west virginia department of environmental protection

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November 22, 2013

***Hand Delivered***

To: **The Joint Legislative Oversight Commission on State Water Resources**

c/o Jay Lazell and Robert Williams for:

The Honorable John R. Unger II
Senate Chair
Room 227M, Building 1
State Capitol Complex
Charleston, WV 25305

and

The Honorable Mike Manypenny
House Chair
Room 203E, Building 1
State Capitol Complex
Charleston, WV 25305

Re: ***Submittal of the West Virginia Water Resources Management Plan***
***W. Va. Code §22-26-1 et seq. Water Resources Protection and Management Act***

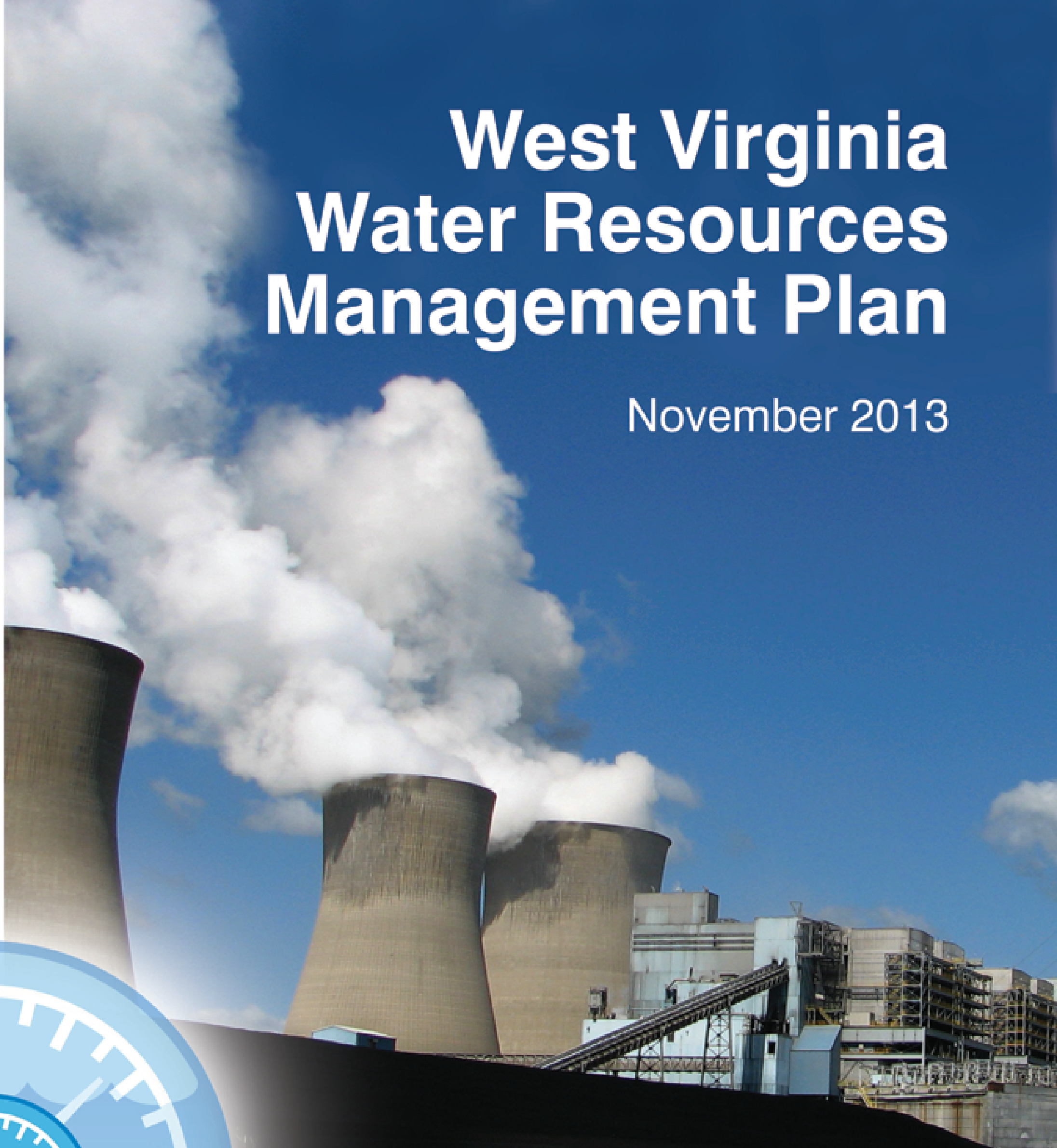
Dear Senator Unger and Delegate Manypenny:

As directed by the Water Resources Protection and Management Act (*W. Va. Code §22-26-1 et seq.*) amended and enacted in 2008, please find enclosed two copies of the State Water Resources Management Plan ("the Plan"), a companion report entitled "West Virginia Watershed Descriptions", a West Virginia Watershed Atlas, and instructions for access to a GIS based web-tool that can be found at http://tagis.dep.wv.gov/WVWaterPlan/.

The Plan Executive Summary will be submitted electronically via the State Agency Report Submission web-site to officially mark the submission date of November 22, 2013. A hard copy of the Plan and a Web-tool Instruction Manual will be presented to each of the Commission Members during the December 2013 Interim Session.

Sincerely,

Brian A. Carr, P.G.
Water Use Section Program Manager



# West Virginia Water Resources Management Plan

November 2013

WATER USE SECTION

west virginia department of environmental protection

# IMPLEMENTATION OF
# THE WATER RESOURCES PROTECTION AND MANAGEMENT ACT
# WEST VIRGINIA CODE, ARTICLE 22-26

Submitted to the Joint Oversight Commission on State Water Resources
West Virginia Legislature
November 22, 2013

Randy C. Huffman, Cabinet Secretary

West Virginia Department of Environmental Protection
601 57th Street, S.E.
Charleston, West Virginia 25304

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# Acronyms and Abbreviations

| Acronym | |
|---|---|
| 7Q10 | annual 7-day minimum flow with a 10-year recurrence interval (non-exceedance probability of 10 percent) |
| BMP | Best Management Practices |
| CBMP | Coal Bed Mapping Program |
| CEGAS | Center for Environmental Geotechnical and Applied Sciences |
| CEU | Continuing Education Unit |
| Cfs | Cubic Feet per Second |
| CMI | Crop Moisture Index |
| CPA | Critical Planning Area |
| CRN | USGS Climate Response Network |
| CWA | Clean Water Act |
| DCP | Data Collection Platform |
| DEP | West Virginia Department of Environmental Protection |
| DHHR | West Virginia Department of Health and Human Resources |
| DHSEM | West Virginia Department of Homeland Security and Emergency Management |
| DMR | WVDEP Division of Mining and Reclamation |
| DNR | West Virginia Division of Natural Resources |
| DOE | US Department of Energy |
| DOH | West Virginia Department of Highways |
| DWWM | Division of Water and Waste Management |
| EPA | Environmental Protection Agency |
| ESRI | Environmental Systems Research Institute |
| ET | Evapotranspiration |
| FEMA | Federal Emergency Management Agency |
| GED | Gallons per employee per day |

| Acronym | |
|---|---|
| GIS | Geographic Information System |
| Gpd | Gallons per day |
| GPS | Global Positioning System |
| GW | Groundwater |
| HUC | Hydrologic unit code |
| ICPRB | Interstate Commission on the Potomac River Basin |
| IFLOWS | Integrated Flood Observing and Warning System |
| IJDC | West Virginia Infrastructure and Jobs Development Council |
| LIDAR | Light Detection and Ranging |
| LQU | Large Quantity User |
| MDDNR | Maryland Department of Natural Resources |
| Mgal/y | Millions of gallons per year |
| Mgd | Millions of gallons per day |
| MPRWA | Middle Potomac River Watershed Assessment |
| MS4 | Municipal Separate Storm Sewer System |
| NAICS | North American Industry Classification System |
| NAWQA | USGS National Water-Quality Assessment |
| NHD | National Hydrography Dataset |
| NID | National Inventory of Dams (USACE Dataset) |
| NLCD | National Land Cover Database |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| NTNC | non-transient, non-community |
| NWS | National Weather Service |
| ORSANCO | Ohio River Valley Water Sanitation Commission |
| OSHA | Occupational Safety and Health Administration |
| PDSI | Palmer Drought Severity Index |

| Acronym | |
|---|---|
| POTW | Publicly Owned Treatment Works |
| PSC | Public Service Commission |
| PSD | Public Service District |
| RW | return flow and withdrawal rate |
| SAMB | West Virginia State addressing and mapping board |
| SIC | Standard Industrial Code |
| SIR | Scientific Investigations Reports (part of USGS publications) |
| SPI | Standard Precipitation Index |
| SRF | State Revolving Fund |
| SW | Surface Water |
| UIC | Underground injection wells |
| USACE | US Army Corps of Engineers |
| USDA | US Department of Agriculture |
| USGS | United States Geological Survey |
| WBR | Winter base-rate |
| WDA | West Virginia Water Development Authority |
| WRMP | Water Resources Management Plan |
| WVCA | West Virginia Conservation Agency |
| WVDA | West Virginia Department of Agriculture |
| WVDHSEM | West Virginia Department of Homeland Security and Emergency Management |
| WVDOH | West Virginia Division of Highways |
| WVDOT | West Virginia Department of Transportation |
| WVGES | West Virginia Geologic and Economic Survey |

# Definitions

**Agriculture/Aquaculture** (Water Use): a grouping of SIC codes (273,921,2048,9210,112510) related to the agriculture or aquaculture industries.

**Chemical** (Water Use) a grouping of SIC codes (2812,2821,2860,2869) related to the Chemical industry.

**Discharge:** Any release of water.

**Discharge Gage:** a stream gage that measures water flow.

**Frac Water** (Water Use): a grouping of SIC codes (1382,1389) related to the gas industry practicing Hydro-fracturing techniques for gas exploration.

**Groundwater**: water located beneath the earth's surface in caves, mined areas, soil pore spaces and in the fractures of rock formations.

**HUC**: A watershed address consists of a name and a number (for example, Little Kanawha watershed, 05030203). The 8-digit number is a **Hydrologic Unit Code** or HUC. The Hydrologic Unit system is a standardized watershed classification system developed by USGS in the mid-1970s. Hydrologic units are watershed boundaries organized in a nested hierarchy by size.

**Hydroelectric** (Water Use) : a grouping of SIC codes (4911) related to the hydroelectric industry.

**Industrial** (Water Use) : a grouping of SIC codes (2631,3069,3312,3313,3356,3695) related to companies classified as industrial.

**Intake**: Any conveyance utilized to withdrawal water at the source.

**LQU**: Large quantity user means any person who withdraws over seven hundred fifty thousand gallons of water in a calendar month from the state's waters and any person who bottles water for resale regardless of quantity withdrawn.

**Mining** (Water Use): a grouping of SIC codes (1211,1220,1221,1222,1241,1422,1446,1499,1611,4921) related to the mining industry.

**Petroleum** (Water Use): a grouping of SIC codes (2865,2911) related to the oil industry.

**Public Water Supply** (Water Use): a grouping of SIC codes (1623,4941,4951,4952,9223,9631) related to the supply of public drinking water.

**PWSID:** Public Water Supply Identification number.

**Recreation** (Water Use): a grouping of SIC codes (4971,7011,7033,7900,7990,7992,7997)related to the recreation industry.

**Secretary:** Cabinet Secretary of the West Virginia Department of Environmental Protection

**SIC Code**: Standard Industrial Classification Code is a United States government system for classifying industries by a four-digit code that was established in 1937.

**Staff gage:** a continuously functioning measuring device in the field designed to record the height of water in a stream or river.

**Stream gaging station**: an active, continuously functioning measuring device in the field for which a mean daily stream flow is computed or estimated and quality assured for at least 355 days of a water year or a complete set of unit values are computed or estimated and quality assured for at least 355 days of a water year.

**Surface Water**: "water" standing, diffused or flowing on the land surface including, artificial lakes, rivers, streams, creeks, branches, brooks, ponds, impounding reservoirs, watercourses and wetlands.

**Thermoelectric** (Water Use): a grouping of SIC codes (4911) related to the coal or gas burning power plants.

**Timber** (Water Use): a grouping of SIC codes (2421,2611,2861) related to the timber industry.

**Watershed**: "Watershed" means a hydrologic unit utilized by the United States Department of Interior's Geological Survey, adopted in one thousand nine hundred seventy-four, as a framework for detailed water and related land-resources planning.

**Water Resources**: "water" or "waters" means any and all water on or beneath the surface of the ground, whether percolating, standing, diffused or flowing, wholly or partially within this state, or bordering this state and within its jurisdiction and includes, without limiting the generality of the foregoing, natural or artificial lakes, rivers, streams, creeks, branches, brooks, ponds, impounding reservoirs, springs, wells, watercourses and wetlands: *Provided,* that farm ponds, industrial settling basins and ponds and waste treatment facilities are excluded from the waters of the state.

**Wetland**: a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem.  Primarily, the factor that distinguishes wetlands from other land forms or water bodies is the characteristic aquatic vegetation that is adapted to its unique soil conditions.

**Withdrawal**: means the removal or capture of water from water resources of the state regardless of whether it is consumptive or nonconsumptive: *Provided,* That water encountered during coal, oil, gas, water well drilling and initial testing of water wells, or other mineral extraction and diverted, but not used for any purpose and not a factor in low-flow conditions for any surface water or groundwater, is not deemed a withdrawal.

# Executive Summary

The Water Resources Protection Act ("Act" or "WRPA"), W.Va. Code §22-26-1 *et seq.,* was enacted March 13, 2004, and established the Joint Legislative Oversight Commission on State Water Resources. The Act was the first step in understanding the quantity and use of one of our most important natural resources, our surface and ground water. The Act created a foundation for developing a comprehensive water management program, requiring all large quantity users to register with the Department of Environmental Protection ("DEP"). In an effort to fill the state's data deficiencies, the Commission authorized the funding of a workgroup within DEP, called the Water Use Program, along with funding enhancing the state's groundwater monitoring and improving surface water gaging.

In 2008, the WRPA was amended and renamed the Water Resources Protection and Management Act ("Act" or "WRPMA"). In addition to claiming ownership of the waters of the state for the use and benefit of its citizens, the Act required the development of a State Water Resources Management Plan ("Plan"). Accordingly, DEP developed this Plan and companion tools, including a report entitled "West Virginia Watershed Descriptions," a West Virginia Watershed Atlas and a GIS based web-tool that can be found at http://dep.wv.gov/WVWaterPlan/.

Based on data DEP has collected in developing this Plan and its companion tools, there are 388 registered Large Quantity Users in West Virginia, whose average annual water demands are approximately 1.2 trillion gallons (excluding use by hydroelectric facilities). West Virginia is blessed with an abundance of water and receives approximately 19 trillion gallons of precipitation annually (an average of 44 inches per year). West Virginia has approximately 54,961 stream miles; 6,017 mine pools that could contain another possible 1.5 trillion gallons; and 399 fresh water lakes containing approximately 389 billion gallons of normal storage. A water budget estimated that the state's river systems can supply an additional average of 42 billion gallons of water per day. On average, the state's consumptive use is six percent of the total annual water withdrawn.

This Plan details past flooding and drought in the state, examines water infrastructure needs, describes the need for continued stream gaging and includes projections of future water use. The Plan also suggests continued improvements to the state's data collection and reporting procedures, which would lead to increased understanding of the state's water resources. Water is essential both to life and to West Virginia's economy and will forever increase in value. Because of the WRPMA, West Virginia now has a set of tools to protect this valuable resource.

# Summary

The West Virginia Legislature required the Department of Environmental Protection (DEP) to develop a Statewide Water Resources Management Plan (the PLAN) by enacting the Water Resources Protection and Management Act, W Va. Code §22-26 (the Act). The Plan is intended to protect and define the state's valuable water resources while promoting its availability for the public, tourism and industry. The Plan also considers the statewide economic development potential for industries dependent on a constant fresh water supply.

In order to satisfy the requirements identified in the Act, it was necessary for the DEP to collect large volumes of data, research procedures necessary to implement the Act and formulate scientific protocol and methods to define the state's water resources. This was set in motion by creating the Water Use Section in 2008. By 2011, the Water Use Section was fully staffed, including a program manager, an environmental resources analyst, a computer technician and two environmental scientists.

The Act claims ownership of the waters of the state to be held by the state for the use and benefit of its citizens. A significant requirement of the Act was to quantify and inventory the state's surface water and to determine its "safe yield" (the maximum sustainable withdrawal that can be made continuously from a water source). Determining the amount of water in the state is a daunting task in that this quantity is always changing depending on the amount of rainfall we receive at any given time in any number of isolated areas. Take for instance the average annual rainfall for our state over the past 29 years shown in Figure A-1.

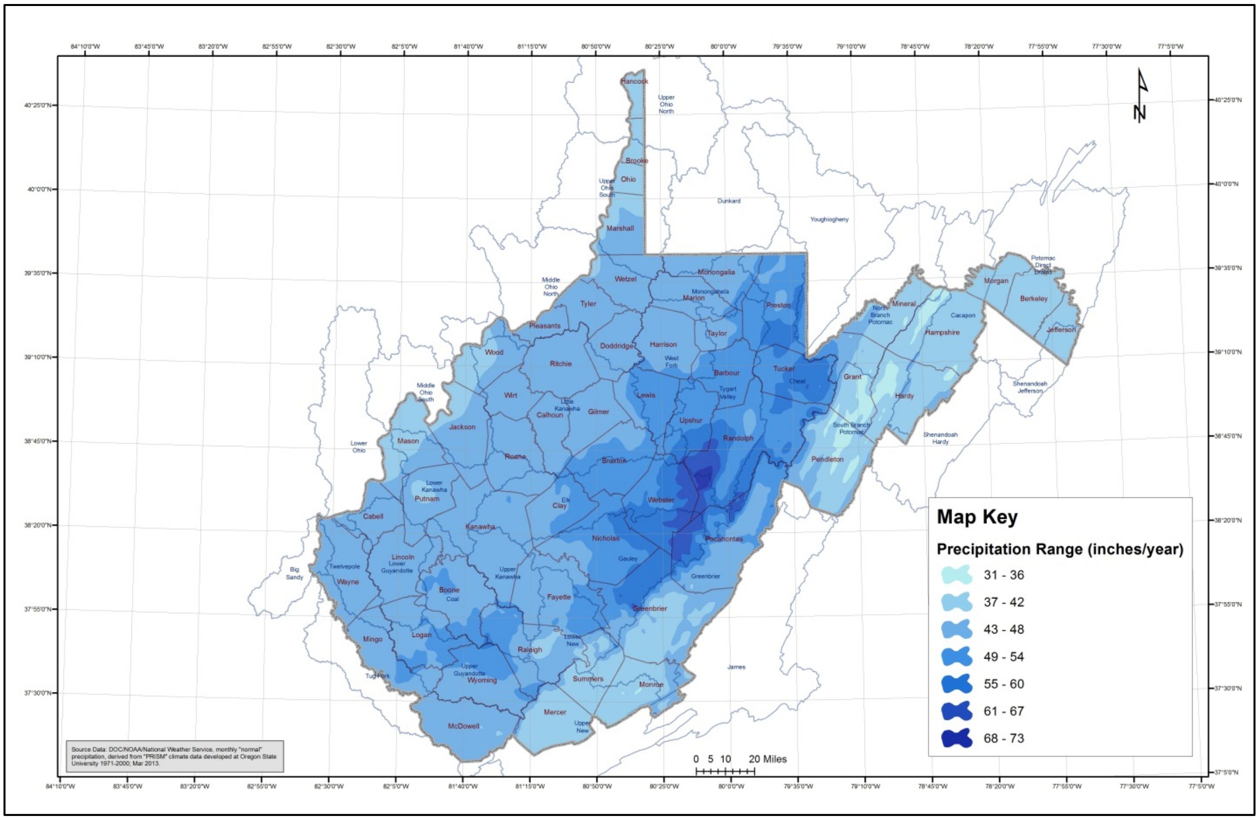



**Figure A-1 Average annual precipitation across West Virginia, 1981-2010.**

The precipitation amounts in Figure A-1 depict the average conditions in our state. Especially notable is the above-average rainfall along the western side of the Appalachian Mountain Range. The mountains metaphorically squeeze the rain from the clouds as they pass over the mountains and create a rain shadow, or lack of rain, on the opposite side shown in Figure A-2. Our state receives an average of 44 inches of precipitation annually. One can calculate an amount of available water based on these average numbers and estimate an annual total of 19.3 trillion gallons of water, but it would be necessary to assume the future precipitation will be consistent and evenly distributed on a daily basis, which will likely not be the case.

