and septic systems,
3. growth and development, and
4. agriculture activities and wildlife.

At the first meeting, the professionals gave briefings, and volunteers selected which subcommittee(s) they wanted to be on. For the next year, the subcommittees met monthly, and the full project team met quarterly to receive progress reports from the subcommittees. All of these meetings were open to the public, and the press was invited to attend. The work of the second phase was completed at the end of June 2003.

WATER RESOURCES

Critical to an understanding of water resources is the ability to inventory and forecast the total water demand, which includes demands made on public water, private wells, and agriculture by residences and businesses. Currently 58 percent of the residents of Berkeley County (including the city of Martinsburg) get their water from public water systems, with the remaining 42 percent using private wells. The city of Martinsburg provides water to about 14,500 people from its Big Spring and Kilmer Spring treatment facilities. Likewise, the Berkeley County Public Service Water District (BCPSWD) currently provides water to approximately 33,280 people with approximately 1,000 new households added each year.[4]

Berkeley County Population

Berkeley County's population increased 28 percent in the decade between 1990 and 2000.[5] The U.S. Census Bureau's population estimates for 2001 and 2002 show the county's growth rate increasing at a rate of 3 percent per annum.[6] Population growth data is included in Appendix D. Sustained growth of this magnitude places a significant demand on surface and groundwater. The BCPSWD has prepared demand forecasts for its customers, which now include nearly one-half of the residences in the county. This forecast is projected out to 2008, 2013, and 2023. For the purpose of this SWAP report, the BCPSWD forecast was expanded to include water demand from all sources—private wells, agriculture, and from the city of Martinsburg. Currently, the BCPSWD provides nearly 4 million gallons of water per day (MGD). In 2008, this number is expected to increase to 5.3 MGD, in 2013 to 6.2 MGD, and in 2023 to 7.8 MGD. (See Appendix E for details of this water-demand forecast.)

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[4] Berkeley County Public Service Water District.

[5] U.S. Census Bureau.

[6] Ibid.

Berkeley County Water Resources—Strategic Plan: Availability, Treatment, and Delivery of Water

The BCPSWD now gets approximately one-half of its water from the Potomac River and the other half from a combination of Ben Speck and LeFevre Springs and small quarries. The combination of population growth and the possibility of a drought similar to that of 2002 prompted the BCPSWD to take several steps to ensure the availability of sufficient water to meet projected demands for public water. The first step was the preparation of a strategic plan.

This strategic plan considers availability, treatment, and delivery of water. The BCPSWD monitors daily water usage and maintains a running total of how many additional gallons can be delivered to new customers without jeopardizing current customers. For the projection of available water, the BCPSWD is using the least sustained yields of the springs and quarries, as determined during the drought of 2002. The minimum sustained flow rates were determined during this severe drought, when source water supplies were reduced by 25 percent. This reduction was primarily due to the fact that the flow rate of the two springs that have been a main source of water for years was reduced by nearly one-half. The BCPSWD is using this minimum sustained yield and the anticipated growth as a means of determining the amount of "new" water that must be found to ensure that the water demands of current and future customers are met.

Not included in the BCPSWD strategic plan are the additional water sources required for those entities not receiving water from the Berkeley County Public Service Water District, primarily private well users and agricultural users. Also missing from any county strategic planning is the potential of a major user of water, be it industrial, bottling, or large municipality. Such withdrawal could impact, if not countywide, certainly local water availability. One measure of protection of the available groundwater is to ensure that large users be supplied through public water. The justification for this strategy is that much of the public water would be withdrawn from sources not affecting adjacent water users, i.e., from the Potomac River.

Complicating the search for new water is the heterogeneity of the water found within karst topography. Within the shale portions of the county, the amount of water is fairly homogeneous and thus predictable. Unfortunately, shale does not produce water in sufficient quantity to warrant the building of treatment plants and delivery systems for public water use. Likewise, the distribution of water in sandstone is generally homogeneous, but there is insufficient sandstone in the county to pursue this source of water. This leaves the karst limestone as the best place to pursue new water sources in the county. But as discussed earlier, heterogeneity of water availability is the rule within this type of topography. Within a space of a few hundred yards, water can vary from large flow to practically nothing.

Berkeley County Water Resources—Past and Current Research

The BCPSWD is actively working with researchers from West Virginia University (WVU) and the USGS to develop a better understanding of the number and size of various aquifer basins in the county. However, understanding the amount of water in karst topography is one of the most difficult hydrogeological tasks. With $228,000 of funding from the BCPSWD and matching funds from the Department of the Interior (see Appendix C), the USGS is currently looking at the hydrological properties of 200 wells throughout the county. By determining how quickly a well draws down and recharges relative to other wells in the area, some insight is gained as to the homogeneity/heterogeneity of the aquifer within the county.

This work is complemented by, and will itself complement, the work of investigators from WVU, who have grants of $202,000 (see Appendix C) to study the network of springs in the county and their interconnections as well as to try to determine both the impacts of drought and the demand on water availability from springs, wells, and quarries in the karst areas of the county. It is hoped that the results of these studies will aid in determining what impact demands of residential and commercial growth have on Berkeley County's groundwater availability, as opposed to the variations in groundwater recharge from widely varying rainfall conditions.

Unlike other topographic areas of the country containing ancient and deep aquifers, in karst, much of the aquifer recharge in any one year comes from rainfall, causing water availability to vary dramatically from year to year. As will be discussed later, without alternative measures, an increase in development and in impervious surfaces in the county will have a substantial impact on this groundwater recharge.

All of these research projects will build upon the earlier work of the USGS in looking at the regional water province. In these earlier studies, dye was introduced into sinkholes and neighboring springs were monitored to see if the dye reappeared. In addition to these past and ongoing studies, the USGS and BCPSWD will propose increasing the number of continuously monitored wells to better gauge the health of the aquifer.

Berkeley County Water Quantity

Finding New Water

These studies will aid our general understanding of water within karst topography, but will not in themselves actually locate water. To do this, the USGS, with a portion of the $228,000 from the BCPSWD and the Department of Interior, will use very sophisticated technology for a fracture trace analysis to discover areas of potential water reserves. Based on the understanding that water moves through fractures and fissures in dense limestone, fracture trace analysis traces the surface reflection of these fractures and fissures and examines their density and pattern. Through fracture trace analysis, an educated determination can be made regarding the potential for finding new water sources, and variations of this same technology can be used to map subsurface water in a very localized area.

Alternatives to Finding New Water: Maximizing Existing Sources of Water

Finding new water is certainly one alternative for meeting the growing water needs within the county, but there are at least two other approaches that are equally attractive and will (1) avoid the expense of drilling for new water resources and (2) solve the inevitable problem of determining subsurface water rights. These alternatives aggressively pursue existing sources of water:

Alternative #1—Increasing Draws from the Potomac River—Recently, the BCPSWD received permission from Maryland to increase the daily maximum water withdrawal from 2.67 MGD to 3.864 MGD. (In an emergency, BCPSWD is authorized to withdraw up to 5.52 MGD, but over the entire year, the 3.864 MGD applies.[7]) This increase in water from the Potomac River will require the construction of a larger treatment facility. The BCPSWD has recently contracted with engineering firms to design a larger and more modern river intake and a new treatment plant. On December 9, 2003, The U.S. Supreme Court ruled that the state of Virginia and its governmental subdivisions did not have to have a permit from Maryland to withdraw water from the Potomac River.[8] It is likely that this ruling will eventually pertain to West Virginia as well.

Alternative #2—Using Water from Quarries—BCPSWD is actively discussing with various quarry owners the possibility of using water from quarries within the county. Due to the expense involved in the construction of a treatment facility and the associated delivery system, a long-term lease of at least 20 years is required. At this time, it is premature to speculate as to the success of these discussions.

As a complement to these studies, the West Virginia Conservation Agency will fund $200,000 to conduct a comprehensive county water planning study (see Appendix C). The direction of this study will be influenced by the findings of the SWAP study.

Berkeley County Water Quality

Besides water quantity, water quality is an issue of concern in Berkeley County. As will be discussed in more detail in later sections of this report, between one-third and one-half of the wells sampled by USGS in 1993 and

[7] Berkeley County Public Service Water District.

[8] Supreme Court of the United States Syllabus: Virginia vs. Maryland 9 Dec 2003.

2000 studies revealed bacterial contamination. This is in large part due to the easy passage of water from the surface to the underground aquifer via sinkholes and fractures in the limestone. When bacterial levels are sufficiently high, the West Virginia Departments of Health and Human Services (DHHR) designates the water as GWUDI (Groundwater Under the Direct Influence of Surface Water). A GWUDI indication means that there is a potential for not only substantial levels of *E. coli* and fecal coliform, but for other more serious protozoa that are difficult to detect, including *Giardia* and *cryptosporidium*. *Giardia* and *cryptosporidium* cannot be treated by chlorine alone. With a GWUDI designation, therefore, water that has not been boiled or subject to further extensive treatment could become unsafe for human consumption. The contamination issue, then, is a significant one for both residential wells and public water users in the county.

Whether this bacterial contamination is from human beings or from domestic, agricultural, or wild animals is difficult to determine. There are several laboratories in the U.S. that try to determine bacteria source from samples of fecal material. With $480,000 in funding from the DHHR, the West Virginia Department of Environmental Protection (WVDEP), the U.S. Department of the Interior, and Berkeley County (see Appendix C), a very comprehensive study was conducted of the various methods these laboratories use. The intent of the study was to determine which of these laboratory procedures was best suited for Berkeley County, considering costs and results. To ensure that the findings were both fair and complete, numerous samples of fecal material from humans, deer, cattle, dogs, horses, geese, and chickens were collected. The samples were sent to each of the participating laboratories across the country so they could develop a source library. Following the identification of known samples, each laboratory was sent a series of blind samples. The source of the blind samples was known to the USGS scientists but not to the laboratories conducting the research. The results were quite unexpected. None of the laboratories, regardless of their claims, was able to identify the blind samples in more than one third of the cases.

This study, which has become known as the Berkeley County Study, demonstrated that the protocol being used to determine the source of bacteria contamination is not satisfactory. These findings are a disappointment in one aspect but a significant cost saver in another sense. Different approaches are being pursued by the USGS laboratory in Leetown, WV, where USGS biologists are using molecular methods to identify and quantify anaerobic bacterial species, which will be evaluated as potential host-specific bacterial tracers of fecal contamination.[9] The laboratory will also test the viability of directly detecting DNA released from human and animal cells found in feces. These techniques will be combined with analyses to detect the presence of household and agricultural chemicals in fecal matter.

[9] The anaerobic bacterial species being tested is *Bifdobacteriumand bacteroides.*

THREATS, IMPACTS, AND RECOMMENDED ACTIONS

THREAT #1: WASTEWATER

The aquifers from which Berkeley County draws its water are partially recharged from our septic systems. For both the public-supplied water and the residential wells, it is important to have the water as free as possible from pollutants such as pathogens, trace metals, medicinal chemicals, and elevated nutrients, among others. For public-supplied water, many but not all of these pollutants are removed. The purity of water from residential wells is a function of the health of the groundwater and the installed purification system.

The objective of all wastewater treatment systems is to produce a high-quality final effluent for a particular soil type, underlying geology, and housing density. If wastewater is treated correctly, the amount and type of pollutants in the groundwater are reduced significantly, requiring much less purification of the water prior to drinking. Accordingly, countywide standards for waste treatment, rather than being blanket prescriptions, should be based on locally specific needs.

In an area of appreciable growth such as Berkeley County, new developments in wastewater technology should be assessed on a regular basis and implemented where applicable. Decentralized wastewater technology (this does not include package treatment plants) is one of the new developments that may apply to the county's treatment needs in karst and other terrains. In particular, pretreatment and pressure dosing are two general types of technologies that have proven effective in producing a high-quality effluent. Pretreatment generally refers to some type of filter placed between a septic tank and a drain field. Sand filters are one accepted example of pretreatment. Pressure dosing refers to a method of distributing effluent so that the entire drain field is dosed at once. This distributes the effluent evenly through the drainfield soils. Some of these technologies have also proven effective in removing nitrates. Decentralized wastewater systems can be designed to serve multiple residences.

THREAT #2: SEPTIC AND SEWER SYSTEMS

Septic Systems

There are more septic systems in Berkeley County than anywhere else in the state. Within the county, there are approximately 13,000 operating septic systems.[10] Since the 2000 census, approximately 5,000 residences have been connected to the public sewer system, but many others have installed new septic systems in areas where public sewers do not exist. Properly installed and maintained septic tank systems can be the best way to handle residential wastewater, because they return pathogen-free water to the aquifer. In times of drought, when the aquifer is under stress, the resupply from a properly functioning septic system is important to the health of the aquifer.

Septic tank systems, however, for various reasons, do not always function as designed. This is especially true as the septic system ages. In addition, if excess household waste is dumped down household drains, and if the tank is not pumped periodically, there is a greater likelihood of a poorly functioning system. Improperly sited drain fields also increase the probability of failure. When a septic system fails, it poses a threat of direct sewage contamination of groundwater. Aerial infrared photography done in 1996 has positively demonstrated the existence of septic systems in the county that have failed to the surface. Within a seven-square-mile area from Inwood to Hedgesville, over 300 systems were determined to have full-time or seasonal failure.[11]

Septic systems failing downward into karst terrain represent an even more serious risk to the quality of our groundwater. Determining the scope and magnitude of this problem is difficult. In karst topography, and in deformed shale, a failed septic system frequently fails downward, polluting the groundwater while leaving little if any trace on the surface.

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10 Berkeley County Health Department.

11 Septic System Analysis—Infrared Photography, Berkeley County Health Department, May 1996.

There are some good indicators that suggest that failed septic systems are sufficiently common to warrant concern. USGS studies in 1993 and 2000 found that of the county wells sampled, approximately 40 percent had bacterial contamination.[12] These studies, however, were not designed to determine the percentage of contaminated wells countywide. Also, these studies were unable to conclusively identify the source of contamination to the groundwater, but failed septic systems are certainly a candidate. Problems with septic systems may result from several causes:

- *Improperly sited systems,* particularly with older systems installed when regulations or modern design and installation practices were not in place. Systems located too close to bedrock, rock outcroppings, or sinkholes are examples of improper siting.
- *Placement of septic systems too close together.* The impact of housing density on groundwater when septic systems are installed is not always recognized or adequately considered. This is especially true in recent years when lot size has continually decreased and is now often less than one acre. The recently revised Subdivision Regulation will help address this concern.
- *The improper matching of certain types of septic systems to a soil type or underlying topography*. The technology utilized may not be adequate to address vulnerable areas, particularly karst terrain. Current regulations do not recognize environmentally sensitive areas, nor do these regulations adequately and consistently differentiate technology and specifications in reference to different types of soils.
- *Improperly maintained systems.* All systems need regular inspections and maintenance. Failure to maintain systems can lead to sewage backups, overflowing or damaged septic tanks, clogged drain fields, or other problems leading to surface and groundwater contamination.
- *User ignorance.* The workings of septic systems are matters most people are not aware of unless they are educated about them. Many

[12] USGS 00-4229 and USGS 93-4073.

users of septic systems have insufficient knowledge of how to care for their systems. For example, they may be unaware that grease, garbage disposals, and non-biodegradable materials like diapers and paper towels can cause system failures, or that the back-washed salt from water softeners may cause erosion of the tank and its baffles, as well as damage to soil structure and the soil's ability to absorb wastewater.

Part of the difficulty of pinpointing specific septic problems is in the detection of failing systems. In karst topography, detection other than a visual indicator on the ground is needed. As mentioned earlier, in karst, the failure is generally downward rather than seepage upward to the ground's surface, which is visible. One method for detecting septic system failure is to insert monitoring ports in the drain field. These ports are vertical tubes placed in the drain field and capped at ground level. In a properly functioning septic system, liquid should be in the monitoring port; conversely, in a failing system there will be no liquid, indicating downward failure. This monitoring method costs little to install and maintain.

An additional challenge posed by septic systems in the county is the need to reduce nitrogen contamination and in particular, nitrates.[13] This form of contamination does not pose public health risks comparable to pathogens, but is nevertheless a health concern. Elevated nitrates in drinking water are a significant health risk to humans, particularly infants, the elderly, and those with compromised immune systems. Currently no standards exist for nitrate removal from septic systems.