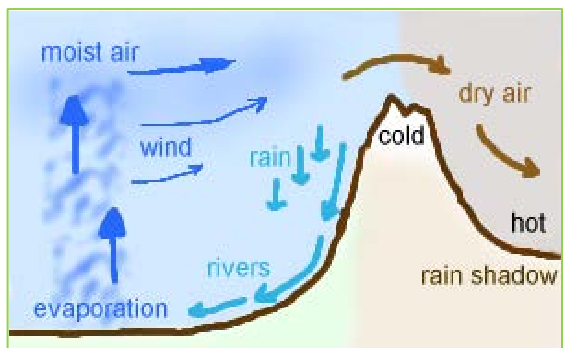



**Figure A-2 Rain Shadow effect**

Our best, and many times, our only source of reference to determine the amount of water in our streams are the USGS stream gages in a network that includes 85 individual stations as of 2013. There were 115 in 1977, and once again funding for these gages is being threatened by budget cuts. The gages are funded by 17 different entities, with the majority funded by the DEP, United State Army Corps of Engineers (USACE), West Virginia Conservation Agency (WVCA), West Virginia Department of Highways (DOH) and the United States Environmental Protection Agency (EPA). The existence of these gages is imperative to the ability to manage our state's water resources. Therefore, every effort should be made to protect the funding and strive to increase the number of gages in the future.

The Act requires identification of the quantity of water being withdrawn and the nature of those withdrawals, both consumptive and non-consumptive. The DEP developed a Large Quantity User Registration survey, requiring anyone withdrawing more than 750,000 gallons per month to report their water use. There are currently 388 large quantity users withdrawing approximately 1.2 trillion gallons of water annually. Our statewide consumptive use was estimated utilizing the highest potential projections for the year 2020 to be 125.3 billion gallons each year. This consumptive use estimate includes the predicted quantity of water that will be consumed for hydro-fracturing of the Marcellus Shale. It should be noted that the total amount of water used for hydro-fracturing of the Marcellus Shale is less than 1% of the state's total annual water use. Based on the 2020 projected consumptive water use quantities and the results of the water budget as discussed below, it is not likely that the states demand for water will outgrow its water resource availability.

The USGS has been collecting stream flow data since the 1930's. Caution must be exercised when using stream flow data from the average of the past thirty years data, since we have been experiencing above-normal stream flows for that period of time. It is possible that we will continue to benefit from these higher-than-normal stream flows in the future, but we could also experience much drier conditions in the future, reminiscent of the conditions experienced in the 1930's during the Dust Bowl. Figure A-3 shows the departure of minimum stream flows as compared to the average stream flow over the past 72 years for selected stream gages. The red shows drier than average conditions and the blue indicates wetter than average conditions, based on the amount of water flowing in the streams.

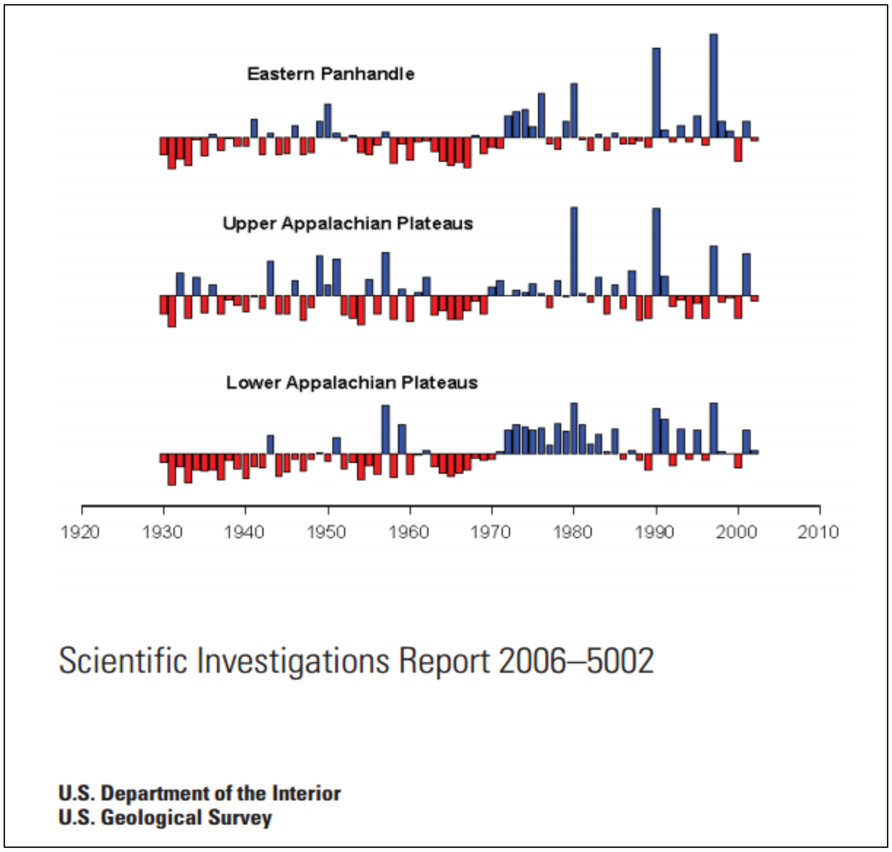



**Figure A-3 Average standardized departures of the minimum flows from the record-period average for 1930-2002 for selected stations in West Virginia**

If the climatic conditions reverted to what we experienced in the 1930's through the 1960's, our state would have significantly less available water than we currently have. Climate changes could also result in an increase in average annual rainfall and we could have significantly more available water. Some experts suggest that we will experience the same amount of annual precipitation produced by fewer, but more intense rain events. We need to be prepared for any of these possibilities. Currently, we are considered a water-rich state, but still can have near drought conditions in the mid-summer months.

To estimate the amount of water available for use, we have developed a water budget for each of the 32 Eight Digit Hydrologic Unit Code (HUC-8) watersheds in the state, as shown in Figure A-4 grouped in regions. The primary water source for the majority of our watersheds is precipitation. The water budget method has been adopted because it can be applied almost anywhere precipitation data is available.

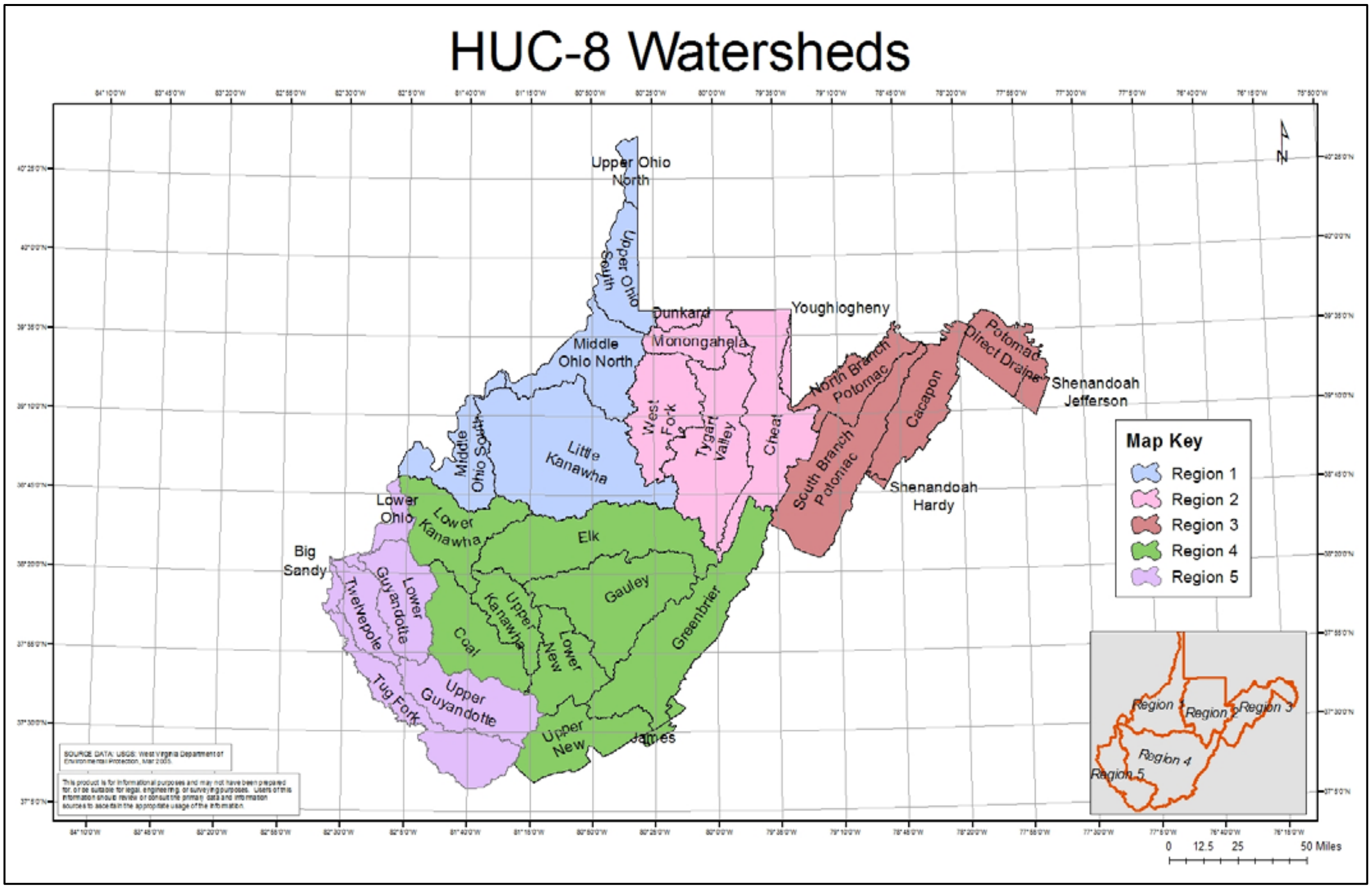



Figure A-4 HUC-8 Watersheds and Regional Grouping

A drawback of the water budget method is that the available water is estimated as the residual term in an equation where the other budget terms are estimated with some degree of error. The amount of water that flows into a watershed, as well as the water that must be allowed to flow out of the watershed to guarantee water quality downstream, must also be estimated (see Chapter 3 for individual watershed numbers). Of course, these quantities are at the outlet end of the watersheds, so if you are in the middle of the watershed there would be approximately half that amount of water available.

A computerized water budget model is under development which will estimate our state's available water resources based on past record and possibly on real time and predicted future conditions. The amount of water that is available for use is dependent on many variables, some controlled by man and some controlled by nature, all continually changing. This computer model is expected to allow us to take that snapshot in time of the available water in any localized region of the state at any time the information is needed. We can then project future availability based on both best and worst case scenarios, regardless of where you are in a watershed.

Groundwater in West Virginia is substantially more difficult to evaluate. Our state's structural geology is so complex that our groundwater resources can only be accurately determined for individual localized regions and performing hundreds of small localized groundwater studies falls well beyond the scope of this survey. The DEP contracted with the WV Geological and Economic Survey (WVGES) to compile a mine pool atlas to identify the known pooled water in mined out coal seams across West Virginia. There is a portal on the Water Resource Management Plan website for anyone to report the location of their private wells and their depth to groundwater. The DEP funded and assisted in the geophysical well logging of the applicable groundwater monitoring wells in the state, the results of which are included in Chapter 1. A number of WVU Master's theses and studies involving groundwater have been gathered for review and a USGS/DEP groundwater quality report has been published (USGS SIR 2012-5186). Along with this data, previously conducted USGS studies, a new USGS groundwater study to be conducted over the next four years and continuation of the DEP's cave and sunken stream studies, the DEP will continue to advance groundwater knowledge in the state.

To help visualize all the elements required for successful water resource management, we have utilized the computer software created by Environmental Systems Research Institute (ESRI) called ArcMap version 10.1 to create an online Web tool. This software links large quantities of information from multiple sources together, and then allows the user to locate the information by selecting icons on a map. All of the state's watersheds, streams, permitted lakes, impoundments and other water related data sets have been mapped and are fully searchable via the website. The website was created to work symbiotically with this report. This website will be a continually updated tool for water management in the state. The tool can be found at the following internet address:

http://tagis.dep.wv.gov/WVWaterPlan/

The website has proven to be very useful for depicting spatial coverage's like state parks, wildlife management areas, scenic rivers and protected lands.

A flood occurs when a rain event is too intense or lasts too long, producing a larger quantity of runoff water than the surface drainage system can handle. In West Virginia, floods are caused by three general storm types: scattered thunderstorms typically during late afternoon and evening in summer, larger frontal systems, and tropical cyclones, which include hurricanes and tropical storms, in late summer or early fall (Doll and others, 1963). In addition, rainfall combined with snowmelt may cause floods in early spring. Extreme flooding generally can be expected on small streams during the summer and on larger streams during late fall or winter. Intense thunderstorms are probably the most dangerous because they generally produce flash floods with little or no warning. Because the terrain of West Virginia consists of many small basins, much of the state is subject to this type of flood. The most devastating floods are caused by hurricanes or tropical storms. These storms generally are most intense on the eastern slopes of the Potomac River Basin and the upper parts of the New River Basin.

The flood of November 4-5, 1985, replaced the 1977 flood as the most devastating in the State. Forty-seven lives were lost, thousands were left homeless, and about 500 bridges were destroyed. Rainfall estimates for the two-day storm were as much as 20 inches along the Eastern Divide between the Ohio River and Potomac River drainages in eastern West Virginia and western Virginia.

The opposing weather phenomenon of a flood is drought. Droughts are characterized by unusual northward expansion of the thermodynamically stable, warm, subtropical high-pressure systems that are in the mid-atmosphere during the summer (Davies and others, 1972). The presence of high-pressure systems greatly decreases afternoon thunderstorms. In addition, flow patterns associated with this type of system tend to keep frontal systems and the attendant precipitation to the north and west of the state. Generally, droughts are less of a problem than floods in West Virginia. However, even short-term droughts can be detrimental to local agricultural communities and can limit surface-water supply.

The drought of 1929-32 was the most severe in West Virginia's recorded history. Some streams that have drainage areas greater than 900 square miles had periods of zero flow during the summer and fall of 1930. At some precipitation stations, annual precipitation was about one-half of normal. The WV Conservation Agency (WVCA), The WV Department of Agriculture (WVDA) and the WV Department of Homeland Security and Emergency Management (DHSEM) are the lead agencies for Flood and Drought. The WVCA published the West Virginia Statewide Flood Protection Plan in 2005 and DHSEM published a statewide Drought Response Plan, Annex U of the West Virginia Emergency Operations Plan in 2008. It is not the intent of this Plan to replace or supersede any findings or recommendations made in either of the aforementioned documents.

When dealing with water management issues, a key component is conservation. We have identified three main categories currently being utilized in our state and surrounding states:

- Improving water use efficiency through implementation of use reduction methods or equipment
- Reusing or recycling water onsite
- Reducing water loss due to leaks and unaccounted water

Various methods that fall under these categories are defined and described in Chapter 5 of the Plan. The DEP will also be establishing a Water Conservation Award and will present it at the DEP's Annual Awards Ceremony.

Water and sewer service in the state continues to be a top issue in water resource management. Not only the ability to continue to provide service to existing customers but also to build the infrastructure necessary to serve our rural citizens who are doing without municipal water and sewer service. There is an obvious environmental issue with the lack of sewer service much of the poorly treated water ends up in our streams. However, the Infrastructure and Jobs Development Council (IJDC) has gone a long way to fulfilling the requirement of pushing the sewer and water system upgrades and projects along, and have mapped the extent of water and sewer coverage in the state (see IJDC Website http://gis.wvinfrastructure.com/). Some current and near future water supply issues in the state have been identified by the DHHR Infrastructure and Capacity Development Office as described in Chapter 5 of the Plan. These areas would be considered for review as a critical planning area (CPA).

The Act stipulates that the Secretary may designate an area as a CPA. A process has been established to allow such areas to be nominated, evaluated, and ultimately designated as a CPA, including a set of minimum requirements and specified timetables for nomination and plan development. This four-stage process is fully defined in Chapter 6 of the Plan. The section of the Act that stipulates that a CPA process be identified can be interpreted in more than one way. Pocahontas County's plan was developed pursuant to W.Va. Code §22-26-9 (f) & (g), which states that a county may enter into an agreement with the DEP to develop a local plan that will be filed as part of the Plan. It is the belief of the Pocahontas County Water Resources Task Force that the community will be best served by creating its own WRMP—one tailored to and created by the people of Pocahontas County. The Pocahontas Plan has been included as Appendix AA.

During activation of the Large Quantity Users registration and review of the Office of Oil and Gas Water Management Plans, the Water Use Section found itself continually asking what our legal powers and restraints were. The Act also required a review of statutes, rules and policies. We employed the DEP Office of Legal Services to compile all water law in the state including ownership of the bordering rivers. The Water Law Review has been included in the Appendices and is posted as a link on the Water Use Section page of the DEP website (http://www.dep.wv.gov/WWE/wateruse).

Lastly, completion of this Plan was an important water management step taken by the Legislature and it marks a major milestone in water resource protection and management in the state. Not only can West Virginians benefit from its data, but those outside the state's borders are encouraged to make use of the Plan, as well as the expertise developed by the agency staff in its compilation. Water is essential to both life and West Virginia's economy. It will forever increase in value. That's why wise management of the state's water resources is so important.

# Acknowledgements

Without the assistance of numerous individuals within the Department of Environmental Protection (DEP), other state and federal agencies, academia, and the private sector, compilation of this report would not have been possible.

The DEP would like to thank the following groups for their assistance: West Virginia Legislature's Joint Legislative Oversight Commission on State Water Resources; U.S. Army Corps of Engineers; U.S. Environmental Protection Agency; U.S. Geological Survey WV Water Science Center; U.S. Fish and Wildlife; WV Bureau for Public Health; WV Geological and Economic Survey; WV Water Gaging Council; Public Service Commission of WV; WV Division of Natural Resources; WV Department of Agriculture; WV Division of Homeland Security and Emergency Management; WV Rural Water Association; WV Conservation Agency; WV Water Development Authority; WV Infrastructure and Jobs Development Council; WV Department of Health & Human Resources; Pocahontas County Task Force; and The Nature Conservancy.

West Virginia is a member of the Ohio River Valley Water Sanitation Commission, Interstate Commission on the Potomac River Basin, and has signed the Chesapeake Bay Agreement. Through these various memberships, the state partners with many of its neighboring states including Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, Maryland, Delaware and the District of Columbia. During discussions in formulating this Plan, these multi-state partnerships have been effective in serving as a forum for understanding interstate water issues.

Special thanks to the Center for Environmental, Geotechnical, and Applied Science at Marshall University for assistance with database and website design, the Water Research Institute at West Virginia University and Interstate Commission on the Potomac River Basin for contributing to the research necessary for this report. Special thanks also to the U.S. Geological Survey for providing data utilized in this report, and the West Virginia Geologic and Economic Survey for providing the Mine Pool Atlas. In addition, the DEP extends special thanks to its Information Technology Office through its Technical Applications and Geographic Information System (TAGIS) for assistance in developing in-house and online services for this report.

# Introduction

The Water Resources Protection Act, W.Va. Code §22-26-1 *et seq.* enacted March 2004, authorized the establishment of a Joint Legislative Oversight Commission on State Water Resources. As the implementing agency for the Act, the DEP was required to submit a yearly progress report to the Commission and a final report to the Joint Committee on Government and Finance. A final report titled "Water Resources Protection Act - Water Use Survey" was submitted in December of 2006. That report suggested the following:

- Develop a statewide water management program
- Address data deficiencies
- Add five groundwater monitoring wells in high-growth areas
- Identify groundwater monitoring wells through electronic logging
- Add three stream gages in western West Virginia
- Continue the Large Quantity Users Registration program
- Develop a standardized definition of drought

The Water Resources Protection Act was amended in 2008 and renamed the Water Resources Protection and Management Act (the Act). Again, the DEP was named the implementing agency for the Act, and was required to submit yearly progress reports and a final report to the Joint Legislative Oversight Commission on State Water Resources by November 30, 2013. This report, along with a West Virginia Watershed Atlas and a GIS based web-tool have been prepared in order to meet the requirements set forth in the Act. A copy of the Act may be found in Appendix A.

In order to initiate the development of a statewide water resource management program, an assessment of programs conducted in border states was undertaken. Several of the border states chose to organize their water planning process by local and regional government jurisdictions Table B-1. For example, Kentucky assigned water resource planning to 15 area development districts (ADD), each encompassing multiple counties, while Maryland and Virginia more loosely assigned responsibility to local jurisdictions such as single counties and other municipalities. By using this division, responsibility is split between state environmental and planning/infrastructure agencies. Ohio and Pennsylvania have designated local governments and sub-regional watersheds within larger area watersheds as the responsible parties for developing water resource plans to contribute to the overall state plan, thereby leaving the entire process in the hands of the respective environmental agencies. Within each overall management plan some additional resources are made available to the responsible parties to aid in their planning process. All of the border states, except Virginia, have developed an interactive online tool with varying degrees of information and capability. More detail regarding the type of web-tool the DEP has created and information available may be reviewed in (Appendix B). Kentucky, Pennsylvania, and Virginia assigned coordinators, committees and councils, respectively, to provide consultations and information. Maryland developed a models and guidelines document.