✓recommended actions for septic systems

1. **Require inspections of septic systems for tank integrity and remaining capacity at periodic intervals**—This should be more frequent in karst terrain than in non-karst areas. There is no certain determination to define what this interval should be. A properly installed and well-maintained system can last for many years; oth-

[13] Berkeley County Health Department.

ers can fail in a very short period of time. As a compromise, an inspection schedule of every five years in karst terrain, every 10 years in non-karst areas, and with the sale of property is recommended. The inspection should determine the need for tank pumping and/or necessary maintenance.

2. **Require drain field inspection ports in new septic systems**, and provide incentives for retrofitting inspection ports in existing systems.

Sewer Systems

Upgrades to sewer treatment plants over the last several decades are one of the most important factors contributing to environmental improvements in Berkeley County's streams and the Potomac River. Sewers are a very vital part of the protection of the county's water resources. Sewers are also the best technology for meeting higher population demands. Unfortunately, sewer pipes can and do break and leak. Both old and new pipelines are subject to failure from a variety of causes such as improper installation or soil subsidence, and are subject to fracture from blasting operations or excavation activities.

The potential for sewer pipe failure is a significant pollution hazard in karst terrains for two reasons. First, due to the erosive nature of the carbonate rock, the support of the pipes can be reduced through time, leaving the pipes subject to unexpected breakage. And second, in karst, large quantities of raw sewage can infiltrate to groundwater in short periods of time, without visible evidence of any leaks or ruptures. Failures of this type threaten or directly impact the health of all those served by wells in the surrounding area, and to a lesser extent by those on public water. Such failures often lead to long-term and costly remediation measures.

While such failures are not common, they do occur. In 1999, in Frederick County, Maryland in terrain similar to Berkeley County, such a failure occurred with devastating consequences. Over a million gallons of raw sewage were released to the aquifer before the break was detected and repaired. Both well water users and public water users were at a severe health risk. Berkeley County Public Service Sewer District (BCPSSD) and the city of Martinsburg are aware of this potential hazard. Both organizations conduct periodic leak-detection inspections on their lines, using flow tests and video cameras. These precautionary measures will serve us well under normal conditions; however, to better the chances of preventing catastrophic failures, the following actions are recommended:

✓recommended actions for sewer systems

1. **Continue to ensure that both sewer utilities replace all lines prior to the lines reaching the end of their reliable service age.**
2. **Continue to ensure the BCPSSD and the County Engineer know the karst locations, sink holes, and areas subject to subsidence.** Request the BCPSSD to use specific construction techniques in sensitive karst areas where potential breakage is likely to occur, and to rigorously inspect the work of placement contractors in these locations.
3. **Prepare an emergency plan for sewage leaks in karst terrain.** Include public notification of known breakages with boil water alerts for well water users.

✓recommended actions for septic and sewer systems

1. **Continue to develop a countywide waste treatment plan** that considers locally specific factors such as geology, soil types, housing densities, etc., to determine the appropriate wastewater treatment requirements, including either public sewer, traditional, or enhanced septic system requirements, or alternative, decentralized, or cluster systems that have recently been developed.
2. **Promote the use of alternative, decentralized, or cluster waste treatment technology in areas of high density of homes**. This should be done in close coordination with the Berkeley County Health Department and the Public Service Sewer District, with emphasis on effluent quality and nutrient reduction. Consideration should be given to providing incentives to subdivision developers

and existing homeowners for using these alternative technologies. The Planning Commission should establish and enforce the county-developed criteria for housing densities in subdivisions not served by public sewers.

THREATS #3 AND #4: SEPTAGE AND SLUDGE

Septage is the collected material from septic tanks, portable toilets, and other disposal units, which is frequently applied to agricultural lands.

Sludge is the treated residue from the output of wastewater treatment plants, which is either disposed of in landfills or as fertilizer on agricultural lands.

Septage and Sludge

Septage haulers are required by the state to mix agricultural lime in specified quantities into their tanks prior to application on agricultural fields. Because inspection of these haulers is limited and the dispersal is inadequately monitored, there are concerns in Berkeley County that the mixing of lime and the spreading of material is not always being done properly. Neither the West Virginia Departments of Health and Human Services nor the West Virginia Department of Environmental Protection has adequate staff to inspect these operations.[14] There are further concerns that raw septage is being applied by unlicensed applicators.

The risks from treated sludge are less than from septage applications, but they still are risks. Although sludge has been treated for some pathogens, persistent viruses and spore-forming organisms may resist treatment and detection.[15] Septage and sludge applications can pollute groundwater, especially in karst topographies, and can pose a potential health risk to humans and livestock.

✓recommended actions for septage and sludge.

1. **Require that all septage be treated at a Berkeley County Public Service Sewer District wastewater treatment facility.** Include es-

14 WV Department of Environmental Protection.

15 USEPA.

timated septage quantities in planned treatment facility capacity studies.

2. **Include septage and sludge in a countywide waste treatment plan**—Included in this plan might be a provision to ban the application of sludge in karst areas of the county. Members of the SWAP team were of two minds on this provision. Some felt that the provision is critical and must be included. Others believed that sufficient regulations are in place such that inclusion of the provision banning the disposal of sludge in karst areas is not warranted. Further study into this issue is recommended. For applying sludge in non-karst areas, the WV Department of Environmental Protection (DEP) and the Eastern Panhandle Conservation District should continue to provide prior approval of the application site, and prominently post signs around the perimeter of the field that state sludge was applied, along with the date of application. As part of the countywide plan, either the Berkeley County Health Department, the DEP, or the Conservation District should be required to conduct post-inspections of any sludge application on agricultural land.

THREAT #5: STORMWATER AND IMPERVIOUS SURFACE MANAGEMENT

An increase in impervious surfaces (e.g., housing, commercial development, parking lots, streets, driveways) affects our groundwater in terms of both quantity and quality. In terms of impacts on quantity, there are two components:

1. the loss of water to the aquifer, and
2. the undesired flooding associated with excessive stormwater runoff.

Impervious surfaces increase surface runoff of precipitation, which, in turn, reduces soil infiltration of moisture. This results in a decrease in groundwater recharge. As amounts of runoff increase, receiving channels begin a process of instability as the channels begin to resize to accommodate increased volumes and flow velocities. The cumulative result is widespread flooding of homes and yards. This situation is dramatically demonstrated during periods of heavy rainfall. Stories of local homeowners who have seen their homes flooded have been all too common during this past year. In terms of water quality, an increase in stormwater runoff has a detrimental effect on receiving streams and the water quality of the recharge. Impervious surfaces collect contaminants such as petroleum products, lawn chemicals, heavy metals, animal (pets and farm) waste, and fertilizers and pesticides that may be washed into groundwater, as well as other water bodies, during storms. With this rapid runoff, there is little opportunity for natural filtration and purification.

This situation is exacerbated in karst topography, where sinkholes channel the contaminated water directly to the aquifer. In receiving streams, channel instability also increases sedimentation that, in turn, decreases capacities of culverts and bridges, and creates adverse biological conditions.

Federal law is responsive to the threat of unmanaged stormwater polluting both surface and groundwater. The EPA's Phase II National Pollution

Elimination System (NPDES) requires both inspection and maintenance requirements for stormwater management systems. NPDES requires the county to

1. establish provisions for regulating construction activities that disturb more than one acre of land,
2. reduce pollutants to the "maximum extent practicable,"
3. mandate public education, and
4. set forth erosion and sediment control requirements.

All of these regulations are designed to protect both surface and groundwater resources.

✓recommended actions for stormwater and impervious surfaces.

To address the impacts of impervious surfaces on both the quantity and quality of water, the next revision of the Berkeley County Stormwater Management Ordinance should include the following changes:

1. **Require that annual groundwater recharge rates be maintained by infiltration.** Specifically, the recharge volume should be mandated in the Berkeley County Stormwater Management Ordinance, in accordance with the soil types of the site. At a minimum, the annual recharge from the post-development site should be equal to the annual recharge from predevelopment site conditions. There are areas of the county, however, where the soil type does not lend itself to infiltration.
2. **Require site designs to minimize the generation of stormwater and to maximize pervious areas for stormwater management.** Encourage and reward nonstructural practices such as
    a. forest retention areas,
    b. lands in protective easement,
    c. riparian buffers, and
    d. the utilization of grassy swales.

Non-structural practices can reduce the amount of stormwater from a site, provide partial removal of pollutants, and provide groundwater recharge.

3. **Encourage the formation of local watershed groups that perform chemical and biological assessments.**

4. **Provide more stringent stormwater management standards in karst areas,** which address the vulnerability of the terrain to pollution. For example:

   a. The conveyance of stormwater should be through vegetated areas, whenever possible.

   b. Synthetic liners should be placed under stormwater collection ponds in areas of potential contamination.

   c. Stormwater discharges from impervious surfaces around commercial structures should be no closer than 500 feet from an unremediated sink hole. A sinkhole that appears in a stormwater management system is a genuine emergency, and action to eliminate or reduce its impact should be completed in a very short period of time. If synthetic liners are used, periodic inspection, usually every 20 years, is necessary to ensure the liner has not failed.

   d. Provide for annual stormwater detention structure inspections.

THREAT #6: OTHER POLLUTANT RISKS

HAZMAT Spills

The karst topography in Berkeley County encompasses I-81 for the entire 28 miles of highway that bisects the county. A major railroad that crosses the northern part of the county and smaller spur lines running north and south are also largely in karst terrain. A fair amount of this truck and rail traffic carries hazardous materials. HAZMAT spills could do serious damage to the surrounding ground and surface water. In addition, West Virginia DEP inspectors have found that several I-81 drains from the Virginia state line to the Tablers Station exit discharge into the immediate vicinity of sinkholes.

Sinkholes and Injection Wells

Along with sinkholes, injection wells pose a significant problem because they also bypass the natural filtration process of soils and carry surface liquids directly into the aquifer. Contained in the liquid being carried through the injection wells are residue from petrochemicals, toxic salts from de-icing, and the risk of chemicals from accidental spills. The WVDEP maintains location data for underground injection wells; however, by their admission, some well data may be missing. The West Virginia Code[16] requires a Groundwater Protection Plan (GPP) for all commercial and industrial establishments, and also requires the permittee to declare if the establishment is located in areas of karst, wetlands, subsidence (sinkholes), or well-head protection areas. WVDEP maintains a file of GPP's.

Storage Tanks

Below-ground storage tanks can have leaks that remain undetected for long periods of time. The WVDEP maintains records of gasoline storage tanks but does not keep records on other types of underground storage

[16] WV Code 22-12.

tanks. Above-ground tanks can also develop leaks, but fortunately, above-ground leaks are more easily detected than those in underground tanks. The liquids in these underground tanks are generally of a toxic nature, and the quantity is such that widespread pollution could occur.

Illegal Dumps

Along with storage tanks, Berkeley County has numerous open dumps. The WVDEP is aware of four illegal dumps and eight illegal tire pile sites within the county. It is a violation of state law[17] when solid waste is disposed of in a manner that does not protect the environment. These dumps and piles are sources of groundwater pollution as well as being health hazards and eyesores.

Junk Automobiles

Another potential source of drinking water pollution is associated with automobiles. Large numbers of junk cars pose a risk to our groundwater. Any leakage of gasoline, motor oil, radiator coolant, or battery acid can be readily transported to the aquifer.

The state has established permitting, inspections, and usage restrictions pertaining to storage tanks, injection wells, commercial establishments, and illegal dumps. Berkeley County must ensure that appropriate local government personnel are aware of their responsibilities to comply with state law and regulations in the course of executing their job responsibilities. For example, the Planning Commission, through its subdivision ordinance, can enforce the prohibition of commercial facilities such as an auto repair shop from using a septic system to dispose of shop wastes.

✓recommended actions for other pollutant threats

1. **Provide guidelines,** which crosscut both state and local organizations, to best protect the aquifer within karst topography, such as

17 WV Code 22-15-1 et seq.

providing the Director of Emergency Services with the locations of sinkholes along major highways and railroad beds.

2. **Provide filtration systems such as grassy swales** for the highway drains adjacent to sinkholes.
3. **Maintain a list of below-ground storage tank permits,** shallow injection well permits, and groundwater protection permits from the WVDEP and routinely compare sites to locations of sinkholes.
4. **Enact an ordinance** to ensure that gasoline, radiator coolant, motor oil and battery acid are removed and properly disposed of from motor vehicles not in operation.
5. **Work closely with the WVDEP to locate and clean up illegal dumps and tire piles in the county.** Take action to curtail illegal dumping.

THREATS #7 AND #8: AGRICULTURAL THREATS AND LOSS OF OPEN SPACE

Farming is a traditional, historic, and important component of life in Berkeley County. Today's farmers are becoming more aware of the importance of water to their livelihood. Drought, water costs, and increasing demand for water by a growing population are concerns for the agricultural community. The agricultural demand for water is calculated to be approximately 21 percent of the total residential need (see appendix E). Farmers are becoming increasingly more aware that this water resource is at risk from many causes, including some farm-related ones. The influence agricultural practices may have on source water quality is also becoming more clear.

Nitrogen and phosphorous are necessary components of agricultural production. With the influx of new residents into Berkeley County, these chemicals are also being used with increasing frequency and abundance on lawns and golf courses. High application rates, excessive moisture from rainfall or irrigation, and the timing of treatments can all contribute to elevated levels in both ground and surface water. Elevated nitrate levels in drinking water are a risk to both humans and animals. The Chesapeake Bay is experiencing alarming increases in nutrient levels. This is largely due to excess nitrogen. High nutrient levels can fuel algae blooms, degrade habitat for fish and other aquatic animals, and contribute to the spread of oxygen-starved "dead zones." West Virginia has recently joined other states as part of the Chesapeake Bay watershed pact, which requires the state to take aggressive action to reduce the level of nitrogen and other contributors to the elevated nutrient level.

Agricultural feeding operations are also a contributor to high nutrient levels. Unless properly managed, manure has the potential to cause significant runoff into streams and groundwater sources. When this happens, runoff increases the deleterious impacts of nitrogen and phosphates on our farms and lawns. Eventually, this leads to a decline in plant species quality and adversely affects the food chain.[18]

Berkeley County's Farmland Protection Program has the potential to develop an open space conservation initiative that can improve source water quality as well as bring economic benefits to citizens, commercial enterprises, and local government. In New York State, through a partnership of public and private interests, 349,000 acres of land were dedicated in an Open Space Conservation Plan.[19] Some of the funding for conservation easements under this plan came from dollars that would have been spent for increased water processing and filtration costs had the watershed areas used for public water consumption not been protected.

In 2002, the EPA allowed a continued exemption (Filtration Avoidance Determination or FAD) from building a filtration plant in the Catskill-Delaware Water Supply area.[20] In addition to improving the quality and quantity of the water supply, the filtration plant has

1. protected farmlands,
2. created recreational facilities,
3. reduced development dollars by channeling growth into less costly infrastructure areas,
4. brought in more tourism dollars, and
5. increased local government's net income.

[18] Sharpley, et al. 1994.

[19] dec.state.ny.us- New York State Dept of Environmental Conservation web site.

[20] Catskill Watershed Corporation; http://www.cwconline.org/index.html

✓recommended actions for agricultural threats and open space protection

1. **Provide nutrient management plans to farmers** so that they can improve their ability to assess crop and soil needs.
2. **Establish a public awareness program on the importance of nutrient management.** Direct this program to homeowners, commercial lawn care companies, and golf courses to seek their commitment to reducing elevated nutrient levels.
3. **Follow EPA and USDA guidelines for Comprehensive Nutrient Management Plans for farm animal feeding operations**.
4. **Promote awareness that land protection through perpetual conservation easements in well head protection areas can protect groundwater quality and reduce water treatment costs.**

WATER RESOURCES ADVISORY COUNCIL

As stated in the introduction, the SWAP Team recognizes the value of a Water Resources Advisory Council (WRAC) for Berkeley County. Several local governments have had success with such a council. Warren County, Virginia has utilized a water resources advisory council for the past two years. More recently, neighboring Jefferson County has formed a similar advisory council. Suggested responsibilities of such a council could include the following:

1. Acting as an advisory body to the Berkeley County Commission regarding water resources issues.
2. Monitoring and assisting the implementation of the actions recommended by this report with which the Berkeley County Commission concurs.
3. Maintaining and establishing working and regulatory relationships with state and federal organizations that have influence on Berkeley County drinking water.
4. Identifying and seeking grants for the preservation and improvement of drinking water in Berkeley County.
5. Continuing Berkeley County's participation in the bi-state Regional Water Resources Policy Committee (RWRPC), the USGS-sponsored Northern Shenandoah Valley Aquifer System research project, and Eastern Panhandle research at the USGS facility in Leetown.
6. Advising and assisting in providing a Source Water Protection Public Information and Education Program for Berkeley County.