**Table B-1 Current progress of border states and available resources regarding a comprehensive statewide water management plan**

| BORDER STATE | DELEGATION OF RESPONSIBILITY | STRUCTURE | ADDITIONAL PLANNING RESOURCES | RELATED DATABASE MANAGEMENT |
|---|---|---|---|---|
| KY | Kentucky Infrastructure Authority (KIA) http://kia.ky.gov/default.htm Environmental Protection Cabinet Division of Water http://water.ky.gov/Pages/default.aspx | 15 area development districts (ADD) by groups of county governments | ADD Water Management Coordinators – provide consultations and information | KIA Water Resource Information System (WRIS) – GIS, facilities, lines, sources, facilities, and projects |
| MD | Maryland Department of Planning (MDP) http://www.mdp.state.md.us/OurWork/WaterResources.shtml Maryland Department of Environment (MDE) http://www.mde.state.md.us/programs/water/water_supply/ | Local jurisdictions – counties and municipalities | Models and Guidelines document – Planning for Water Supply and Wastewater and Stormwater Management | MDP interactive maps – Priority funding, land cover, ag., census 2010 (demographic / economic outlook), schools, political districts |
| OH | Ohio Department of Natural Resources (ODNR) Division of Soil and Water Resources http://www.dnr.state.oh.us/water/ | 5 Major watershed regions and communities and sub-regional hydrologic units | ODNR Water Inventory Program – precipitation, groundwater levels, reservoir storage, and stream flow data | ODNR Action Plan Map, links local plans with a state endorsement status regarding supply, quality, flooding, and land mgmt. |
| PA | Pennsylvania Department of Environmental Protection (DEP) Office of Water Management http://www.portal.state.pa.us/portal/server.pt/community/watershed_management/10593 | 6 Regional watersheds and local governments | State Water Plan Committee meetings and training, withdrawal data, WAVE and eMap PA tools for resource and environmental data, and stream stats | State Plan/ Digital Water Atlas an Interactive web GIS tool - Plan areas, resources, storm/flooding maps, geology, land cover, supply and WWT |
| VA | Virginia Department of Environmental Quality (DEQ) http://www.deq.virginia.gov/Programs/Water.aspx | All counties, cities, and towns | State Supply Plan Advisory Committee, Proposed State Work Plan | Status of Virginia's Water Resources: A Report on VA Water Resources Management Program Activities, 2011 |
| SRBC | Susquehanna River Basin Commission http://www.srbc.net/about/index.htm | 4 Commissioners (Federal, PA, MD, and NY) for entire Susquehanna basin | Biannual Water Resources Program used to implement the "actions needed" listed in the Comprehensive Plan (updated every 5 years) | SRBC Maps & Data Atlas includes maps, downloadable GIS data, and a current projects map gallery |

In accordance with the objectives to be considered in the State Water Resources Management Plan (the Plan) outlined in §22-26-8(d), stakeholders listed in §22-26-9(c) and others were engaged through local meetings that were organized by USGS 8-Digit Hydrologic Unit Code (HUC-8) watersheds. The meetings were held in central locations within each watershed at various locations ranging from the DEP training rooms, local fire departments and conference centers to hotel meeting spaces. Beverages, snacks and lunches were provided in consideration of the various distances stakeholders may have had to travel to attend meetings. Invitations were sent to stakeholders in each watershed (including, but not limited to, state agency representatives, county commissioners, mayors and other elected officials, watershed association members, economic development council members, city planners and engineers, flood plain managers and large quantity users).

Stakeholders in attendance (see Figure B-1) were provided with a thorough presentation to educate and inform them about the purpose and progress regarding the Plan and the information currently collected relating to their respective watershed. In the second half of the daylong meetings, the attendees were provided with group discussion questions aimed at obtaining local information that should be considered in the Plan. Issues addressed during discussions were future industrial development, population shifts, groundwater concerns, reservoir construction, drought response, stormwater runoff and other topics related to water resource management relevant to the given watershed meeting being conducted. Specific questions were developed to guide the discussions and address the following topics; development, population trends, drought/flood issues, groundwater and wells, local water agreements, precipitation data, recreational uses, resource areas and competition for resources.

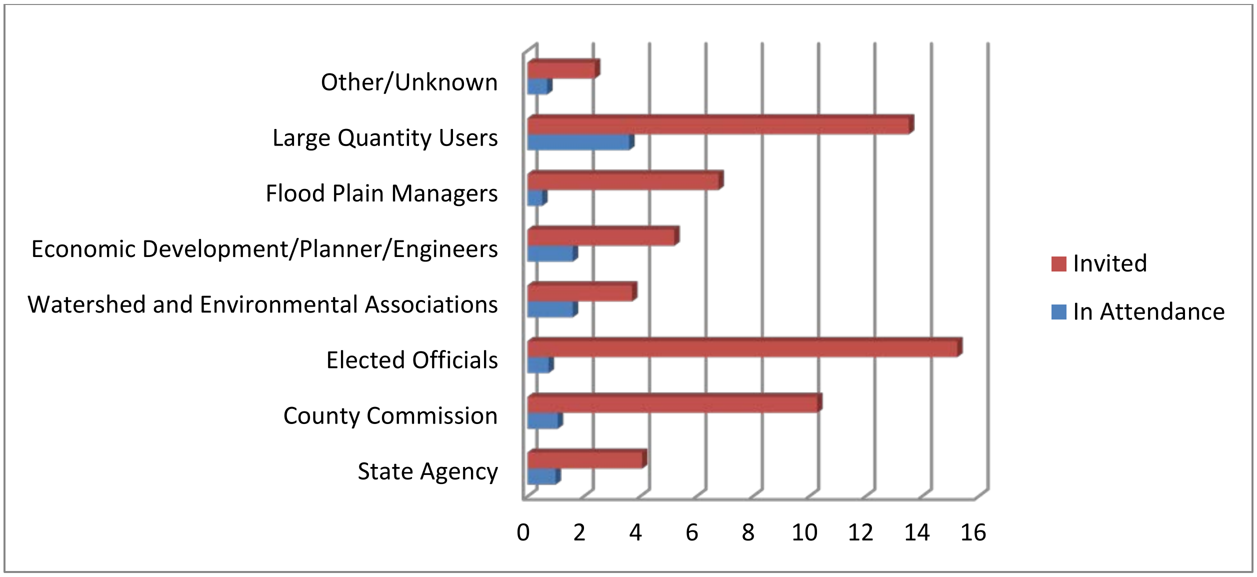



**Figure B-1 Average invited vs. in attendance to each watershed meeting by group**

Meeting organizers recorded attendance and made note of the agencies represented. The discussion questions were in the form of short answer, and the final questionnaire was yes/no format with an opportunity for additional comments and suggestions at the end. Additionally, attendees were given the opportunity to volunteer to serve as a contact for the DEP as a support group member. For further explanation of the information obtained and limitations see Appendix C.

For organizational purposes, and the fact that water does not obey political boundaries, the state's water resources were analyzed based on HUC-8 watershed boundaries. There are 32 HUC-8 watersheds in the state, 14 fully within its borders and 18 crossing into the border states. These HUC-8 watersheds were grouped into five regions to simplify a future regional approach to water resource management.

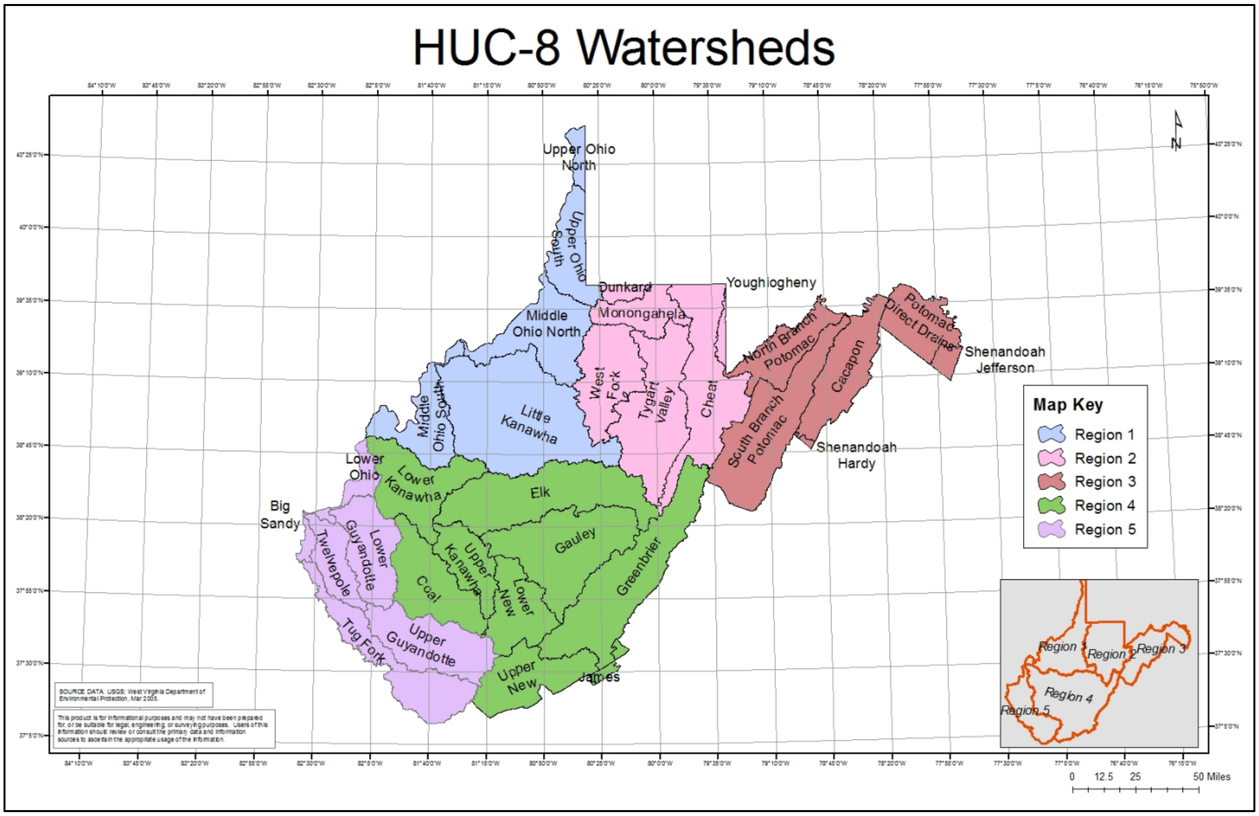



Figure B-2 HUC-8 watersheds

In order to address all of the requirements set forth in the Act, an inclusive approach was taken to review all of the elements in a comprehensive manner. The following describes the organization of the Plan and highlights requirements and considerations:

Chapter 1 serves as an inventory of the state's surface and groundwater resources. Key details include the quantity of rivers, streams, lakes, and reservoirs. Essential to this discussion is an explanation of the tools used to measure or monitor these resources, specifically the USGS Stream Gaging Network with an updated list of all the gages in the network. A plan for identification of the groundwater aquifers across the state is discussed in this chapter. Also included are the details of the geophysical well logging of the state's groundwater monitoring network, the addition of five groundwater monitoring wells, and a description of the creation of an atlas of our state's mine pools. Ways to improve data collection related to the resource are also discussed, including the fact that the USGS is doing a regional aquifer study that will improve our ability to identify the groundwater resources in our state.

Chapter 2 can be viewed as quantification of existing demands on surface and groundwater resources, or simply “water use.” The continuation of the Large Quantity Users Registration program and the efforts made to improve its accuracy are described. The chapter provides detailed descriptions of water use by watershed and industry type regarding water withdrawal data collected since 2005. An explanation of the methodology used to collect, analyze, and improve the data is provided. The information gathered about water use provides the DEP with valuable insight into the state’s use of its water resources. The continued collection of this data will enable future water management professionals to make better water resource decisions.

Chapter 3 addresses the concept of safe yield by calculating a water budget. The budget estimates the quantity of available water in each of the watersheds. The ultimate goal of a water budget is to estimate the quantity of water available for use in a system after all other natural and anthropogenic factors are considered. As explained in the chapter, calculations of water budgets rely on assumptions with inherent error. In order to reduce the associated error, the DEP has collaborated with CEGAS to complete phase I of an additional study that may serve as a prelude to an improved water budget.

Chapter 4 projects the future water needs of the state. Projections of high and low consumptive-use scenarios regarding Large Quantity Users are presented, along with justifications and rationale. Non-consumptive uses in unique natural, scenic, environmental, and recreational areas are identified. Potential studies to determine the amount of required water in these areas of concern are discussed.

Chapter 5 presents a review of other factors that affect water availability. Included is a brief history of the major flood and drought occurrences, as well as how these events are defined and managed during emergencies. The availability of public water supply and sewer services in the state is discussed. Also included is an evaluation of the ability of public water suppliers to meet their demand, using data from multiple state agencies. Anthropogenic factors such as changes in land cover and land use has also been included in this chapter, along with potential water conservation methods and conflicts. Suggestions are outlined for the continued improvement of data collection and interagency collaborations.

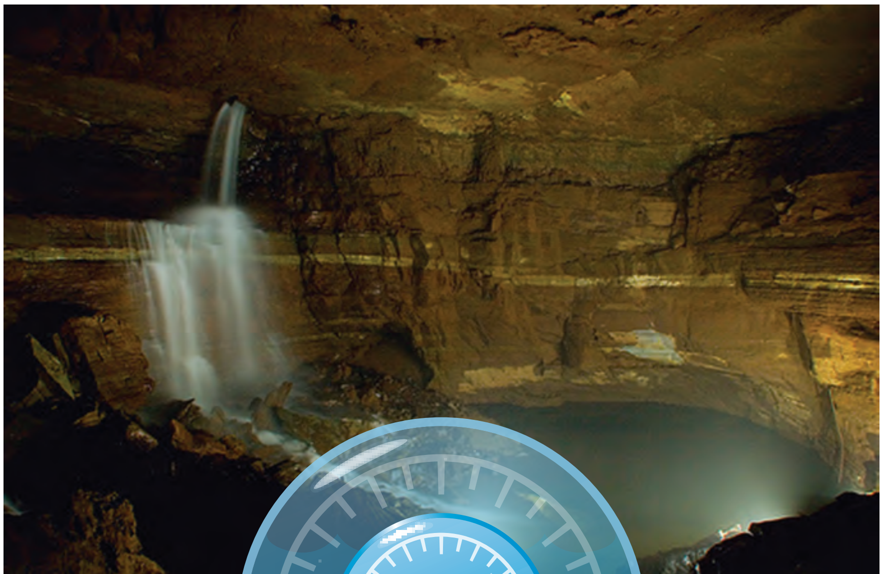
Chapter 6 describes the process necessary to declare an area a “Critical Planning Area,” (CPA) which refers to an area without the resources necessary to accommodate projected needs. To that end, a process has been established to allow such areas to be nominated, evaluated, and ultimately designated as a CPA. To the extent resources and authority allow, the Secretary will facilitate project implementation. Additionally, regional plan addendums to the Plan are described.

Chapter 7 includes summary, future pursuits that will be undertaken by the Water Use Section in order to further West Virginia's water resource knowledge and recommendations for meeting programmatic water resource needs of the state.

Additionally, included in Appendices A and D are the Act and a synopsis of West Virginia's Water Laws, Regulations, and Rights. The West Virginia Watershed Descriptions companion report provides details on each of the 32 HUC-8 watersheds. Water resources and demands specific to each watershed are presented, as well as a brief summary of sources and reported interbasin transfers.

*Brush Creek Falls, Mercer County at confluence of Brush Creek and Bluestone River*

*Taggard Falls and Crayfish Pool. My Cave, Pocahontas County, WV*



# CHAPTER ONE
# WATER RESOURCES

**WATER USE SECTION** west virginia department of environmental protection

*Summersville Lake*

## Chapter - 1 Water Resources

### 1.1 Water Resources and Population Overview

Water Resource issues are a concern worldwide.  Overpopulation, inadequate water treatment infrastructure and the lack of proper water resource management practices which have led to water shortages and all of the associated famine and disease that come with it.  There are some who say the next major war on this planet will be over water.

The amount of fresh water on a planetary scale brings things into perspective.  As shown in the table below, fresh water on our planet makes up a mere 2.5% of the total.  Of that 2.5%, the majority is locked up in ice caps and glaciers.  The remaining 0.62% is available for the planet's needs including the plants, animals and humans.

| Water source | Water Volume (cubic miles) | Water Volume (cubic kilometers) | Percent of freshwater | Percent of total water |
|---|---|---|---|---|
| **Oceans, Seas, & Bays** | 321,000,000 | 1,338,000,000 | -- | 96.54 |
| **Icecaps, Glaciers & Permanent Snow** | 5,773,000 | 24,064,000 | 68.6 | 1.74 |
| **Groundwater** | 5,614,000 | 23,400,000 | -- | 1.69 |
| **Fresh** | 2,526,000 | 10,530,000 | 30.1 | 0.76 |
| **Saline** | 3,088,000 | 12,870,000 | -- | 0.93 |
| **Soil Moisture** | 3,959 | 16,500 | 0.05 | 0.001 |
| **Ground Ice & Permafrost** | 71,970 | 300,000 | 0.86 | 0.022 |
| **Lakes** | 42,320 | 176,400 | -- | 0.013 |
| **Fresh** | 21,830 | 91,000 | 0.26 | 0.007 |
| **Saline** | 20,490 | 85,400 | -- | 0.007 |
| **Atmosphere** | 3,095 | 12,900 | 0.04 | 0.001 |
| **Swamp Water** | 2,752 | 11,470 | 0.03 | 0.0008 |
| **Rivers** | 509 | 2,120 | 0.006 | 0.0002 |
| **Biological Water** | 269 | 1,120 | 0.003 | 0.0001 |
| ***Source: "Water in Crisis: A Guide to the World's Fresh Water Resources" (Peter H. Gleick, editor) – chapter 2, "Worlds fresh water resources" by Igor A Shiklomanov.*** | | | | |

Since the colonization of North America, the understanding and management of drinking water have dictated the location and growth of settlement. Not surprising, some of our largest cities are located near plentiful water sources. Chicago resides on the banks of Lake Michigan, the only one of the five North American Great Lakes that is entirely located within the United States, the second largest of the Great Lakes and the seventh largest freshwater lake in the world. Chicago has a seemingly limitless water supply. However, increases in population have forced some U.S. cities to construct extensive aqueducts to gather water from distant sources to meet their water needs. New York has constructed three significant aqueducts, the New Croton, Delaware and Catskill, transporting water distances of 22, 85 and 163 miles, respectively, in order to keep up with growth of the city. The Metropolitan Water District of Southern California built a canal 242 miles from the Colorado River to Los Angeles and San Diego to meet those cities drinking water needs. Houston Texas gathers 70% of its water supply from the Trinity River but must augment the surface water by pumping the other 30% from the Evangeline and Chicot groundwater aquifers. These aquifers have a limited ability to recharge and could eventually run dry. Texas is second only to California in the quantity of groundwater it consumes. Both of these states endured some of the most intense legal battles over water rights in the nation.

A key driver of increased worldwide water resource needs is population, and West Virginia is no different. The state's population experienced a fairly steady increase from 959,000 in the 1900's, reaching its peak in 1950 with over two million people. Since then, the population of West Virginia has mimicked the state's fluctuating economy. From 1950 to 1970, the state saw a loss in population of over 260,000 residents. A variety of factors contributed to this decline, but most notable were increasing mechanization in the coal mines as well as increased economic opportunities beyond the state's borders.

| Year | Total Population | Change | Percent Change |
|---|---|---|---|
| **1950** | 2,005,053 | -- | -- |
| **1960** | 1,860,421 | -144,632 | -7.77% |
| **1970** | 1,744,237 | -116,184 | -6.25% |
| **1980** | 1,949,644 | 205,407 | 11.78% |
| **1990** | 1,793,477 | -156,167 | -8.01% |
| **2000** | 1,808,344 | 14,867 | 0.83% |
| **2010** | 1,852,944 | 44,600 | 2.41% |

***source: United States Census Bureau**

The state's population trend from the 1900's to present day is depicted in Figure 1-1. Due in part to an energy crisis in the 1970's that revitalized coal mining, the state saw its population climb back up near the 1950 level. A global recession during the 1980's, coupled with the economic restructuring in the state's major manufacturing and coal mining sectors resulted in a population decrease to 1.79 million by

1990. The state's population has increased modestly during the past two decades, highlighted by a by 2.41% growth from 2000 to 2010. However, that slight increase is still well below the 24.1% national average.