✓recommended action

1. **Appoint a Water Resources Advisory Council (WRAC)** to advise the County Commission in the implementation of recommendations included in this report and to take other action pursuant to the preservation of our source water.

PUBLIC INFORMATION AND EDUCATION ABOUT WATER CONSERVATION AND WATER QUALITY

An intensive and ongoing public information and education program can lessen many of the threats to source water that have been identified in previous sections of this report. The starting point for this program is the immutable fact that Berkeley County's water supply is not without limits. All of us have taken water availability for granted and have rarely considered that there might be a time when our water supply could be greatly reduced and/or polluted. Accordingly, the primary objectives of this section are to foster water conservation and to inform and educate Berkeley's citizens about what they can personally do to minimize the contamination of source water.

A portion of the SWAP grant funding is to be used to produce a public education booklet outlining many of the considerations for safeguarding water for residents of Berkeley County. Should the County Commission decide to form a Water Resources Advisory Council as recommended in this report, such a council could advise and assist the County Commission with the continuation of this education and information program. Public information and education about water conservation and water quality could include the following eight topics, with different media used to direct information to specific target audiences.

1. The special vulnerability of the county's terrain to water contamination and what people can do to minimize contamination.
2. The need to conserve water, along with conservation tips.
3. Proper fertilizer and pesticide application and disposal.
4. The maintenance and care of septic systems.
5. Proper methods for the disposal of animal waste.
6. Awareness of the effect of sinkholes.
7. The effects of impervious surfaces.
8. Proper disposal of petrochemicals and toxic substances.

APPENDICES

APPENDIX A
ACKNOWLEDGMENTS

The Berkeley County SWAP Project gratefully acknowledges the support provided by the following organizations and their representatives:

1. Berkeley County Development Authority:
   Bob Crawford
2. Berkeley County Health Department:
   Rick Hertges, Twila Carr
3. Berkeley County Office of Emergency Services:
   Steve Allen
4. Berkeley County Solid Waste Authority:
   Clint Hogbin
5. Berkeley County Planning Commission:
   Fred Gantt, Lavonne Paden, B. Pennington, John Jeans
6. Berkeley County Public Service Water District:
   Paul Fisher, Hoy Shingleton, Bill Stubblefield, Chris Thiel
7. Berkeley County Public Service Sewer District:
   Cliff Browning, Curtis Keller, Walt Sebert
8. Blue Heron Environmental Network:
   Sherry Evasic
9. Canaan Valley Institute:
   Dave Clark, Matt Sherald
10. Eastern Panhandle Homebuilders Association:
    Katy Fidler, Hunter Wilson
11. Interstate Commission on the Potomac River Basin:
    Jim Cummins
12. Inwood Watershed Advisory Committee:
    Edgar Mason

13. Jefferson County Commission:
    Al Hooper, Greg Corliss

14. Jefferson County Public Service District:
    Sue Lawton

15. Martinsburg City:
    Steve Knipe

16. Environmental Finance Center, University of Maryland:
    Michelle O'Herron, Dan Nees

17. Shepherd College:
    Sharon Kipetz, Dick Latterell (Prof. Emeritus)

18. The Conservation Fund-Freshwater Institute:
    Joe Hankins

19. U.S. Dept of Agriculture:
    Roger Boyer, D. Dirting, Rebecca MacLeod

20. U.S. Geological Survey:
    Hugh Bevans, Mark Kozar, Melvin Mathes, Carol Boughton

21. WV Conservation Agency:
    Danny Evans

22. WV Department of Environmental Protection:
    Dave Watkins, Evelyn Hopkins, Teresa Koon

23. WV Department of Public Health:
    Bill Toomey, Scott Rodeheaver, Alan Marchun

24. WV Rural Water Association:
    Lewis Baker

25. West Virginia University Geology Department: *Dr. Joe Donovan, Dr. Dorothy Vesper*

APPENDIX B
BERKELEY COUNTY SWAP TEAM PARTICIPANTS

Bill Alexander	Steve Allen	Lewis Baker	Hugh Bevans
Carol Boughton	Roger Boyer	Cliff Browning	Twila Carr
Greg Corliss	Dave Clark	Bob Crawford	Jim Cummins
Joe Donovan	Danny Evans	Sherry Evasic	Katy Fidler
Paul Fisher	J. W. Fleshman	Fred Gantt	Joe Hankins
Rick Hertges	Clint Hogbin	Evelyn Hopkins	Al Hooper
John Jeans	Curtis Keller	Jeff Keller	Sharon Kipetz
Steve Knipe	Teresa Koon	Mike Kozar	Dick Latterell
Sue Lawton	Rebecca MacLeod	Alan Marchun	M. Mathes
Edgar Mason	M. O'Herron	Dan Nees	L. Paden
B. Pennington	S. Rodeheaver	Walt Sebert	Matt Sherald
B. Stubblefield	H. Shingleton	Chris Thiel	Bill Toomey
Dorothy Vesper	Dave Watkins	Hunter Wilson	

APPENDIX C
GRANTS SUMMARY, BERKELEY COUNTY SWAP PROJECT

Grant	Applied for by	Purpose	Amount	Local Match
Fracture Trace Analysis to locate add'l water sources in the county	Berkeley County PS Water Dist. To the USGS	Locate high-yield aquifer sites	$132,000	$96,000
Technical assistance for SWAP project in Berkeley County	Potomac Headwaters RC&D to the EPA	Public Education Booklet final report preparation	$25,000	None
Berkeley County Water Resources Assessment & Implementation Plan	WV Conservation Agency, Eastern Panhandle Conservation District, NRCS	Comprehensive county water planning	$200,000	None
Final SWAP Report Preparation	Regional Environmental Finance Center, Univ. of MD, Seagrant Program	Combine subcommittee reports	$8,000	None
Urbanization &climate change impacts on the Great Valley Karst Aquifer, WV-VA	Drs. Donovan & Vesper, WVU to USDA	Determination of drought & demand impacts on springs, quarries & wells	$180,000	None
Hydraulic connections & impacts on water supply in local area	Drs. Donovan & Vesper, WVU to WVU Water Resources Institute	Identify aquifer compartments used to determine water movement, availability and quality	$22,000	$11,000
Bacteria source tracking study	Berkeley County and WV Bureau for Public Health to US Dept. of Interior	Bacterial contamination of well water in Berkeley County	$480,000	$20,000

APPENDIX D
BERKELEY COUNTY POPULATION PROJECTIONS

	Population Estimates			**Estimates Base**	**Census 2000**
Geographic Area	**July 1, 2002**	**July 1, 2001**	**July 1, 2000**	**April 1, 2000**	**April 1, 2000**
West Virginia	1,801,873	1,801,975	1,807,326	1,808, 350	1,808, 344
Berkeley County	81,262	78,690	76,429	75,905	75,905

APPENDIX E
BERKELEY COUNTY WATER DEMAND FORECASTS

Forecast Assumptions and Explanations

1. The average water consumption for residences with private wells is assumed to be the same as the average for residences served by public water.

2. The initial quantification of agricultural water demand was kept constant for the twenty-year period of these forecasts. This number will be updated periodically with new data provided by the U.S. Department of Agriculture.

3. The city government provided water demand data for Martinsburg.

4. Existing industrial customers were grouped into high, medium, and low water consumer categories, and average consumption data was calculated from historical data for each category. The Executive Director of the Berkeley County Development Authority then provided growth estimates for each category for the twenty-year period of these forecasts. Because industrial high water consumers have a major impact on water demand requirements, a close liaison with the Development Authority will be required to update these forecasts as conditions warrant.