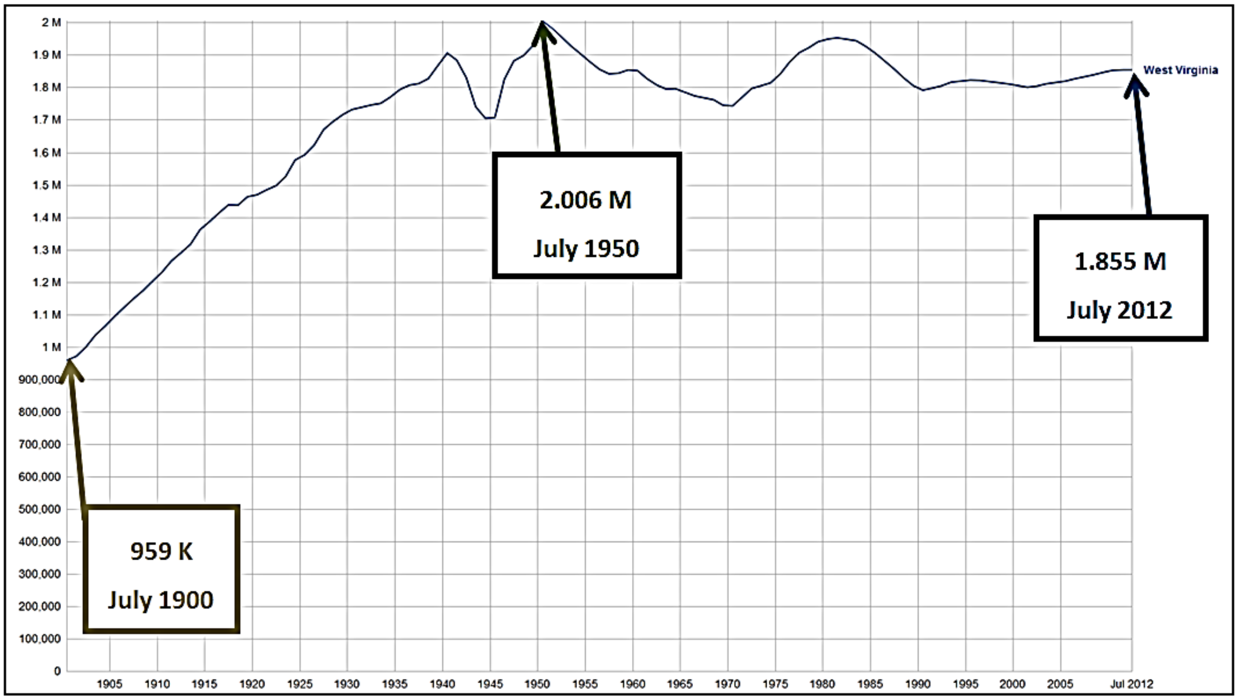



**Figure 1-1 Population trend for the state of West Virginia from July 1900 to July 2012. Data Source: U.S. Census Bureau, 4/9/2013**

Historically, West Virginia has had plenty of water, at times too much, but that does not allow us to ignore the need for sound management of the state's water resources politically, commercially and

**West Virginia Water Facts**

- 19.32 trillion gallons of precipitation – based on 44 inches/year
- 1.07 trillion gallons – maximum storage of dams/lakes
- 388.7 billion gallons - normal storage of dams/lakes
- 1.48 trillion gallons –potential mine pool storage
- 1.20 trillion gallons - withdrawn by Large Quantity Users annually
  - ~6% or 72 billion gallons/year consumptive use
- 54,961 – total stream miles statewide
- ≥ 4 billion gallons per day - minimal additional available surface water (see Chapter 3)

environmentally for our citizens and future generations. In order to quantify and monitor our surface water resources, there are two main networks in place: the precipitation gage network, operated by the National Oceanic and Atmospheric Administration (NOAA) and WV Department of Homeland Security and Emergency Management (DHSEM), and the stream gage network operated by the United States Geological Survey (USGS). Above is a list of West Virginia water facts derived from these gages.

### 1.1.1 Rain Gages

Nationally recognized average annual precipitation for West Virginia is 44 inches per year, which translates to 19.32 trillion gallons of water. Recently, many tools have been used to determine not only the annual precipitation but also the average seasonal precipitation rates across the state. Monthly precipitation rates have been provided by NOAA that was derived from "PRISM" climate data developed at Oregon State University. The 30-year monthly precipitation values were derived using data from 1981-2010. NOAA claims they "are considered the most detailed, highest-quality spatial climate datasets currently available." This data was downloaded by the DEP as ESRI ASCII grids, overlain by the USGS Hydrologic Unit Code Eight Digit (HUC-8) watershed boundaries and the data grids within the HUC-8 were extracted for each month. Analysis conducted by the DEP confirms that West Virginia receives an average of 44.21 inches of precipitation per year. Monthly precipitation maps for each HUC-8 watershed can be assessed on the Plan's website. A map of average annual precipitation, derived from the PRISM dataset, can be seen in Figure 1-2.

> Cheat Watershed receives the most rainfall annually with an average of 51 in/yr. South Branch Potomac receives the lowest annual rainfall at 38 in/yr.

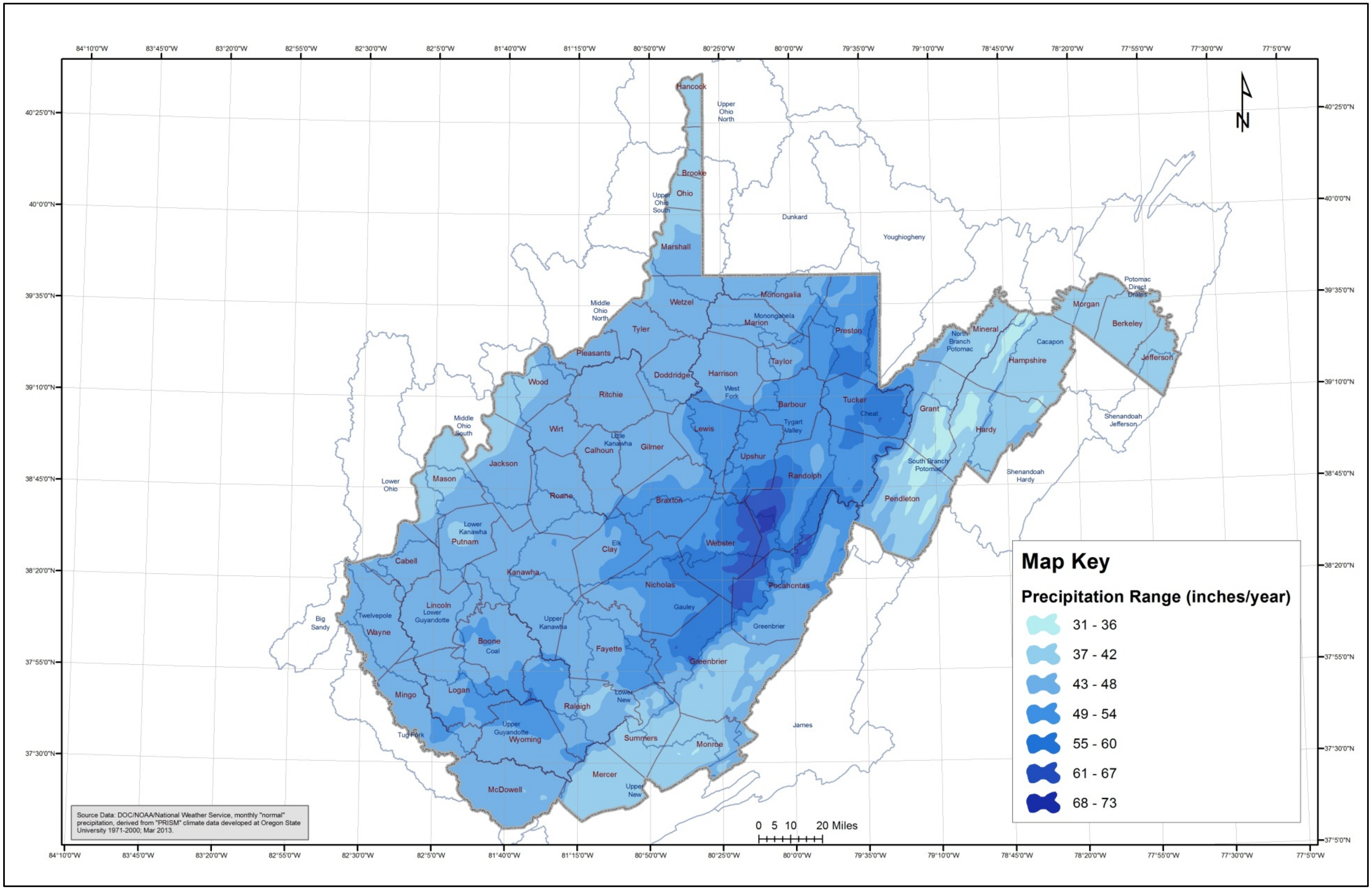



Figure 1-2 Average annual precipitation for West Virginia - 1981 to 2010

It is important to note that there are several areas within the state that receive up to 67 inches of rainfall annually, while other areas receive an average of 31 inches annually. The HUC-8 watershed that receives the highest annual precipitation is Cheat. With over 203 PRISM grid points in the watershed, the Cheat receives an average of 51 inches of precipitation annually.

Precipitation, providing groundwater and runoff, is the primary source of stream flow in the state, which is exemplified by the formation of several HUC-8 rivers in an area where over 61 inches of precipitation falls annually. This area is highlight by the darkest blue portions in Figure 1-2. Table 1-1 shows both the number of prism grid points within each HUC-8 watershed as well as the average precipitation values.

For current daily precipitation data the Federal Integrated Flood Observing and Warning System (IFLOWS) maintains 228 precipitation gages (www.rainfall.net), while the Data Collection Platform (DCP) maintains 143 precipitation gages (www.nws.noaa.gov/oh/hads/states/WV_dcps.htm) in West Virginia. The locations of these gages can be seen in Figure 1-3.

**Table 1-1 HUC-8 watershed average precipitation**

| HUC-8 Watershed | Average Precipitation | # PRISM Grid Points | Rank* in HUC-8 |
|---|---|---|---|
| Big Sandy | 41.86 | 10 | 20 |
| Cacapon | 37.84 | 125 | 30 |
| Cheat | **51.00** | 203 | 1 |
| Coal | 45.68 | 137 | 6 |
| Dunkard | 43.88 | 17 | 13 |
| Elk | 48.84 | 229 | 5 |
| Gauley | 50.62 | 215 | 3 |
| Greenbrier | 42.81 | 249 | 18 |
| James | 42.19 | 12 | 19 |
| Little Kanawha | 44.64 | 345 | 11 |
| Lower Guyandotte | 43.28 | 113 | 16 |
| Lower Kanawha | 41.62 | 137 | 21 |
| Lower New | 43.41 | 109 | 14 |
| Lower Ohio | 40.43 | 35 | 24 |
| Middle Ohio North | 44.91 | 140 | 9 |
| Middle Ohio South | 41.35 | 105 | 23 |
| Monongahela | 44.80 | 66 | 10 |
| North Branch Potomac | 39.54 | 91 | 25 |
| Potomac Direct Drains | 37.69 | 83 | 31 |
| Shenandoah Hardy | 38.71 | 1 | 26 |
| Shenandoah Jefferson | 38.10 | 17 | 28 |
| South Branch Potomac | ***37.65*** | 203 | 32 |
| Tug Fork | 43.07 | 141 | 17 |
| Twelvepole | 43.34 | 70 | 15 |
| Tygart Valley | 49.80 | 206 | 4 |
| Upper Guyandotte | 45.65 | 144 | 7 |
| Upper Kanawha | 44.16 | 77 | 12 |
| Upper New | 38.04 | 124 | 29 |
| Upper Ohio North | 38.34 | 17 | 27 |
| Upper Ohio South | 41.49 | 84 | 22 |
| West Fork | 45.60 | 133 | 8 |
| Youghiogheny | 50.99 | 10 | 2 |
| **Total** | **44.21** | **3,648** | |

***Rank – 1 being the most precipitation and 32 being the least**

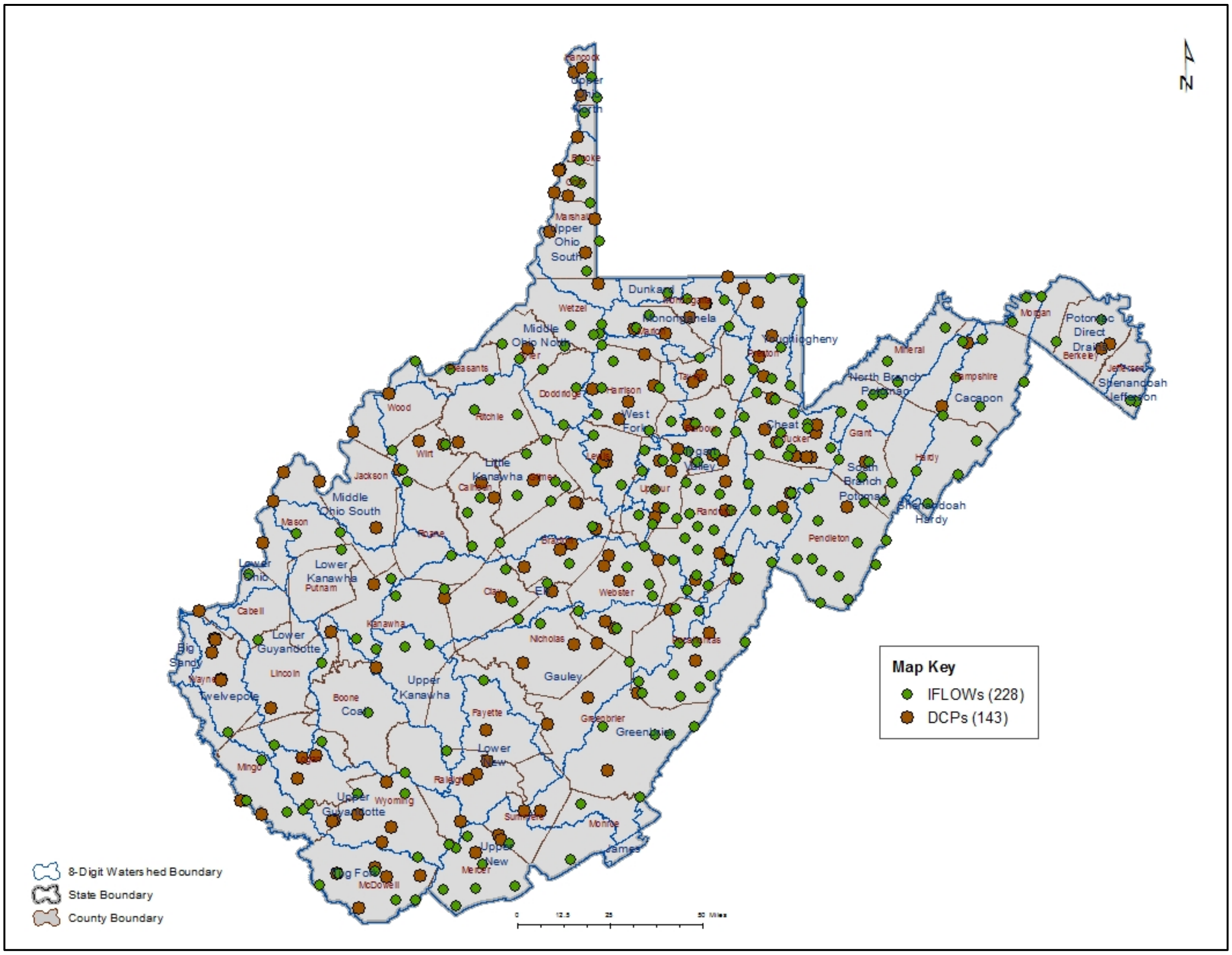



**Figure 1-3 Locations of IFLOW and DCP precipitation gages in West Virginia**

## 1.2 Surface Water


West Virginia is blessed with an abundance of rivers and streams. These rivers and streams have been designated by the state for a variety of uses, including fish and wildlife propagation, recreation, transportation, public water supply, agriculture, and industry. West Virginia has a comprehensive strategy for monitoring the flowing waters of the state, by far the most prevalent surface water body type in the state. The DEP's Watershed Assessment Branch utilizes a tiered approach, collecting data from long-term monitoring stations; targeted sites within watersheds on a rotating basin schedule; randomly selected sites; and sites chosen to further define impaired stream segments in support of TMDL development. Each of these approaches is fully described in the Integrated Water Quality Monitoring and Assessment Reports which can be downloaded from the DEP Webpage at the following link:

http://www.dep.wv.gov/WWE/watershed/IR/Pages/303d_305b.aspx

Most of West Virginia's streams begin at the crest of a mountain and form ravines or gullies. With distance, numerous gullies merge in a dendritic pattern, are fortified by springs and groundwater seeps and eventually become tributaries of larger rivers. These springs, groundwater seeps, streams and rivers that all drain to the same point are collectively referred to as a watershed. A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place, normally the mouth of a river.

The United States is sub-divided into successively smaller hydrologic units which are classified into six levels: regions, sub-regions, accounting units, cataloging units, watersheds and sub-watersheds. The hydrologic units are nested within each other. The largest geographic areas are referred to as regions and the smallest are referred to as sub-watersheds.

Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to 12 digits based on the six levels of classification in the hydrologic unit system.

- 2-digit HUC first-level (region)
- 4-digit HUC second-level (sub-region)
- 6-digit HUC third-level (accounting unit)
- 8-digit HUC fourth-level (cataloging unit)
- 10-digit HUC fifth-level (watershed)
- 12-digit HUC sixth-level (sub-watershed)

The first level of classification divides the nation into 21 major 2-digit HUC watersheds referred to as regions. These geographic areas contain either the drainage area of a major river or the combined drainage areas of a series of rivers. The second level of classification divides the 21 regions into 221 sub-regions. A sub-region includes the area drained by a river system, the reach of a river and its tributaries, a defined basin or a group of streams forming a coastal drainage area. The third level of classification subdivides many of the sub-regions into accounting units. These 378 hydrologic accounting units are nested within, or can be equivalent to the sub-regions.

The fourth level of classification is the 8-digit HUC (Cataloging Unit). A cataloging unit is a geographic area representing part of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature. For example the Elk River is an 8-digit HUC. There are 2,264 cataloging units in the nation. These units can be further divided into smaller areas at the 10-digit and 12-digit level referred to as watersheds and sub-watersheds. The newest list of the national HUC Codes, Values and Names are in the USGS Watershed Boundary Dataset that can be viewed at the following website link:

http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

In order to meet the requirements of the Act, and to divide the state into manageable pieces, we have separated the state into five regions all consisting of several HUC-8 watersheds as shown in Figure 1-4.

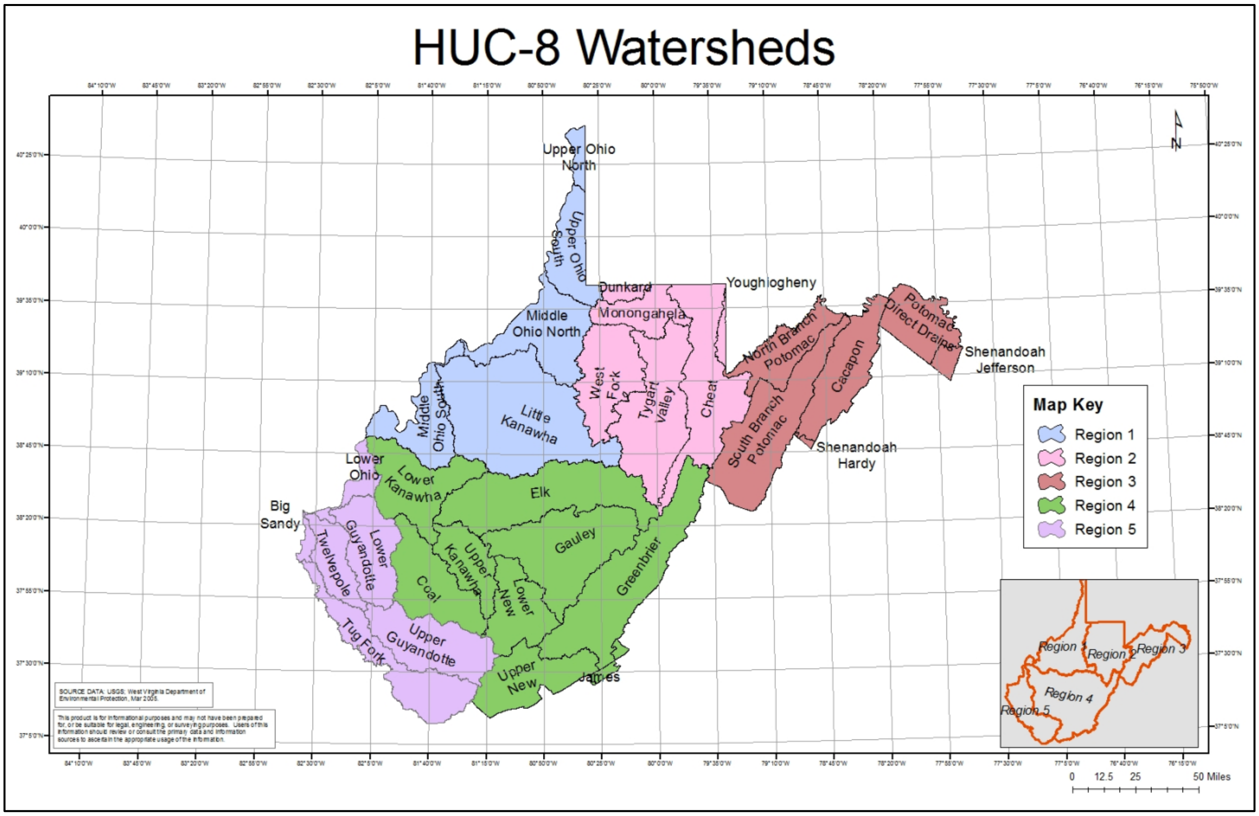



Figure 1-4 HUC-8 watersheds classified into five regions

There are 32 HUC-8 watersheds in the state, the majority of which eventually flow into the Ohio River, with the exception of Region 3 which flows to the Chesapeake Bay via the Potomac River. Figure 1-5 defines the interconnectivity of the HUC-8 watersheds. Notice that some of the watersheds, like the Little Kanawha and the Cheat, do not have another watershed upstream therefore water resource issues of the other watersheds do not influence or affect their water resources. However, there are some watersheds, like the Lower New and the Upper Kanawha, that receive water from one watershed and pour into another. It is imperative that water managers understand these relationships and work together to properly manage the water resources.

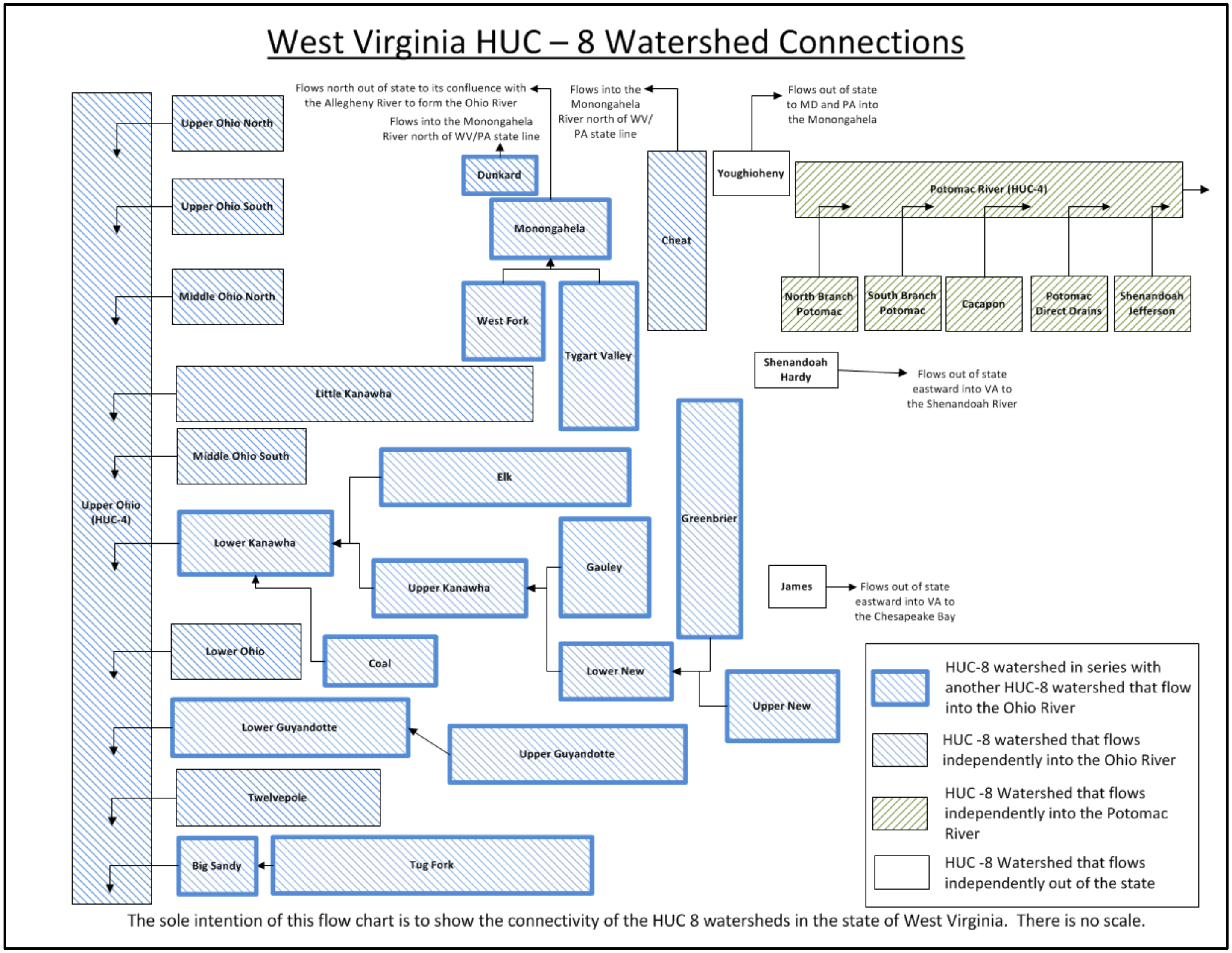



**Figure 1-5 The connectivity of the HUC-8 watersheds in West Virginia**

### 1.2.1 Inventory of Streams

According to the USGS National Hydrography Dataset (NHD) there are 54,961 total stream miles in the state. The Little Kanawha Watershed encompasses an area of 2,308 square miles and contains a total of 5,425 stream miles, more than any other HUC-8 watershed in the state. Table 1-2 lists the HUC-8 watersheds and the number of total stream miles they contain.

> The Little Kanawha Watershed, with a total area of 2,308 square miles has the most stream miles (5,425). The Shenandoah Hardy with a total area of only 17 sqmi, has the least stream miles (47).

**Table 1-2 Total HUC-8 stream miles in West Virginia**

| Watershed Name | Total Stream Miles | Rank in HUC-8 (1 = most stream miles) |
|---|---|---|
| Little Kanawha | 5,425 | 1 |
| Greenbrier | 3,509 | 2 |
| South Branch Potomac | 3,476 | 3 |
| Tygart | 3,226 | 4 |
| Elk | 3,213 | 5 |
| Gauley | 3,063 | 6 |
| Cheat | 2,538 | 7 |
| Middle Ohio North | 2,283 | 8 |
| Tug Fork | 2,249 | 9 |
| Coal | 2,232 | 10 |
| Upper Guyandotte | 2,200 | 11 |
| Upper New | 2,000 | 12 |
| Cacapon | 1,971 | 13 |
| Lower Kanawha | 1,965 | 14 |
| West Fork | 1,888 | 15 |
| Middle Ohio South | 1,803 | 16 |
| Lower Guyandotte | 1,796 | 17 |
| Lower New | 1,612 | 18 |
| Upper Kanawha | 1,244 | 19 |
| Upper Ohio South | 1,234 | 20 |
| North Branch Potomac | 1,173 | 21 |
| Twelvepole Creek | 1,139 | 22 |
| Potomac Direct Drains | 1,085 | 23 |
| Monongahela | 867 | 24 |
| Lower Ohio | 546 | 25 |
| Dunkard Creek | 246 | 26 |
| Upper Ohio North | 246 | 27 |
| James | 217 | 28 |
| Big Sandy | 201 | 29 |
| Shenandoah Jefferson | 140 | 30 |
| Youghiogheny | 127 | 31 |
| Shenandoah Hardy | 47 | 32 |
| **Total** | **54,961** | |

Many of the larger rivers in our state are regulated, mainly for navigation, water quality and flood control, by the U.S. Army Corps of Engineers (USACE) dams which are disgussed later in this chapter. For a breakdown of stream miles by HUC-10 and HUC-12 watershed please refer to Appendix E.

### 1.2.2 Stream Gaging Network

The United States Geological Survey (USGS) maintains a system of approximately 144 stream gages within and around West Virginia. This system should be maintained and added to as necessary, as the stage and flows of the various West Virginia streams and rivers are critical to calculating the hydrologic characteristics of the streams and rivers. Stream gages are the best and most important water resource data source.

Stream gages are the best and most important water resource data source.

The water-data network is operated by the USGS in West Virginia. The USGS continuously monitors stream flow, stage, reservoir level, groundwater level, precipitation and certain water-quality constituents in West Virginia. Data from these networks are transmitted to the World-Wide Web in near-real time at URL http://waterdata.usgs.gov/wv/nwis/rt and may be viewed either as a table or on a map. The networks are funded partly by federal appropriations to the USGS and partly by other state, federal and local agencies and other interested parties. The number of sites in the networks changes frequently in response to cooperator needs and available funding, but the current numbers of continuous-record stations are shown at URL:

http://waterdata.usgs.gov/wv/nwis/current?submitted_form=introduction.

Table 1-3 lists the numbers of active continuous sites in the network as of March 2013 and Appendix F lists their locations, types of continuous data collected at them and their status with respect to regulation.

Table 1-3 Numbers of U.S. Geological Survey continuous-record stations operated in West Virginia as of March 20, 2013

| Water-Level or Flow Parameters | Number of Sites |
|---|---|
| Depth to groundwater, feet below land surface | 16 |
| Stage gage, relative height of stream | 137 |
| Lake or reservoir water-surface elevation | 3 |
| Stream velocity | 1 |
| Streamflow | 85 |
| **Water-Quality Parameters** | |
| Dissolved oxygen | 8 |
| pH | 10 |
| Specific conductance | 12 |
| Water temperature | 19 |
| Total partial pressure of dissolved gases | 1 |
| Turbidity | 2 |
| **Meteorological Parameters** | |
| Total precipitation | 36 |

The goal of the USGS stream gaging program is to provide hydrologic information needed to help define, use and manage the nation's water resources (Wahl, Thomas, Jr., & Hirsch, 1995). The program provides a continuous, well-documented, well-archived, unbiased and broad-based source of reliable and consistent water data. Uses of streamflow information include flood warnings; current and short-term (days to months) operational decision making in withdrawals, hydropower production and navigation; assessing and mitigating flood risks and determining floodplains; planning and designing water infrastructure; managing and improving water quality and assessing stream habitat; monitoring legal agreements on the allocation of water resources; recreational uses; and improving the scientific understanding of the environment and how it is changing over time (Bailes, et al., 2004). Streams that are important for water supply, flood warning, or other critical operational needs are directly gaged; these include most major rivers.

For many smaller streams, streamflow information is provided in the form of regional equations for selected flow characteristics. For West Virginia, regional equations have been developed for flood frequency discharges (Wiley & Atkins, Jr., 2010), annual and seasonal low-flow statistics (Wiley, 2006; Wiley, 2008; Wiley and Atkins, 2010) and bank-full channel characteristics (Wiley et al., 2002; Keaton et al., 2005; Messinger, 2009). To provide the information needed to develop, maintain and refine these equations, stream gages are operated on small streams draining basins that represent larger areas. Understanding regional hydrology requires information on the variability of streamflow regionally, as well as through time. Because of the infrequency of critical streamflow events, such as major droughts and floods, streams must be continuously gaged for long periods to reliably measure trends. The numbers of stream gages have fluctuated. Currently, streamflow is measured continuously at 85 stations. The maximum number of stations was 115 in both 1969 and 1977. Historic data, including that for discontinued stations, is critically important for developing regional equations and stream gages with extended periods of record are among the most valuable because they provide baseline information for detecting future changes (National Hydrologic Warning Council, 2006).

> In order to manage our state's water resources we must first know how much water there is. The only way to determine the total quantity of water in the state is through calculations based on the data provided by the stream gaging network.

Many stream gages are used and funded for multiple purposes by multiple parties. The partners in the stream gaging network organized the West Virginia Water Gaging Council (http://wvwgc.wvca.us/) in 2004, to simplify communication among them. A particular concern was the survival of continued communication of water data needs between agencies beyond leadership or emphasis changes of partner agencies. In 2013, stream gages and other continuous-record stations in West Virginia were funded by 17 entities, counting different divisions or programs within an agency separately (Table 1-4). Costs of continuous-record data-collection stations vary depending on the parameter(s) to be measured (Table 1-5). Entities that fund five or more gages, or contribute lump sums to the program equal to the cost of five or more stream gages, include the USGS Cooperative Water Program, USGS National Streamflow Information Program, USACE Huntington District, USACE Pittsburgh District, U.S. Environmental Protection Agency (EPA) Chesapeake Bay Program, West Virginia Conservation Agency (WVCA), WVDEP Division of Waste and Water Management (DWWM), WVDEP Division of Mining and Reclamation (DMR) and the West Virginia Department of Transportation (WVDOT), Division of Highways (WVDOH). The DEP recommends that the funding for the stream gaging network be continued by the involved agencies. In addition, should a partner agency become unable to maintain its contribution level, it should notify the USGS and the Commission so alternative funding sources can be identified. The Commission should consider codifying this notification as a requirement of the Act.

The USGS Cooperative Water Program provides matching funds to state and local government organizations that enter cooperative agreements with USGS for data collection and interpretation (http://water.usgs.gov/coop/). The USGS National Stream Information Program (NSIP) has designed and maintained a federally funded network to ensure that federal streamflow needs are met at a minimal number of stations (Bailes, et al., 2004); http://water.usgs.gov/nsip/).

Both in West Virginia and nationally, the USACE is among the principal funders and users of the stream gaging network. The USACE uses flow and water level information for design and operation of locks, dams and other structures used to control flooding, enable water transportation and otherwise manage streams and rivers. The EPA Chesapeake Bay Program uses streamflow information to determine loads of water-quality constituents to the Chesapeake Bay, as part of ongoing restoration efforts. The WVCA, like the Corps, designs and operates dams and other structures used to manage streams and floodplains.

The DEP's Division of Water and Waste Management uses streamflow data, regional equations and other products derived from them for a variety of purposes, including managing and accessing watersheds; interpreting water-quality data; reviewing, managing and enforcing discharge permits; and providing guidance on water withdrawn for hydraulic fracturing. The DEP's Division of Mining and Reclamation uses streamflow information in developing, managing and enforcing discharge permits and in Cumulative Hydrologic Impact Assessment. The WVDOH uses peak-flow information for designing bridges, culverts and drainage structures.

Other agencies, companies and municipalities that have an interest in water resources in West Virginia, or need for information on a specific stream, also help fund the water-data networks. These groups include, in alphabetical order, Allegheny Power, Berkeley County, Brookefield Renewable Power, the City of Hurricane, West Virginia, Maryland Department of Natural Resources, National Park Service, the USGS National Water-Quality Assessment (NAWQA) program and the West Virginia Department of Natural Resources (DNR). Three natural gas companies, CNX Gas Company LLC, BRC Operating Company and CONSOL Energy, have contracted with the DEP to install three new stream gages and maintain them for a minimum target of five years. In combination, the current cost of the streamflow gaging network is approximately $1.36 million dollars annually.

Stream gages are also used extensively by paddlers, anglers, and other river users to plan outdoor activities. While difficult to place a monetary value on this aspect, the information is priceless to thousands of recreationalists using West Virginia's waters.

**Table 1-4 Agencies, counties, municipalities, and companies that fund continuous-record water-data collection stations operated by the U.S. Geological Survey in West Virginia as of March 20, 2013**

| Cooperating Agency | Office or Program |
|---|---|
| U.S. Geological Survey | National Streamflow Information Program |
| | Data collection of basic records (Office of Groundwater) |
| | National Water-Quality Assessment Program |
| U.S. Army Corps of Engineers | Huntington District |
| | Pittsburgh District |
| U.S. Environmental Protection Agency | Chesapeake Bay Program |
| West Virginia Department of Agriculture | West Virginia Conservation Agency |
| West Virginia Department of Environmental Protection | Division of Water and Waste Management, Division of Mining and Reclamation |
| West Virginia Department of Commerce | Division of Natural Resources |
| West Virginia Department of Transportation | Division of Highways |

**additional cooperating entities: Allegheny Power, Berkeley County, WV, Brookefield Renewable Power, City of Hurricane, WV, Maryland Department of Natural Resources, and National Park Service*

**Table 1-5 Costs for continuous-record stations operated by the U.S. Geological Survey in West Virginia in 2013 (operation, maintenance, data-processing and publication costs are included)**

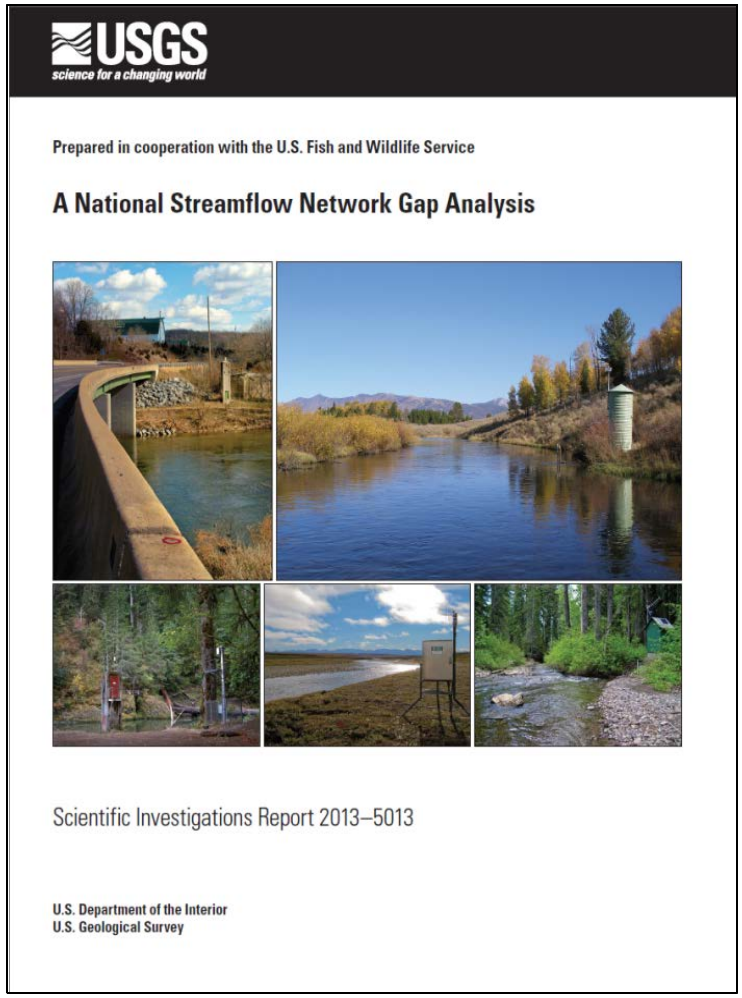
| Station Type | 2013 Cost |
|---|---|
| Operation and maintenance of a cableway | 1,540.00 |
| Annual peak flow at a crest-stage gage | 1,900.00 |
| Streamflow, from a stage-discharge rating | 14,400.00 |
| Streamflow, from an index-velocity-discharge rating | 17,000.00 |
| Rainfall at a stand-alone station | 4,800.00 |
| Rainfall, as an add-on to another continuous site | 2,660.00 |
| Suspended sediment samples and daily load computation | 25,000.00 |
| Air temperature and relative humidity, as an add-on to another continuous site | 2,660.00 |
| Water temperature, as an add-on to another continuous site | 2,660.00 |
| Water temperature and specific conductance, as a stand-alone site | 7,400.00 |
| Water temperature and specific conductance, as an add-on to another continuous site | 5,200.00 |
| Water temperature, specific conductance, dissolved oxygen and pH, as a stand-alone site | 17,000.00 |
| Water temperature, specific conductance, dissolved oxygen and pH, as an add-on to another continuous site | 15,000.00 |
| Water temperature, specific conductance and pH, as an add-on to another continuous site | 13,000.00 |
| Turbidity, as an add-on to another continuous site | 5,000.00 |
| Water level, periodic, cost per site visit (max 6x per year) | 325.00 |
| Water level, continuous, as an add-on to another water-level site (as in nested wells) | 2,660.00 |
| Water level, continuous, as an add-on auxiliary water-level to an existing site (as in a stage backup) | 2,660.00 |
| Water level with satellite transmission | 4,800.00 |

In addition to continuously recorded data, the USGS also assesses many of these and other parameters as individual measurements in other networks. Annual peak flows are determined in a network of crest-stage gages operated in cooperation with the West Virginia Department of Transportation, Division of Highways.  The peak-flow data is used to develop, maintain and refine flood-frequency equations that are needed for designing bridges, culverts and other structures. Crest-stage gage locations are selected to help define boundaries of regions where flood-frequency equations apply, or to reduce error terms in areas with large amounts of variability. A network of partial-record low -flow sites in the New River Gorge has been operated in cooperation with the National Park Service to provide flow information needed to interpret water-quality data collected in the course of park resource management. In many states, partial-record low-flow sites are used to refine regional low-flow frequency equations, although such a network is not presently operated in West Virginia.