Current year 2003 Water Demand, Berkeley County, WV

Residential Water Demand			
Population, persons	67,000	15,000	82,000
Population on public water	33,280	14,500	47,780
% of population on public water	49.7%	96.7%	58.3%
Residents per household	2.6		
Residential Water Accounts - Number	12,800		
Residential usage, gallons/month/household	4,300		
Residential usage, gallons/day/person	54		
Total Residential Usage, gallons/day	**1,809,534**		
Non-Residential Water Demand			
Industry			
Industry - High Water Usage (>1,000,000 gal/mo)			
Number	5		
Ave demand gallons/day	83,579		
Total demand gallons/day	417,895		
Industry - Med Water Usage (100,000-1 Mgal/mo)			
Number	3		
Ave demand gallons/day	13,567		
Total demand gallons/day	40,701		
Industry - Low Water Usage (<100,000 gal/mo)			
Number	11		
Ave demand gallons/day	2,436		
Total demand gallons/day	26,794		
Total Industrial Demand, gallons/day	485,390		
Schools and Government			
Total Demand, gallons/day	127,758		
Commercial, Health Care and Other			
Total Demand, gallons/day	681,612		
Total Demand, Non-Residential, gallons/day	**1,294,760**		
Total Demand, All Users, gallons/day	**3,104,294**		
Water Loss Factor, %	23%		
Required Public Water Production, gallons/day	**4,031,551**	**4,000,000**	**8,031,551**
WATER DEMAND, PRIVATE WELLS			
Residential Water Demand			
Population on private wells			34,220
Total Residential Usage, gallons/day			**1,860,645**
Agricultural Water Demand			
Total Agricultural Demand, gallons/day			387,941
Required Water Well Production, gallons/day			**2,248,586**
TOTAL WATER DEMAND, ALL SOURCES, GALLONS/DAY			***10,280,137***

Projected Year 2008 Water Demand, Berkeley County, WV

Projected Data	BCPSWD	City of Martinsburg	Berkeley County
WATER DEMAND, PUBLIC SUPPLY			
Residential Water Demand			
Annual Growth Rate, 2003-2007	3.6%	2.1%	3.3%
Projected 2008 Population, persons	79,960	16,643	96,603
Population on public water	48,301	16,143	57,710
% of population on public water	50.0%	97.0%	59.7%
Residential Water Accounts - Number	18,577		
Residential usage, gallons/month/household	4,300		
Residential usage, gallons/day/person	54		
Total Residential Usage, gallons/day	**2,608,273**		
Non-Residential Water Demand			
Industry			
Industry - High Water Usage (>1,000,000 gal/mo)			
Number	5		
Ave demand gallons/day	83,579		
Total demand gallons/day	417,895		
Industry - Med Water Usage (100,000-1 Mgal/mo)			
Number	4		
Ave demand gallons/day	13,567		
Total demand gallons/day	54,268		
Industry - Low Water Usage (<100,000 gal/mo)			
Number	12		
Ave demand gallons/day	2,436		
Total demand gallons/day	29,232		
Total Industrial Demand, gallons/day	501,395		
Schools and Government			
Annual Growth Rate, 2003-2007	3.6%		
Total Demand, gallons/day	152,471		
Commercial, Health Care and Other			
Annual Growth Rate, 2003-2007	3.6%		
Total Demand, gallons/day	813,460		
Total Demand, Non-Residential, gallons/day	**1,467,326**		
Total Demand, All Users, gallons/day	**4,075,598**		
Water Loss Factor, %	23%		
Required Public Water Production, gallons/day	**5,292,985**	**4,438,014**	**9,730,999**
WATER DEMAND, PRIVATE WELLS			
Residential Water Demand			
Population on private wells			38,893
Total Residential Usage, gallons/day			**2,100,200**
Agricultural Water Demand			
Annual Growth Rate, 2003-2007			-5.0%
Total Agricultural Demand, gallons/day			**300,181**
Required Water Well Production, gallons/day			**2,400,381**
TOTAL WATER DEMAND, ALL SOURCES, GALLONS/DAY			***12,131,381***

Projected Year 2013 Water Demand, Berkeley County, WV

Projected Data	BCPSWD	City of Martinsburg	Berkeley County
WATER DEMAND, PUBLIC SUPPLY			
Residential Water Demand			
Annual Growth Rate, 2003-2007	3.6%	2.1%	3.3%
Annual Growth Rate, 2008-2012	3.0%	2.1%	2.8%
Projected 2013 Population, persons	92,696	18,465	111,161
Population on public water	57,804	17,911	66,407
% of population on public water	52.0%	97.0%	59.7%
Residential Water Accounts - Number	22,232		
Residential usage, gallons/month/household	4,300		
Residential usage, gallons/day/person	54		
Total Residential Usage, gallons/day	**3,121,392**		
Non-Residential Water Demand			
Industry			
Industry - High Water Usage (>1,000,000 gal/mo)			
Number	5		
Ave demand gallons/day	83,579		
Total demand gallons/day	417,895		
Industry - Med Water Usage (100,000-1 Mgal/mo)			
Number	6		
Ave demand gallons/day	13,567		
Total demand gallons/day	81,402		
Industry - Low Water Usage (<100,000 gal/mo)			
Number	13		
Ave demand gallons/day	2,436		
Total demand gallons/day	31,668		
Total Industrial Demand, gallons/day	530,965		
Schools and Government			
Annual Growth Rate, 2003-2007	3.6%		
Annual Growth Rate, 2008-2012	3.0%		
Total Demand, gallons/day	176,756		
Commercial, Health Care and Other			
Annual Growth Rate, 2003-2007	3.6%		
Annual Growth Rate, 2008-2012	3.0%		
Total Demand, gallons/day	943,023		
Total Demand, Non-Residential, gallons/day	**1,650,743**		
Total Demand, All Users, gallons/day	**4,772,136**		
Water Loss Factor, %	23%		
Required Public Water Production, gallons/day	**6,197,579**	**4,923,993**	**11,121,572**
WATER DEMAND, PRIVATE WELLS			
Residential Water Demand			
Population on private wells			44,754
Total Residential Usage, gallons/day			**2,416,700**
Agricultural Water Demand			
Annual Growth Rate, 2003-2012			-5.0%
Total Agricultural Demand, gallons/day			**232,275**
Required Water Well Production, gallons/day			**2,648,974**
TOTAL WATER DEMAND, ALL SOURCES, GALLONS/DAY			***13,770,546***

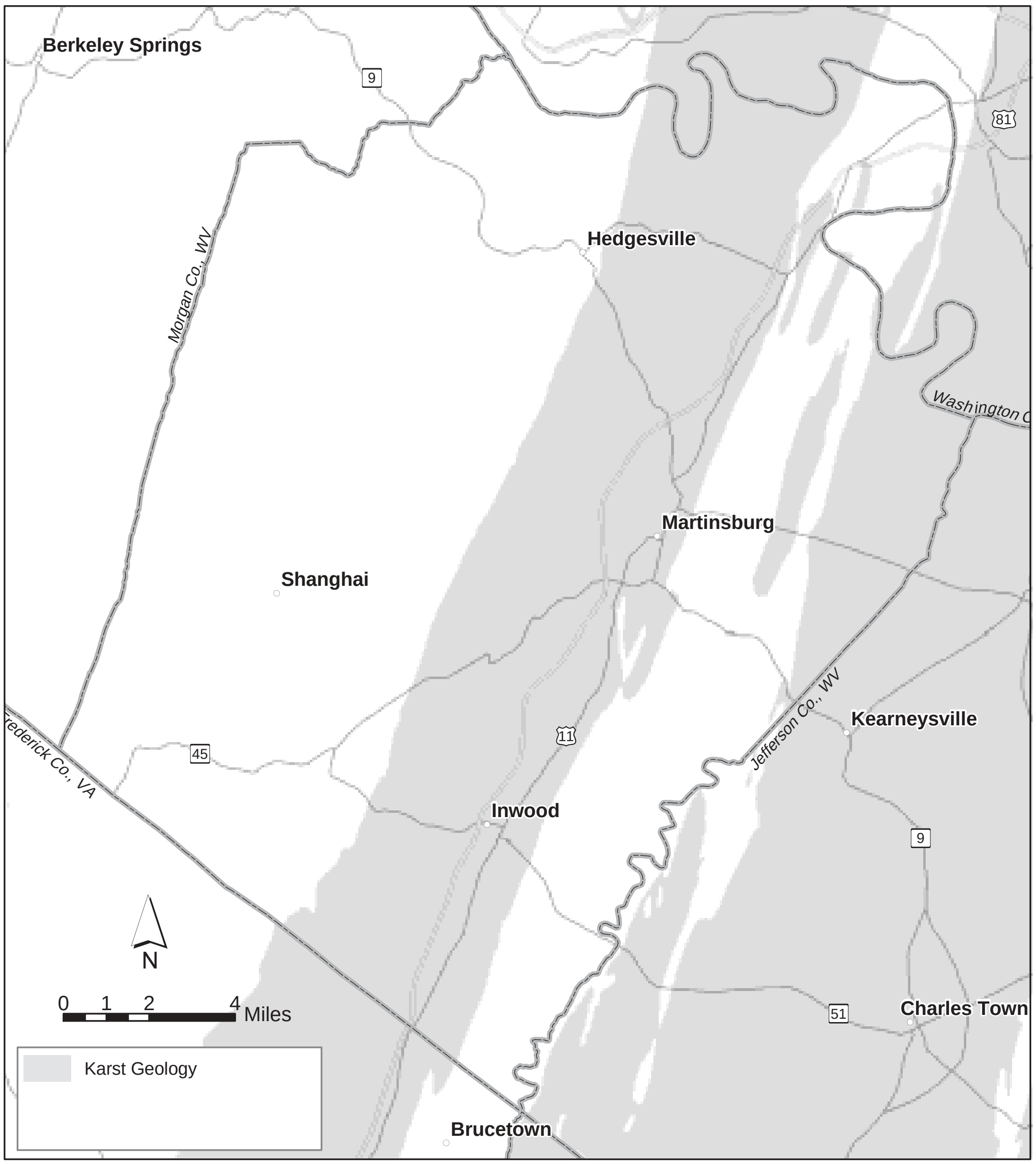
Projected Year 2023 Water Demand, Berkeley County, WV