The USGS operates two perennial networks in which the quality of water samples is assessed. The Chesapeake Bay Program's Non-Tidal Monitoring Network is designed to assess the concentrations, trends and loads of nutrients, total suspended solids and sediment in streams draining to the Chesapeake Bay. Within West Virginia, stations are operated in cooperation with the DEP, the EPA and Maryland Department of Natural Resources. Samples are collected monthly, and additional samples are collected at high flows. The Ambient Groundwater Sentinel-Well Network is operated by USGS in cooperation with the DEP to monitor the quality of West Virginia's aquifers. This network of 27 wells and springs distributed throughout West Virginia is operated to detect and assess long-term trends in shallow groundwater quality.

The USGS also operates a network of continuous water-quality monitors in cooperation with the DEP, USACE and West Virginia Division of Natural Resources.  The network consists of 19 stations:  11 are multi-parameter (where two to five parameters are measured) and then there are eight that measure water-temperature. At these stations, water-quality measurements are made at hourly or more frequent intervals. These monitors are operated for a variety of purposes, including, but not limited to, long-term trend detection, dam operation and basic understanding of water-quality patterns.

According to USGS Scientific Investigations Report (SIR 2013 – 5013), our ability to estimate important flow statistics for West Virginia such as annual mean and flood-frequency equations is well above the national average. Two major reasons for this is the nature of our hydrology, in that some basic statistical assumptions break down in the arid west for fundamental things like the frequency distribution that the annual peak series fits, and there is no reason to develop estimating equations for the 7Q10 in a state where it's zero for most streams. Our low-flow equations are mostly competitive with neighboring states, but they have some room for improvement. Overall, West Virginia has been commended for maintaining a good stream gaging network for a reasonably long period of time.




### 1.2.3 Dams

In order to be included in the National Inventory of Dams (NID) dataset, a dam must meet at least one of the following conditions: High hazard classification (loss of one human life is likely if the dam fails); Significant hazard classification (possible loss of human life and likely significant property or environmental destruction); Equal or exceed 25 feet in height and exceed 15 acre-feet in storage; or Equal or exceed 50 acre-feet storage and exceed 6 feet in height.

Summersville Dam, also known as Summersville Lake, located in Nicholas County and the Gauley Watershed, is the largest in the NID Database by comparison of normal storage. Summersville Dam has a normal storage of 62.4 billion gallons of water.

NID dams are/can be used for the following purposes: irrigation, hydroelectric, flood control, stormwater management, navigation, water supply, recreation, fire protection, stock, or small farm pond, fish and wildlife pond, debris control, tailings, grade stabilization and other. In the dataset the order is listed indicating the relative decreasing importance of the purpose. Codes are concatenated if the dam has multiple purposes.

Among the information contained in the NID dataset is the dam's name, allocated use, normal storage, regulatory authority and the minimum release (where established). The dataset contains over 610 dams for the state. The 399 dams (Figure 1-6) reported here are the larger freshwater dams in the state, not including 200 coal slurry dams and 11 locks and dams on the Ohio and Kanawha Rivers. It should also be noted that small private dams and farm ponds are not listed. The reported total normal storage for this dataset is 1,192,940 acre/feet or 388.7 billion gallons. One acre foot (ac/ft) of water is a volume equal to one acre covered by one foot of water. There are 43,560 square feet in one acre. If an acre sized square box was one foot tall, it would have a volume of 43,560 cubic feet. Every cubic foot can hold 7.48052 gallons of water. Therefore, one acre foot contains 43,560 cubic feet of water multiplied by 7.48052 gallons of water per cubic foot which equals 325,851.45 gallons of water.

**<u>Selected Conversion Factors</u>**

1 acre = 43,560 square feet

1 acre foot = 43,560 cubic feet

1 cubic foot = 7.48052 gallons of water

1 cubic foot of water = 62.428 pounds

1 acre foot = 325,851.45 gallons

1 acre foot of water = 2.719 million pounds

1 inch of rain equals 27,200 gallons per acre

1 cubic foot per second = 7.48 gallons per second

1 cubic foot per second = 448.8 gallons per minute

1 cubic foot per second = 646,272 gallons per day

| HUC-8 Watershed | No. Dams in HUC-8 | Total Normal NID Storage (ac/ft) | Total Maximum NID Storage (ac/ft) |
|---|---|---|---|
| Cacapon | 9 | 2,416 | 15,338 |
| Cheat | 19 | 2,698 | 4,794 |
| Coal | 1 | 6,566 | 8,990 |
| Elk | 6 | 120,284 | 531,223 |
| Gauley | 12 | 384,943 | 835,253 |
| Greenbrier | 13 | 5,819 | 13,474 |
| Little Kanawha | 22 | 35,859 | 188,486 |
| Lower Guyandotte | 8 | 4,785 | 25,915 |
| Lower Kanawha | 19 | 12,695 | 31,379 |
| Lower New | 15 | 8,170 | 12,982 |
| Lower Ohio | 1 | -- | -- |
| Middle Ohio North | 3 | 590 | 20,956 |
| Middle Ohio South | 21 | 7,506 | 63,636 |
| Monongahela | 25 | 2,260 | 12,501 |
| North Branch Potomac | 45 | 55,318 | 103,992 |
| Potomac Direct Drains | 20 | 4,299 | 8,000 |
| Shenandoah Jefferson | 2 | 1,012 | 1,372 |
| South Branch Potomac | 31 | 3,411 | 43,574 |
| Tug Fork | 4 | 821 | 1,541 |
| Twelvepole | 5 | 52,756 | 240,110 |
| Tygart Valley | 14 | 203,262 | 715,413 |
| Upper Guyandotte | 3 | 68,744 | 407,677 |
| Upper Kanawha | 3 | 3,196 | 6,786 |
| Upper New | 25 | 81,727 | 1,278,451 |
| Upper Ohio North | 9 | 468 | 2,715 |
| Upper Ohio South | 22 | 1,666 | 35,688 |
| West Fork | 40 | 121,525 | 326,302 |
| Youghiogheny | 2 | 144 | 188 |
| **Grand Total** | **399** | **1,192,940** | **4,936,734** |

*There are a total of 610 dams in the NID dataset. However 200 of the dams were coal slurry/flyash/refuse dams and 11 locks and dams on the Ohio and Kanawha, and are therefore not included in this list of freshwater dams. There are 16 federal regulated dams that are counted in these numbers. For a complete list of all information included in the NID dataset, please visit the WV Water Resource Management Plan Website.

The Summersville Dam, also known as Summersville Lake, located in Nicholas County within the Gauley Watershed, is the largest in the NID Database by comparison of normal storage. Summersville Dam has a normal storage of 62.4 billion gallons of water. The Locks and Dams along the Ohio River reported larger normal storage quantities than the Summersville Dam; however, they are reporting the waters of the navigation pools of the Ohio River. The North Branch Potomac Watershed has the greatest number of dams, totaling 45; however, the Gauley Watershed has the largest combined normal storage capacity of 384,943 acre feet.

The dams are fairly well distributed across the state as can be seen in Figure 1-6.

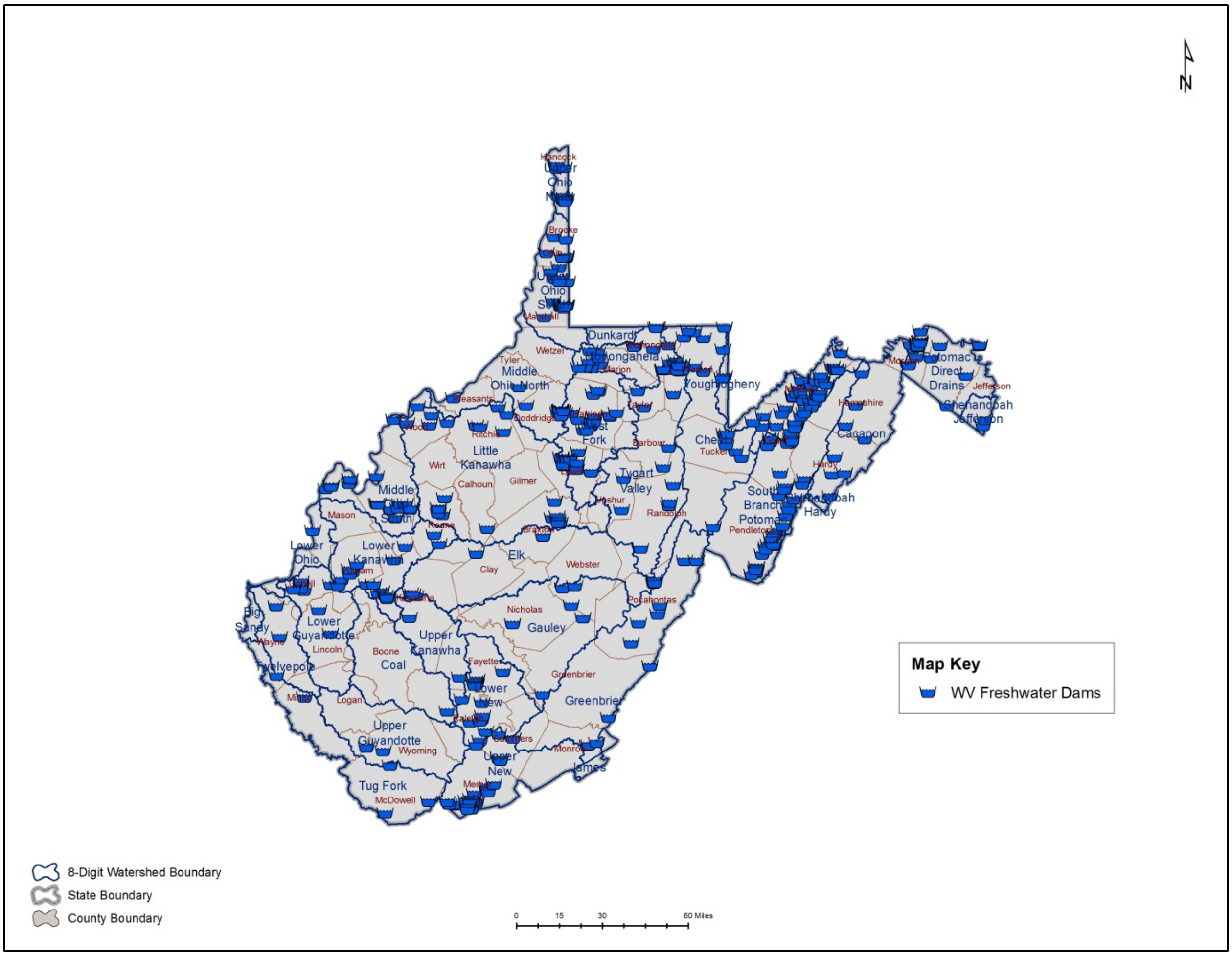



Figure 1-6 Locations of NID Dams within the state

Most of the larger USACE operated dams have a minimum release strategy based on years of observation and the minimum flows needed for barge traffic and water quality. This means that at least this much water will be released at all times from these dams, but more often there is much more water being released. The USACE monitors flows at target gage locations downstream from the locks and dams, increasing or decreasing the flow as is required to maintain the appropriate downstream conditions. Some important minimum releases from selected locks and dams and target stream flows are listed in the following tables.

| Ohio River Estimated 7Q10 Flow Values | | |
|---|---|---|
| **River Reach** | | **Min. 7-day, 10 yr. Low Flow in cfs** |
| **Pittsburgh** | To Montgomery Dam (MP 32.4) | 4,800 |
| **Montgomery** | To Willow Island Dam (MP 161.8) | 5,800 |
| **Willow Island** | To Gallipolis Dam (MP 279.2) | 6,800 |
| **Gallipolis** | To Greenup Dam (MP 341.0) | 8,500 |
| **Greenup** | To Meldahl Dam (MP 436.2) | 9,800 |
| **Meldahl** | To McAlpine Dam (MP605.8) | 11,000 |
| **McAlphine** | To Uniontown Dam (MP 846.0) | 13,000 |
| **Uniontown** | To Smithland Dam (MP 918.5) | 18,800 |
| **Smithland** | To Cairo Point (MP 981.0) | 46,300 |
| ***Minimum 7-day, 10 year low flow (in cubic feet per second) based on calculations by the U.S. Army Corps of Engineers** | | |

| USACE Target Minimum Flows for Selected Streams | |
|---|---|
| **Stream** | **Minimum Flow CFS** |
| **Kanawha River - Upper** | 1890 |
| **Kanawha River - Lower** | 1980 |
| **Monongahela River @ Opekiska Lock and Dam Lowsville, WV** | 420 |
| **Tygart River @ Colfax, WV** | 303 |
| **West Fork River @ Enterprise, WV** | 117 |
| ***Source: US Army Corps of Engineers – Pittsburgh, PA*** | |

| USACE Minimum Releases for Selected Dams | | |
|---|---|---|
| **Stream** | **Dam** | **Minimum Release in CFS** |
| **Little Kanawha River** | Burnsville Dam | 20 |
| **Elk River** | Sutton Dam | 75 |
| **Bluestone River** | Bluestone Dam | 610 |
| **Gauley River** | Summersville Dam | 100 |
| **Guyandotte River** | R.D. Bailey Dam | 45 |
| **Twelvepole Creek** | East Lynn Dam | 10 |
| **Beech Fork** | Beech Lake Dam | 5 |
| **Tygart Valley River** | Tygart Valley Dam | 100 |
| **Monongahela River** | Hilderbrand Lock and Dam | 340 |

## 1.3 Groundwater

West Virginia is comprised of several different geomorphic provinces and geological regimes throughout 32 HUC-8 watersheds. The state experiences variable precipitation rates, vegetative cover, seasons, land uses and quantities of groundwater use. Each of these variables can be complex and can have an impact on the quality, quantity and recharge rate of our state's groundwater. For example, the groundwater throughout the Appalachians moves within faulted, fractured and folded geological landscapes, some heavily affected by karst topography. However, the groundwater in the Ohio River Valley can be expected to flow within the thick alluvial aquifers. Conversely, much of the groundwater within the lower Greenbrier Valley flows in large conduits to base-level karst springs. Similarly, the groundwater in such places as East River and Back Allegheny Mountains moves within springs throughout the mountainside to the deeper tributary valleys. The aquifers in the Ridge and Valley of the Potomac Highlands may also follow the trend of the mountains, or may be in small flows that descend the mountains. Additionally, the groundwater aquifers in the Central Appalachian Plateau can be small, local, disconnected and seemingly flow in many different directions. The result is that there is no simple explanation of the groundwater characteristics in West Virginia, as the state's aquifers are individual and localized. The best way to identify aquifers is with a long-term, sustained and localized investigative program.

The 2003-2005 Water Use Survey provided little information on aquifers. Of the respondents who identified groundwater as a source, some were able to provide a lithology type, but few provided an actual formation name. There are typically numerous formations within each geologic system. To fully identify and quantify the groundwater resources of the state, the aquifers must be identified, mapped and tested. Data on the aerial distribution, thickness, fractures, yield rates and lithology of the aquifers will be required. Only further work aimed at delineating the state's aquifers will permit successful management of the groundwater resources.

Although the actual location of the groundwater resources cannot be mapped, the information obtained from the water use survey does indicate where large quantity users of groundwater are located. A current map showing the locations of the state's large quantity groundwater users can be seen in Figure 1-7. Obviously, many factors other than water availability determine where a facility is located and the absence of a large quantity user does not necessarily mean there is an absence of significant ground water reserves.

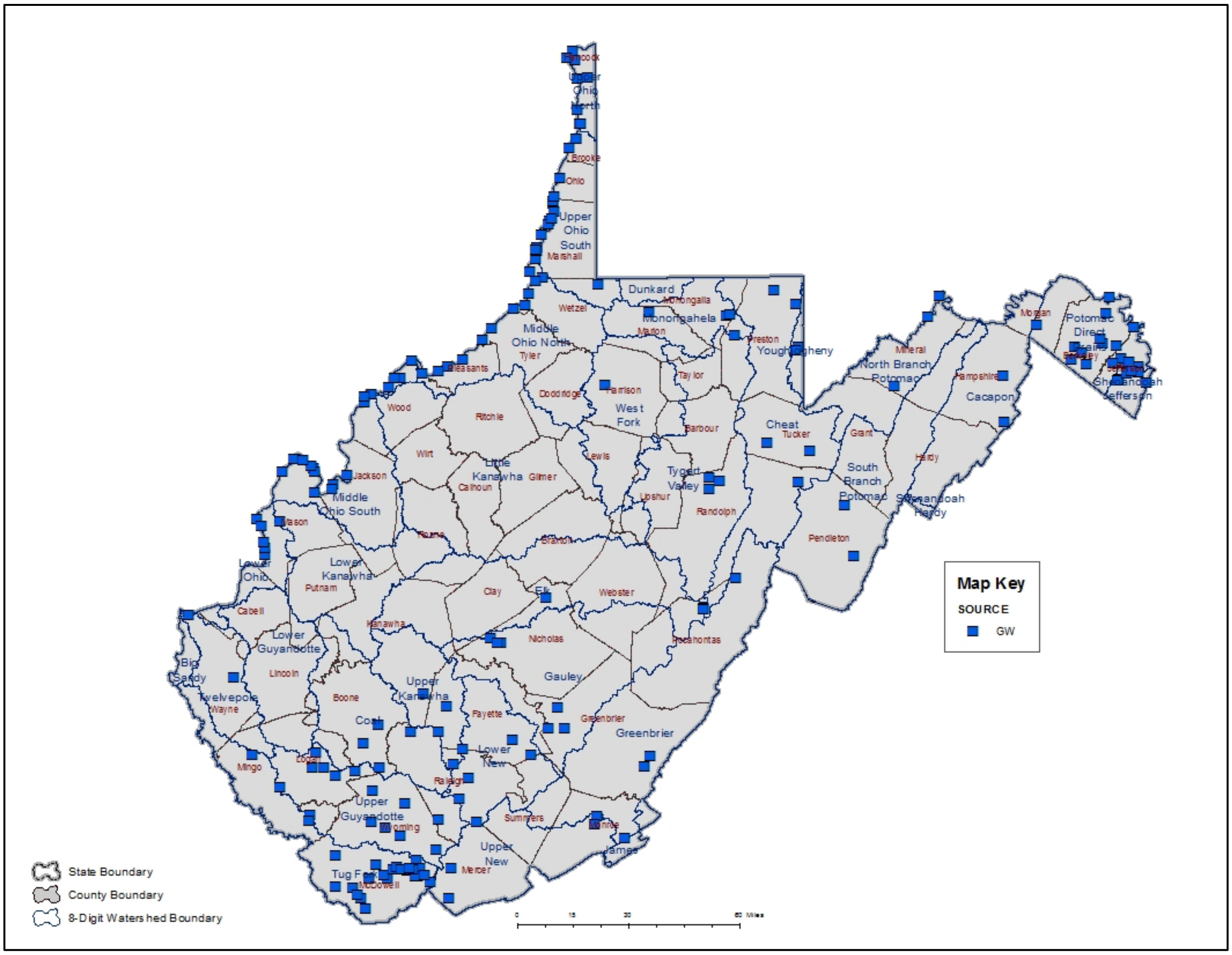



Figure 1-7 Mapped locations of Large Quantity Users who withdraw groundwater

Using data from the initial 2003-2005 Water Use Survey, it was determined that there are two general areas where the groundwater resources are both abundant and most commonly used - along the Ohio River and in the Eastern Panhandle. Along the Ohio River, groundwater usage accounted for 64.5% of the total surveyed. Various chemical manufactures accounted for the majority of the users in the area. In the Eastern Panhandle, groundwater usage accounted for 19.5% of the state's total. The major use in this area was for cement manufacturing. The remaining parts of the state accounted for 16% of the state's total, with coal mining being the major use.

### 1.3.1 Aquifer Characteristics

In order to provide a data set from which recharge rates and transmissivity can be estimated, the USGS (SIR 2001-4036) compiled specific-yield, storage- coefficient and specific-capacity for data wells in the state. Using this data, more accurate groundwater modeling can be developed for specific localized study areas. For instance, according to the USGS (USGS, SIR 2001-4036), analysis of available storage-coefficient and/or specific-yield data indicates the Ohio River alluvial aquifer has a median specific yield of 0.20. This is characteristic of an unconfined aquifer. The specific yield is the quantity of water which a unit volume of aquifer, after being saturated, will yield by gravity; it is expressed either as a ratio or as a percentage of the volume of the aquifer. Characteristic of a semi-confined aquifer, the median specific yield of the Kanawha River aquifer was 0.003. Fractured-bedrock aquifers, which had a median storage of 0.007 is characteristic of a confined aquifer. (USGS, SIR 2001-4036)

Recharge is the process whereby groundwater is replenished by water draining into the groundwater system. Recharge does not include water held in the soil in the unsaturated zone that may be evaporated, taken up by plants, or discharged at topographic lows. Groundwater can be recharged from rainfall, irrigation infiltration or leakage from surface water bodies (e.g. stream, channel, lake). Recharge to unconfined aquifers occurs over a wide area directly above the aquifer. Recharge to confined aquifers occurs where the aquifer is exposed at the surface, or from leakage through confining layers. Recharge to confined aquifers can occur directly where it outcrops (i.e. typically at a higher elevation many kilometers away where it is unconfined) or via slow downward seepage through an overlying leaky aquifer.

The eastern portion of the Kanawha River Watershed has a mean annual recharge rate of 24.6 in/yr – highest in the state.

The Kanawha River Watershed (eastern portion), with a mean annual ground-water recharge rate of 24.6 in/yr, is the highest in the state (Table 1-6). With high reliefs and peak elevations greater than 4,000 feet, this area frequently receives over 50 inches of precipitation annually. The Monongahela River Watershed has a mean annual recharge of over 21 in/yr and extends northward toward Pennsylvania. (USGS, SIR 2001-4036**)**

Unlike the eastern portion, the western portion of the Kanawha River Watershed has relatively low relief, resulting in a much lower mean annual precipitation. This portion of the watershed has a mean recharge of only 11.9 in/yr. The southern part of the state, consisting of wells in the Tug Fork, Twelvepole Creek and Guyandotte River watersheds has a mean annual recharge rate of 12.6 in/yr. Interesting to note is that the area with the lowest mean annual recharge rate in the state is the Little Kanawha River Watershed and Ohio Tributaries at 8.4 in/yr. The Little Kanawha River Watershed and tributary streams in the region ultimately discharge into the Ohio River, the state's largest river. (USGS, SIR 2001-4036)

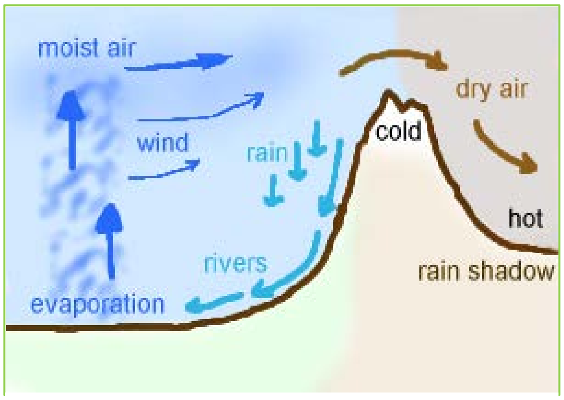



Figure 1-8 Rain shadow

Characterized by long linear northeast to southwest trending ridges and valleys is the state's Eastern Panhandle. Due to a rain shadow (Figure 1-8) created by the Appalachian Mountain Range, this area receives less precipitation than the rest of the state. With a mean annual groundwater recharge rate of 9.4 in/yr, this region is drained by the Potomac River and its tributaries. (USGS, SIR 2001-4036)

Table 1-6 Mean annual recharge rates for the river basins of West Virginia. (Reproduced from USGS Water Resources Investigations Report 2001-4036)

| Station Name | County | Drainage Area (sq mi) | Recharge (in/yr) |
|---|---|---|---|
| **Potomac River Watershed** | | | |
| Back Creek near Jones Springs | Berkeley | 235 | 8.5 |
| South Fork South Branch Potomac River at Brandywine | Pendleton | 103 | 9.0 |
| North Fork South Branch Potomac River at Cabins | Grant | 335 | 11.0 |
| Cacapon River near Great Cacapon | Morgan | 675 | 8.7 |
| South Fork South Branch Potomac River near Moorefield | Hardy | 277 | 7.3 |
| Opequon Creek near Martinsburg | Berkeley | 273 | 9.8 |
| South Branch Potomac River near Petersburg | Grant | 676 | 11.6 |
| Tuscarora Creek above Martinsburg | Berkeley | 11.3 | 11.4 |
| Patterson Creek near Headsville | Mineral | 211 | 7.3 |
| | **Mean** | | **9.4** |
| **Little Kanawha River Watershed and Ohio Tributaries** | | | |
| Hughes River at Cisco | Ritchie | 453 | 7.1 |
| Wheeling Creek at Elm Grove | Ohio | 281 | 9.6 |
| Little Kanawha River at Glenville | Gilmer | 387 | 9.3 |
| Little Kanawha River at Grantsville | Calhoun | 913 | 8.8 |
| Middle Island Creek at Little | Tyler | 458 | 8.0 |
| Reedy Creek near Reedy | Wirt | 79.4 | 6.7 |
| West Fork Little Kanawha River at Rocksdale | Calhoun | 205 | 8.7 |
| Steer Creek near Grantsville | Calhoun | 162 | 9.2 |
| | **Mean** | | **8.4** |

| Station Name | County | Drainage Area (sq mi) | Recharge (in/yr) |
|---|---|---|---|
| **Monongahela River Watershed** | | | |
| Big Sandy Creek at Rockville | Preston | 200 | 21.2 |
| Blackwater River at Davis | Tucker | 85.9 | 22.5 |
| Cheat River near Parsons | Tucker | 722 | 19.9 |
| Middle Fork River at Audra | Barbour | 148 | 24.5 |
| Shavers Fork at Parsons | Tucker | 213 | 24.8 |
| Tygart Valley River at Belington | Barbour | 406 | 15.4 |
| | **Mean** | | **21.4** |
| **Kanawha River Watershed (Western Portion)** | | | |
| Big Coal River at Ashford | Boone | 391 | 11.9 |
| Little Coal River at Danville | Boone | 269 | 11.9 |
| Piney Creek at Raleigh | Raleigh | 52.7 | 11.9 |
| | **Mean** | | **11.9** |
| | | | |
| **Station Name** | **County** | **Drainage Area (sq mi)** | **Recharge (in/yr)** |
| **Kanawha River Watershed (Eastern Portion)** | | | |
| Cherry River at Fenwick | Nicholas | 150 | 27.8 |
| Cranberry River near Richwood | Nicholas | 80.4 | 31.6 |
| Elk River Below Webster Springs | Webster | 266 | 23.9 |
| Gauley River at Camden on Gauley | Webster | 236 | 25.2 |
| Greenbrier River at Durbin | Pocahontas | 133 | 21.1 |
| Meadow River near Mount Lookout | Nicholas | 365 | 20.6 |
| Little Kanawha River near Wildcat [1] | Braxton | 112 | 19.8 |
| Williams River at Dyer | Webster | 128 | 26.4 |
| | **Mean** | | **24.6** |
| **Tug, Twelvepole Creek and Guyandotte River** | | | |
| Guyandotte River at Baileysville | Wyoming | 306 | 14.5 |
| Clear Fork at Clear Fork | Wyoming | 126 | 14.8 |
| East Fork Twelvepole Creek near Dunlow | Wayne | 38.5 | 12.4 |
| Tug Fork at Litwar | McDowell | 504 | 11.3 |
| Panther Creek near Panther | McDowell | 31.0 | 11.1 |
| Tug Fork at Williamson | Mingo | 936 | 12.5 |
| Tug Fork at Kermit | Mingo | 1,280 | 11.2 |
| | **Mean** | | **12.6** |

[1] Although the Little Kanawha River near Wildcat is located in the Little Kanawha River Basin, it has precipitation and recharge rates characteristic of the eastern portion of the Kanawha River Basin.

USGS Scientific Investigations Report 2001-4036, also determined transmissivity rates for several aquifers within the state. What they found was that the highest median transmissivity of an aquifer in the state occurs in Ohio River alluvium at 4,800 $ft^2/d$ (Table 1-7). Transmissivity is measured as the rate ($ft^2/d$ ) at which groundwater can flow through an aquifer's entire saturated section of unit width under a unit hydraulic gradient which can be determined by pump testing of a groundwater well using time-drawdown data.

**Table 1-7 Transmissivity measurements of certain aquifers within the state as identified in USGS SIR 2001-4036**

| Aquifer | Transmissivity Rate ($ft^2/d$) |
|---|---|
| **Ohio River Alluvium** | 4,800 |
| **Kanawha River Alluvium** | 1,600 |
| **Conococheague Formation** | 92 |
| **Mahantango Formations** | 92 |
| **Oriskany Sandstone** | 82 |
| **Hampshire Formation** | 74 |
| **Brallier-Harrell Formations** | 72 |
| **Waynesboro-Tomstown-Harpers-Weverton-Loudon** | 67 |
| **McKenzie-Rose Hill-Tuscarora** | 23 |

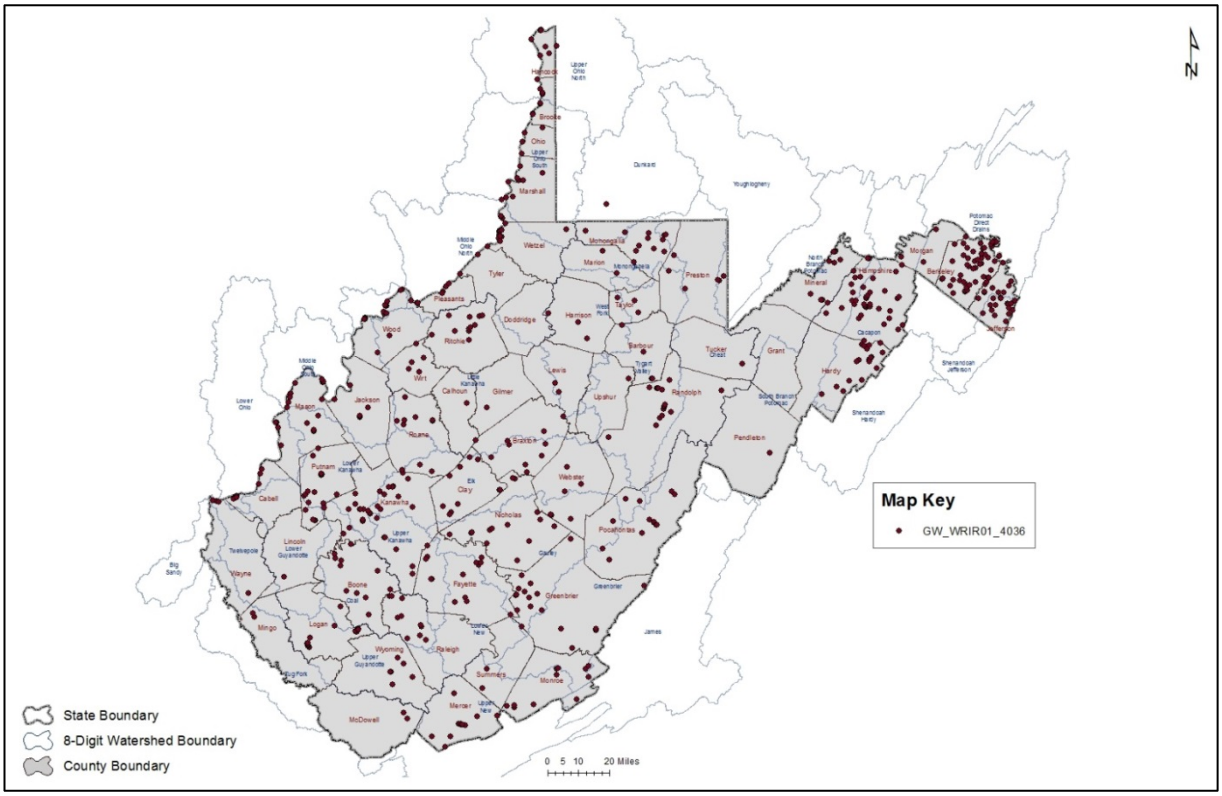



**Figure 1-9 Sample locations in examining aquifer characteristics of West Virginia. (The DEP produced map using data provided in USGS, Water-Resources Investigations Report 2001-4036)**

## 1.3.2 West Virginia Mine Pool Atlas

One currently underutilized and frequently overlooked source of stored groundwater is abandoned coal mines. Recently, mine pools have been considered as a source for large quantity water use to facilitate various processes, such as aquaculture, public supply, coal-to-liquid hydrocarbons, hydraulic fracturing for gas wells and power plant cooling. In response, the WVGES and the DEP have collaborated to produce a Mine Pool Atlas to estimate the potential groundwater reserves within these abandoned coal mines across the state. Although the state receives an average of 44 inches of precipitation per year and is considered to have an abundant supply of water, much of the precipitation runs off and leaves the state via the Ohio and Potomac rivers. The remainder infiltrates the ground surface and recharges the groundwater aquifers. In this state, abandoned coal mines could be considered an aquifer.

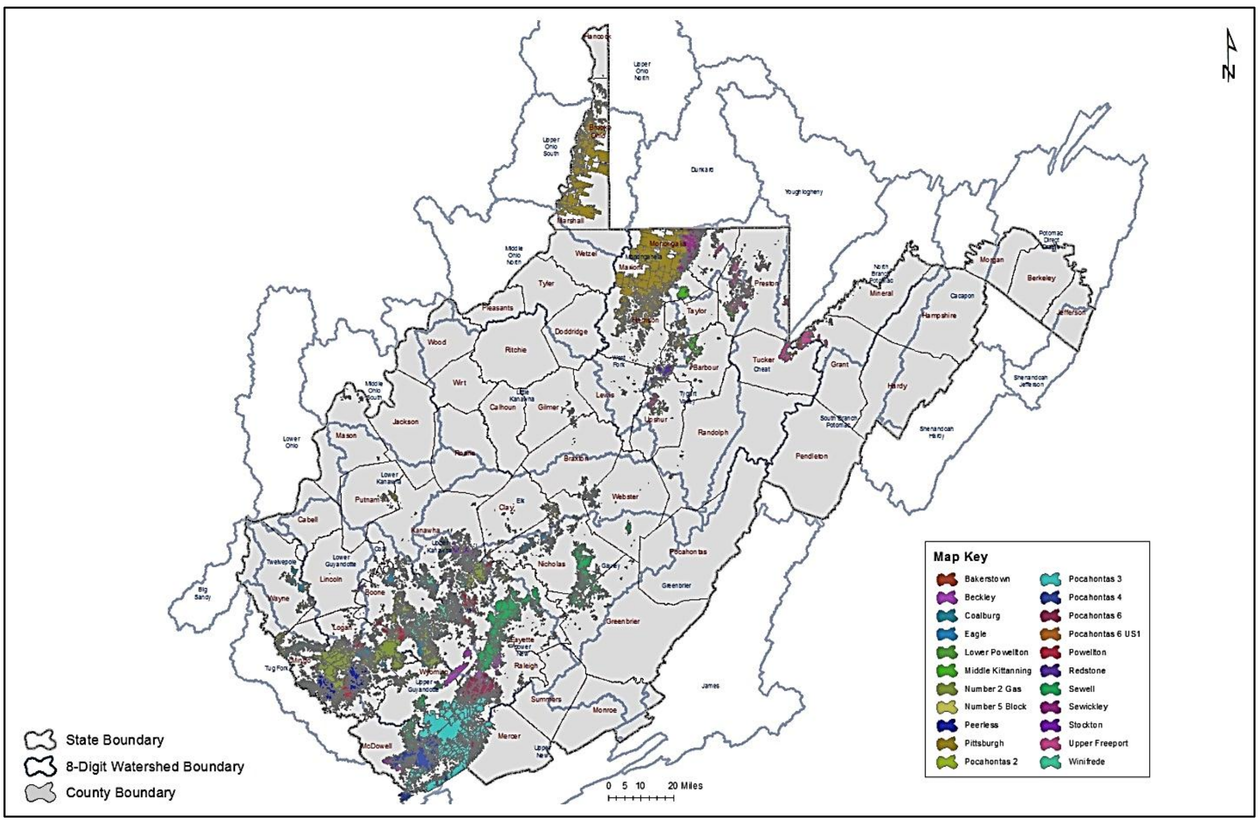



**Figure 1-10 Footprints of all documented underground mines in West Virginia and coal seam delineated areas of potential mine pools**

This study was designed to facilitate prospecting for large volumes of water by using available Coal Bed Mapping Program (CBMP) products to identify underground coal mines that have the potential to store large quantities of groundwater, especially those mines that are located below or near drainage. This study provides an initial effort to locate all of the large mine pools in the state, both stratigraphically and geographically. The potential mine void volumes were based on the WVGES CBMP GIS data which provide an up-to-date picture of the state's coal resource. This dataset includes many mine maps that have been collected by the CBMP.

Significant underground mining has taken place in 69 of 73 of West Virginia's mineable coal beds. Mine polygons, coal crop-lines, structure contours and scanned mine maps of 69 coal beds were visually examined. This helped to establish which areas had adequate data to determine the position of each mine relative to major drainage and to develop a tool to predict which mines could be partially or totally filled with groundwater.

Nineteen coal beds containing underground mines located near or below drainage that were 500 acres or larger and located near or below drainage were considered major coal beds in this study.

The results of this study are summarized in the report including maps and statistics related to potential mine pools of major coal units identified by the CBMP. As the individual CBMP data layers are dynamic rather than static, all results presented in the report are preliminary and are undergoing constant updating. However, a preliminary hard copy report has been completed and can be downloaded from the following website:

http://www.dep.wv.gov/WWE/wateruse/Documents/MinePoolAtlas.pdf

**Table 1-8 Brief overview of the information contained within the Mine Pool Atlas**

| Key information contained in The Mine Pool Atlas: |
|---|
| • **General descriptions of major coal beds within each formation**<br>• **Stratigraphic columns showing the position of all coal beds within each formation**<br>• **Tables showing the distribution of potential totally and partially flooded mines in each seam by mine footprint area and position with respect to drainage**<br>• **Tables showing the distribution of potential partially flooded areas of above and near drainage underground mines by coal bed**<br>• **Maps of coal beds in which potential partial and/or total flooding was present in mines that had areas of 500 acres or greater**<br>• **Structural contours of the coal beds**<br>• **Isopach maps (total bed thickness)**<br>• **Seam overview**<br>• **Extent of potential total flooding**<br>• **Extent of potential partial flooding**<br>• **Overview tables for seams in which potential partial and/or total flooding were present in mines less than 500 acres in area** |

Much of the underground mining in the state has occurred above drainage. Examination of 9,539 mine polygons in 69 coal units determined that 8,907 mines are above drainage; 325 near drainage, 178 are below drainage and 129 are currently undetermined. Study results showed that 99 mines, which exceed 500 acres in area, are generally located below drainage and are potentially totally flooded.

Five hundred thirty-two mines exceeding 500 acres in area are potentially partially flooded, 147 of these mines are located near drainage and 385 mines are above drainage. These mines are in 19 major coal beds. Fourteen of these coal beds have mines that are potentially totally flooded as listed below in Table 1-9.

**Table 1-9 Potentially totally flooded mines are located within these 14 major coal beds**

| Potentially totally flooded mines are located within these 14 major coal beds: |
|---|
| • Pittsburgh coal in Ohio, Marshall, Monongalia, Marion and Harrison counties |
| • Upper Freeport coal in Preston County |
| • Middle Kittanning coal in Preston and Barbour counties |
| • Coalburg coal in Wayne and Lincoln counties |
| • Peerless coal in Kanawha, Nicholas and Mingo counties |
| • Number 2 Gas coal in Logan, Mingo, Boone and Kanawha counties |
| • Powellton coal in Boone, Logan and Mingo counties |
| • Lower Powellton coal in Mingo County |
| • Eagle coal in Nicholas, Fayette, Kanawha, Boone, Logan and Mingo counties |
| • Sewell coal in Nicholas, Fayette, Raleigh and Wyoming counties |
| • Beckley coal in Fayette, Raleigh and Wyoming counties |
| • Pocahontas No. 6 coal in Raleigh County |
| • Pocahontas No. 4 coal in McDowell County |
| • Pocahontas No. 3 coal in Wyoming, McDowell and Raleigh counties |

Additionally there are five major coal beds that have potentially partially flooded mines (Table 1-10).