Projected Data	BCPSWD	City of Martinsburg	Berkeley County
WATER DEMAND, PUBLIC SUPPLY			
Residential Water Demand			
Annual Growth Rate, 2003-2007	3.6%	2.1%	3.3%
Annual Growth Rate, 2008-2012	3.0%	2.1%	2.8%
Annual Growth Rate, 2013-2022	2.1%	2.1%	2.1%
Projected 2023 Population, persons	114,108	22,730	136,839
Population on public water	73,893	22,048	81,747
% of population on public water	54.0%	97.0%	59.7%
Residential Water Accounts - Number	28,420		
Residential usage, gallons/month/household	4,300		
Residential usage, gallons/day/person	54		
Total Residential Usage, gallons/day	**3,990,214**		
Non-Residential Water Demand			
Industry			
Industry - High Water Usage (>1,000,000 gal/mo)			
Number	6		
Ave demand gallons/day	83,579		
Total demand gallons/day	501,474		
Industry - Med Water Usage (100,000-1 Mgal/mo)			
Number	10		
Ave demand gallons/day	13,567		
Total demand gallons/day	135,670		
Industry - Low Water Usage (<100,000 gal/mo)			
Number	16		
Ave demand gallons/day	2,436		
Total demand gallons/day	38,976		
Total Industrial Demand, gallons/day	676,120		
Schools and Government			
Annual Growth Rate, 2003-2007	3.6%		
Annual Growth Rate, 2008-2012	3.0%		
Annual Growth Rate, 2013-2022	2.1%		
Total Demand, gallons/day	217,586		
Commercial, Health Care and Other			
Annual Growth Rate, 2003-2007	3.6%		
Annual Growth Rate, 2008-2012	3.0%		
Annual Growth Rate, 2013-2022	2.1%		
Total Demand, gallons/day	1,160,859		
Total Demand, Non-Residential, gallons/day	**2,054,565**		
Total Demand, All Users, gallons/day	**6,044,779**		
Water Loss Factor, %	23%		
Required Public Water Production, gallons/day	**7,850,362**	**6,061,426**	**13,911,789**
WATER DEMAND, PRIVATE WELLS			
Residential Water Demand			
Population on private wells			55,092
Total Residential Usage, gallons/day			**2,974,953**
Agricultural Water Demand			
Annual Growth Rate, 2003-2022			-5.0%
Total Agricultural Demand, gallons/day			**139,071**
Required Water Well Production, gallons/day			**3,114,024**
TOTAL WATER DEMAND, ALL SOURCES, GALLONS/DAY			***17,025,813***

APPENDIX F
MAPS

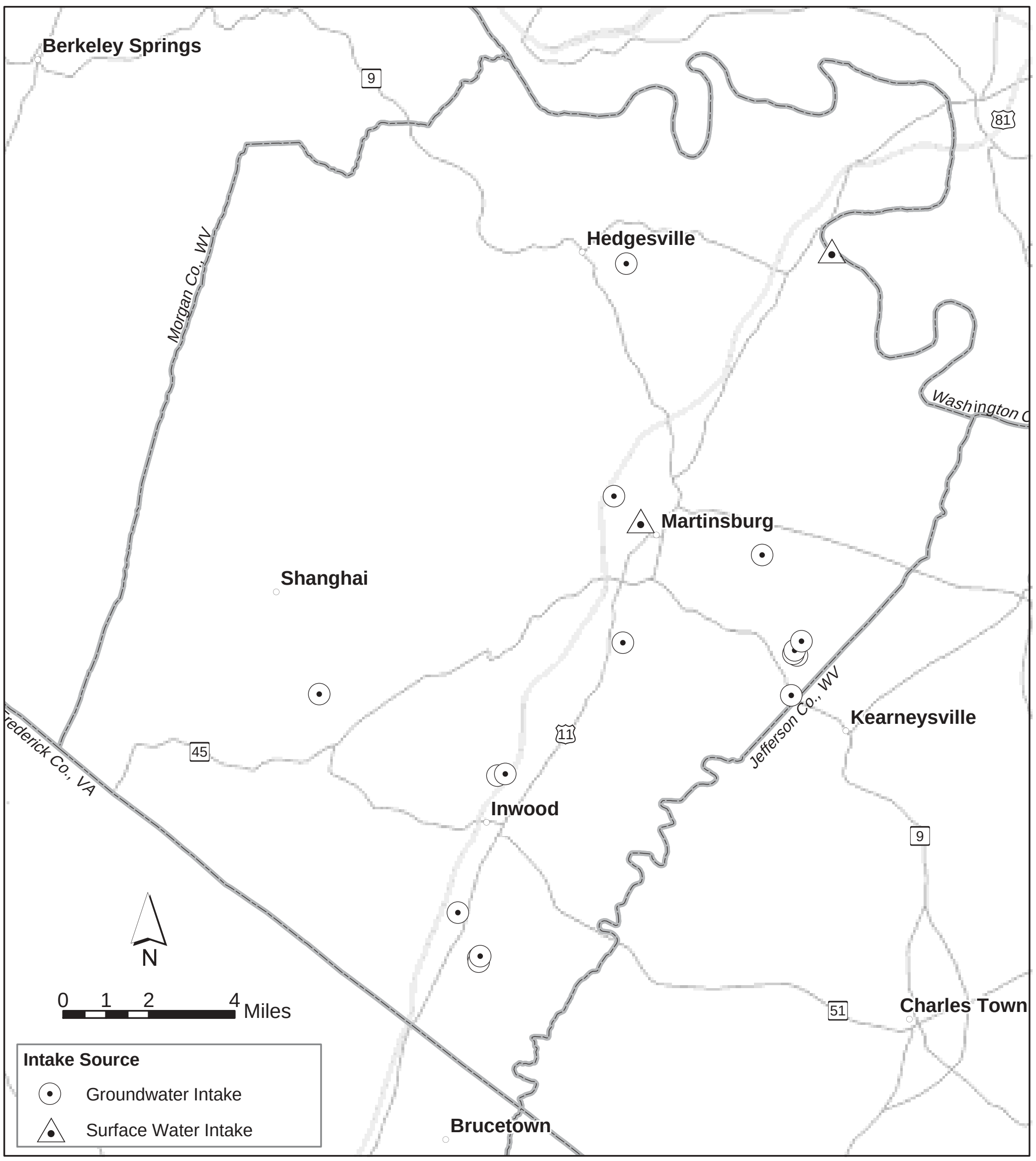
Map # 1. Karst Geology of Berkeley County

Description: A ribbon of carbonate geology runs through Berkeley County. This geology is a regional feature that is notable as a major source of groundwater. While it represents a zone of high yield (most major wells are located in it), it is also an area where pollutants may be able to quickly penetrate groundwater stores.



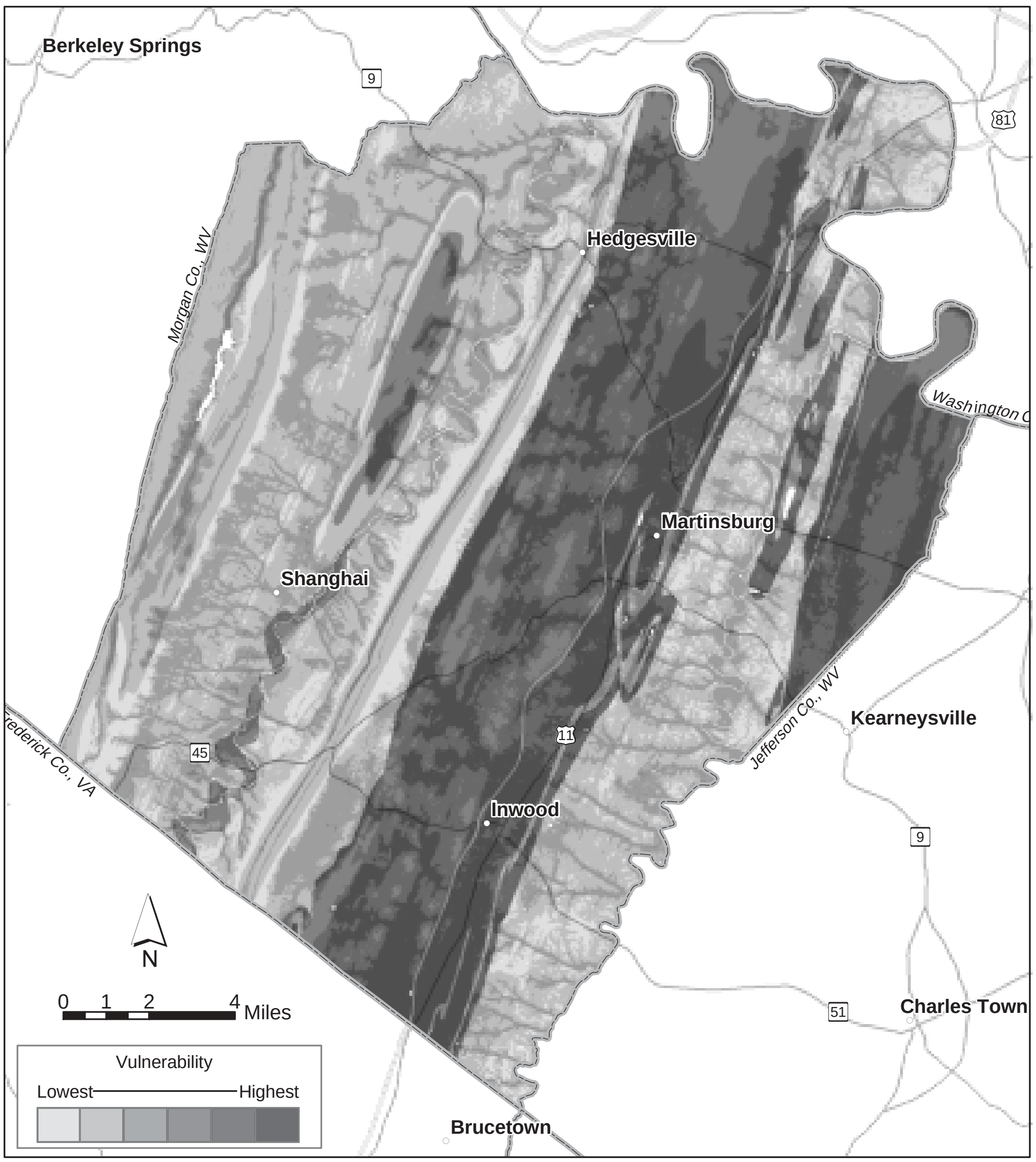
Map #2. Public Water Intakes (Ground and Surface) in Berkeley County

Description: The water intakes represented here include major public sources as well as small sources that supply a public facility with water. Water is drawn from both wells and from surface sources such as the Potomac River.



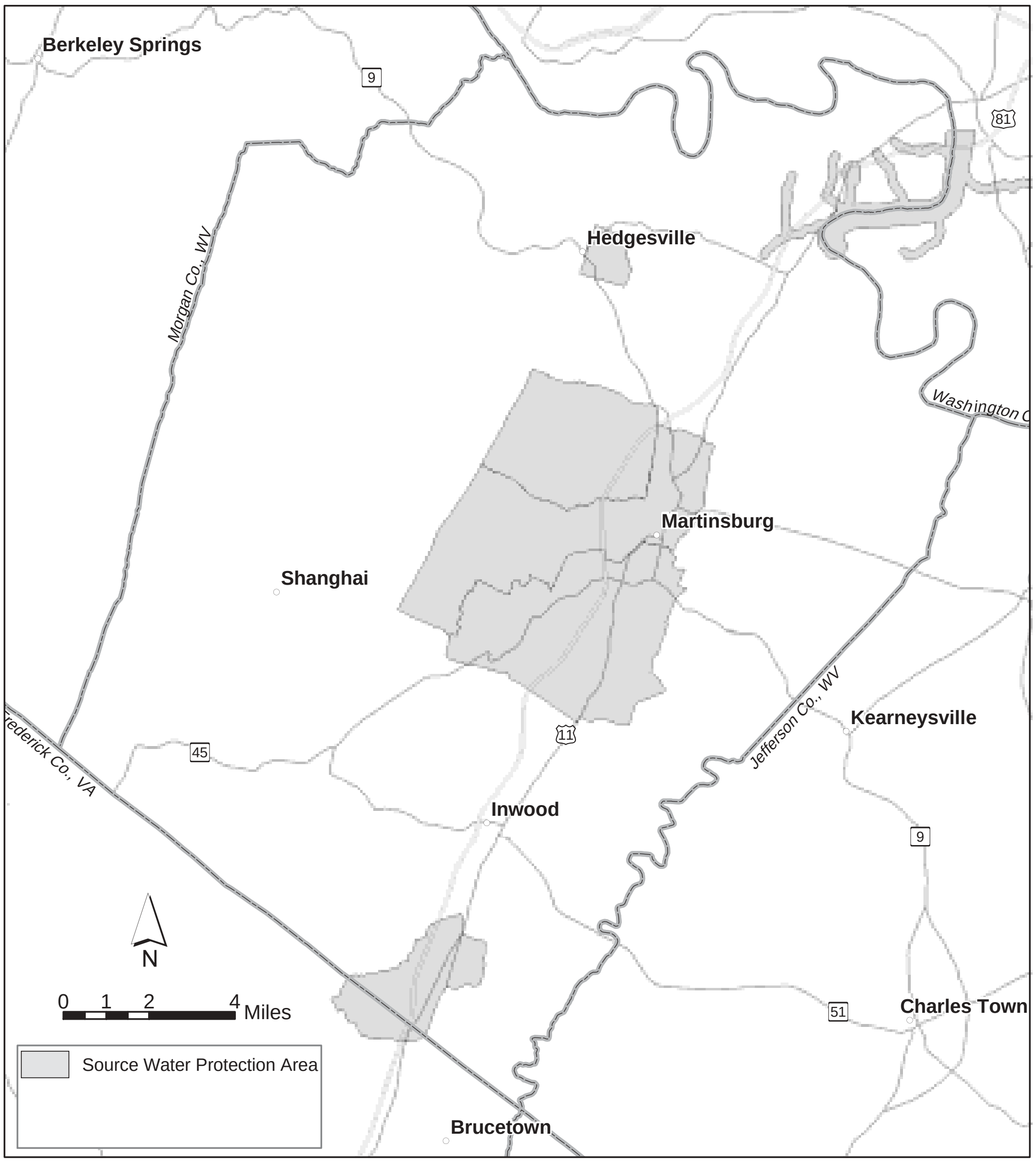
Map 3. Groundwater Vulnerability to Pollution in Berkeley County

Description: The mottled appearance of this map is a representation of groundwater pollution potential. The light shades demonstrate areas that are less vulnerable to pollution, while darker shades indicate areas of highest vulnerability. This map was created using a method of analysis called, DRASTIC. The DRASTIC methodology combines multiple criteria such as topography, geology, and soils to estimate vulnerability. It illustrates that groundwater vulnerability is influenced by many natural factors and can therefore vary from location to location.



Map # 4. Source Water Protection Zones in Berkeley County

Description: These zones have been established by the West Virginia Bureau of Public Health through map interpretation and modeling. Well Head Protection Areas and the Zone of Critical Concern along the Potomac illustrate land that contributes to a major public water supply. Contamination within these areas may make its way into the water supply.



APPENDIX G
TECHNICAL REFERENCES

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SWAP

Source Water Analysis & Protection Program

BERKELEY COUNTY, WEST VIRGINIA