**Table 1-10 Coal beds that have potentially partially flooded mines**

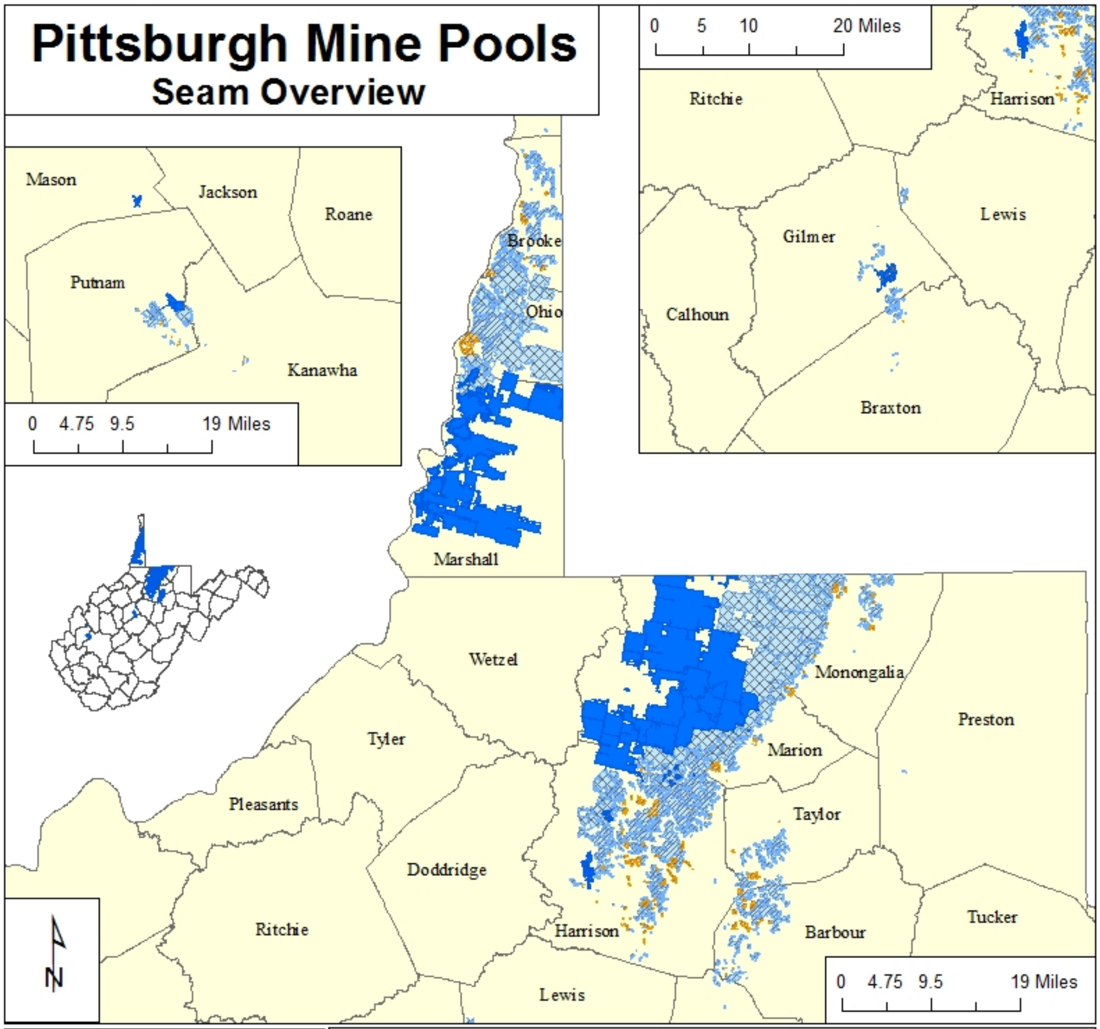
| Coal beds that have potentially partially flooded mines: |
|---|
| • Sewickley coal in Monongalia and Marion counties |
| • Bakerstown coal in Preston, Grant and Tucker counties |
| • Number 5 Block coal in Braxton, Nicholas, Clay, Kanawha, Boone, Lincoln, Mingo and Wayne counties |
| • Stockton coal in Braxton, Nicholas, Kanawha, Boone, Logan, Lincoln and Mingo counties. |
| • Pocahontas No. 2 coal in Raleigh County. |

> With a total of 1.475 trillion gallons of potential storage, the average mine pool holds close to 245 million gallons of water.

Although efforts are made to use the best available data and locate mines as accurately as possible, mine locations should be considered approximate. The actual extent of mining may be unknown because final mine maps at the time of mine closure are not always available and not all underground mining has been documented by mine maps. The quality of mine maps is highly variable in the amount of detail and information presented. Some of the newer mine maps are available in digital form; however, many older mine maps have been photographically reduced from dimensionally unstable paper copies. Photographic reduction also introduced distortion due to lens geometry. Also, coal correlations may change with additional information. Active mines are not differentiated from recently closed mines in the CBMP database.

The extent of potential mine flooding is dependent on several factors, including mine orientation, mine entry location, proximity to other underground mines and direction of groundwater flow. Groundwater pumping to enable underground mining can affect water levels in adjacent underground mines. The groundwater flooding potential for underground mines in one coal bed also may be affected by underground mining in stratigraphically lower coals. In general, once pumping ceases, the mines begin to flood. The results of this study should be considered a “snapshot” rather than a finished product. New mines continually open in West Virginia and in adjoining states near the state’s borders. In addition, newly obtained geospatial mining coverage’s are being constantly updated in the CBMP GIS as new information becomes available. All of these factors reinforce the need for detailed site-specific studies to determine the presence of adequate water resources. Figure 1-11 and Table 1-11 are examples of the maps and data included in the Mine Pool Atlas.

Now that we have a better understanding of the location of these mine pools, it would be advantageous to begin gathering existing water quality data and sampling, where necessary, to give public water suppliers, industry and others a clearer idea of the potential uses for this vast water source.




## Legend

**Position**

- Above Drainage
- Near Drainage
- Below Drainage

**Potential Extent of Flooding**

- Undetermined
- Flooded areas unlikely
- Partially flooded
- Totally flooded

## Pittsburgh Mine Pool Statistics

| | Undetermined | Potentially flooded areas unlikely | Potentially partially flooded | Potentially totallyflooded |
|---|---|---|---|---|
| No. of Mines | 0 | 196 | 564 | 46 |
| Mean coal thickness (feet) | 0.00 | 5.61 | 6.06 | 6.38 |
| Min. foot print area (acres) | 0.00 | 0.01 | 0.01 | 0.92 |
| Max. foot print area (acres) | 0.00 | 652.31 | 14,923.99 | 20,204.27 |
| Mean foot print area (acres) | 0.00 | 42.05 | 350.55 | 3,933.91 |
| Median foot print area (acres) | 0.00 | 6.97 | 22.44 | 641.06 |
| Total foot print area (acres) | 0.00 | 8,242.18 | 197,712.71 | 180,959.81 |
| Estimated void volume (acre feet) | 0.00 | 28,227.65 | 673,947.07 | 625,388.68 |
| Max. potential storage (million gallons) | 0.00 | 9,199.39 | 219,639.35 | 203,814.17 |

Figure 1-11 Example map and associated statistics for coal seams in the in the mine pool atlas. Shown is the Pittsburgh Mine Pools Seam Overview with pool statistics

Table 1-11 Total quantity of potential water contained in partially and fully flooded mine seams as reported by the Mine Pool Atlas (this table was created by the DEP with data acquired from the mine pool atlas)

| Coal Seam | All Mine Pools in Coal Seam | Average Seam Thickness | Total Potential Storage (Gallons) | Average Potential Storage (Gallons) |
|---|---|---|---|---|
| **Bakerstown** | 84 | 190,289.02 | 5,362,694,730.74 | 63,841,603.94 |
| **Beckley** | 271 | 512,123.01 | 46,562,234,336.75 | 171,816,362.87 |
| **Coalburg** | 301 | 688,039.12 | 69,481,552,108.26 | 230,835,721.29 |
| **Eagle** | 494 | 657,912.24 | 109,039,800,012.10 | 220,728,340.11 |
| **Lower Powellton** | 119 | 252,847.75 | 10,094,764,525.04 | 84,829,953.99 |
| **Middle Kittanning** | 43 | 1,270,021.07 | 18,321,862,524.86 | 426,089,826.16 |
| **Number 2 Gas** | 566 | 874,568.58 | 166,073,555,902.78 | 293,416,176.51 |
| **Number 5 Block** | 426 | 134,799.71 | 19,265,850,085.57 | 45,225,000.20 |
| **Peerless** | 284 | 572,645.65 | 54,562,524,724.28 | 192,121,565.93 |
| **Pittsburgh** | 806 | 1,599,979.05 | 432,652,914,379.32 | 536,790,216.35 |
| **Pocahontas 2** | 15 | 191,408.72 | 963,259,171.30 | 64,217,278.09 |
| **Pocahontas 3** | 299 | 1771,566.09 | 177,712,803,595.72 | 594,357,202.66 |
| **Pocahontas 4** | 58 | 2609,149.44 | 50,771,206,000.88 | 875,365,620.70 |
| **Pocahontas 6** | 262 | 270,540.70 | 23,780,666,168.39 | 90,765,901.41 |
| **Pocahontas 6 US1** | 65 | 40,722.41 | 888,040,044.31 | 13,662,154.53 |
| **Powellton** | 321 | 346,959.75 | 37,365,788,172.33 | 116,404,324.52 |
| **Redstone** | 199 | 191,288.85 | 12,771,219,690.76 | 64,176,983.37 |
| **Sewell** | 600 | 446,188.76 | 89,817,273,030.60 | 149,695,455.05 |
| **Sewickley** | 76 | 936,117.85 | 23,869,000,345.11 | 314,065,794.01 |
| **Stockton** | 160 | 574,426.84 | 30,835,052,890.38 | 192,719,080.56 |
| **Upper Freeport** | 285 | 530,953.26 | 50,768,138,431.70 | 178,133,819.06 |
| **Winifrede** | 283 | 463,933.74 | 44,048,623,298.22 | 155,648,845.58 |
| **Grand Total** | **6,017** | **730,675.33** | **1,475,008,824,169.40** | **245,140,240.01** |

### 1.3.3 Water-well Inventory

The West Virginia Department of Health and Human Resources (DHHR) currently requires that well drillers provide a water-well completion report for any public drinking water supply well. When a driller installs a privately owned drinking water well, they are required to obtain a permit from their county health department. The permit requires the driller to report the name of the landowner, the county in which the well is located, a driller's log, casing and grouting information and the well driller's name and registration numbers, and amount of water the well produced. West Virginia Code does not currently require the driller to report the latitude, longitude or the depth to water surface, which is preferred by the DEP for mapping purposes. A groundwater database with precise well locations and aquifer characteristics would be required to create a statewide groundwater model. Latitude and longitude is the preferred coordinate system, in decimal degrees.

The drillers often provide the postal address of the well owner in lieu of the latitude and longitude of the well's actual location. There are several problems with providing a postal address for the location of the well. An off-site address or P.O. Box may be used, the property may have been sold, the postal residence destroyed, or the landowner may have moved. Thus, vague imprecise postal locations do not allow accurate mapping of the well locations. The DHHR has years of water well data, but the aquifers have not been characterized, the wells have not been mapped, nor have the potential maximum withdrawal rates been established for the state's groundwater aquifers. The DHHR sanitary surveys are another potential source of data. However, they are predominately aimed at protecting human health and do not include detailed aquifer data.

Once precise locations for each well are acquired, an elevation for that well can be obtained using a digital elevation model. By including the depth to water and quantity of water the well-produced on the well completion report, additional aquifer characteristics can be determined.

The "depth to water" can be used, together with the wellhead elevation, to determine an elevation for the top of the groundwater surface and a map of these surfaces can then be produced. This map is the first step in creating a statewide groundwater model. This information would be useful to public and private water managers, oil and natural gas well drillers and water well drillers. It must be emphasized that a groundwater model cannot be created without knowing where the groundwater is located in the subsurface. To fully identify the groundwater location within the subsurface, the latitude, longitude and elevation of the wellhead, as well as the depth to groundwater and aquifer thickness, must be known.

The elevation of the groundwater from numerous wells in the same localized area can be used to determine the flow direction of the local groundwater system. Once the basemap for the groundwater model has been produced, variables such as, but not limited to, groundwater quality, yield and recharge can be added.

The DEP plans to provide a portal on its new web page to allow private water well owners to provide the location and depth to groundwater in their wells, which will aid in future mapping of the state's groundwater resource.

### 1.3.4 Groundwater Monitoring Network

State and regulatory agencies in the past have had few options available for predicting or assessing groundwater conditions in West Virginia, especially during a drought. Historically, streamflow data was used to assess and predict water resource conditions and evaluate the affects of drought. This approach did not adequately assess changes in groundwater storage. However, real-time groundwater level data provides a much more effective way of assessing regional changes in groundwater storage for evaluating and predicting groundwater conditions and assessing water availability. The USGS in cooperation with the DEP collects continuous water-level data within a network of 16 wells (Figure 1-12). These 16 wells that comprise the current statewide water-level monitoring network are equipped with satellite telemetry to provide real-time data for groundwater-level monitoring and analysis. Real-time data is especially useful for assessing water-level conditions during periods of drought, when daily or weekly management decisions are needed with respect to water conservation measures.

The overall purpose of the groundwater-level monitoring network is to collect real-time fluctuations of groundwater elevations within the state. The network now has at least two wells in each of the state's six major climatological regions (Figure 1-12) to assess the impact of changes in groundwater storage, especially with respect to drought. These 16 wells provide federal, state and local water management agencies with critical data for assessing and evaluating groundwater conditions and assessing the impact of drought throughout the state. Certain areas of the state that are highly dependent on groundwater, especially the agricultural areas of the Cambro-Ordovician karst aquifers in the Eastern Panhandle, have a higher density of wells due to importance of the resource in that region.

All real-time data collected at each of the 16 wells is posted on the Internet so that federal, state and local agencies, as well as water plant operators, industry, agricultural organizations, farmers and individuals, may obtain current water-level information quickly and easily. All 16 wells are currently displayed on both the USGS climate response network (CRN) and real-time groundwater-level websites (http://groundwaterwatch.usgs.gov/). The CRN and real-time websites have the capability to update water-level statistics and display the results of historical and current water-level trends graphically over the Internet, which makes it easy for users to assess current groundwater-level trends.

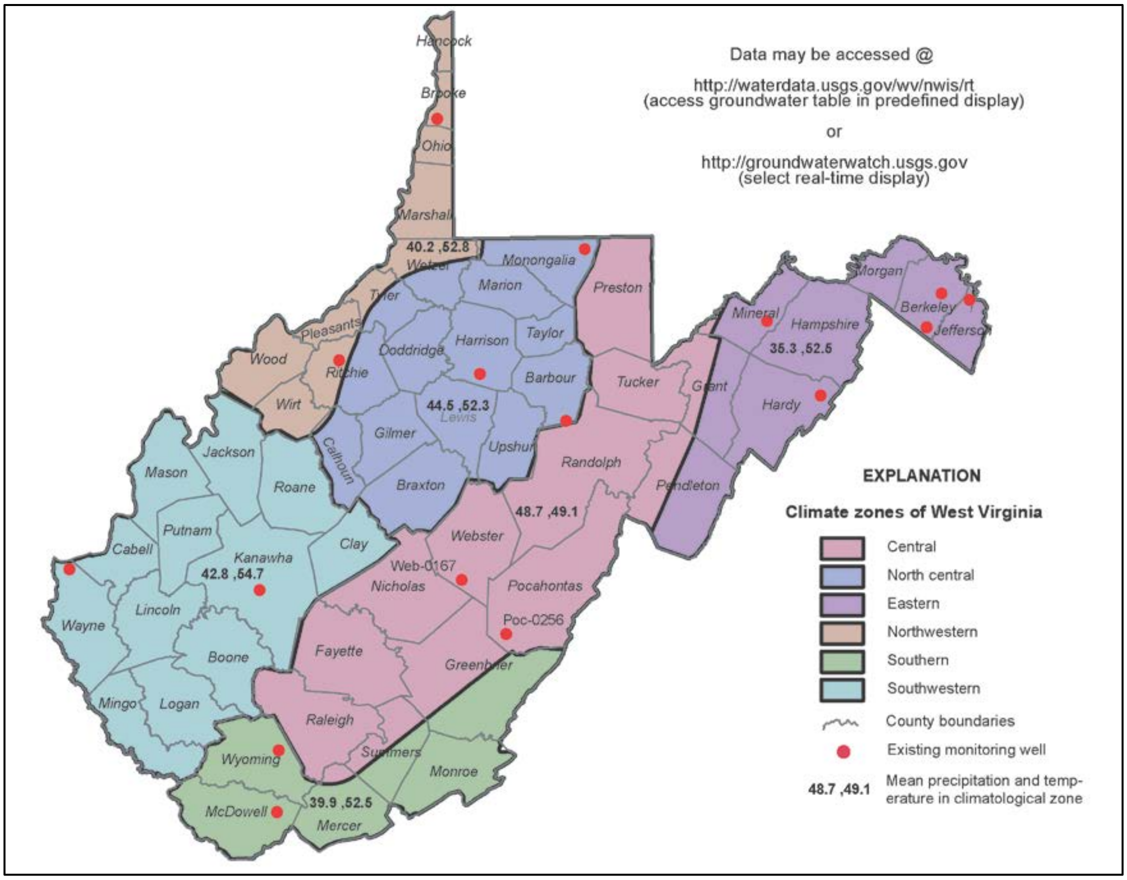
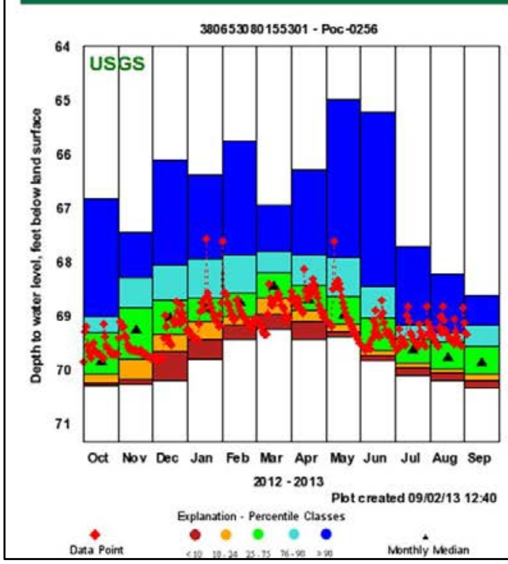



Figure 1-12 Climatological zones and monitoring wells for the statewide water-level monitoring network in West Virginia (source NOAA-NWS and USGS)

Continued maintenance of this network will result in a groundwater-monitoring program for the state which can be used to assess changes in groundwater storage and to assess the areal distribution and extent of droughts. Public water suppliers, federal, state and local agencies will have real-time access to groundwater-level information and statistical data on current and historical groundwater levels. The information can be used in the decision-making processes on whether or not water conservation measures should be initiated and where those measures may be needed. The data can also be used by federal and state agencies for issuing drought warnings and making declarations of drought emergencies.

The groundwater monitoring network continues and is operating as originally envisioned. All wells are being maintained and instrumentation has been upgraded on the wells to current standards for data storage, transmission and telemetry. Real-time data can be accessed at the following USGS website: http://waterdata.usgs.gov/wv/nwis/current/?type=gw&group_key=county_cd

One well, in Monongalia County, provides accurate data for low-flow periods, but water levels fluctuate between two distinct bedding planes which make it difficult to assess trends in groundwater storage above a certain threshold level. The USGS has plans to replace the Monongalia County well with a more suitable well as soon as possible. The USGS is in consultation with West Virginia University to potentially drill a well on university property in the Morgantown area. If this alternative proves difficult to implement, then a suitable well location elsewhere may be necessary, perhaps in Preston County. At this time, the water level monitoring wells are too sparsely distributed to be of use in developing a statewide understanding of its groundwater resources (Figure 1-12).




Site Statistics

Most recent data value: 69.35 on 9/2/2013
Period of Record Monthly Statistics for 380653080155301
Depth to water level, feet below land surface
All Approved Continuous & Periodic Data Used In Analysis
Note: Highlighted values in the table indicate closest statistic to the most recent data value.

| Month | Lowest Median | 10th %ile | 25th %ile | 50th %ile | 75th %ile | 90th %ile | Highest Median | Number of Years |
|---|---|---|---|---|---|---|---|---|
| Jan | 69.79 | 69.42 | 69.09 | 68.86 | 68.66 | 67.93 | 66.36 | 36 |
| Feb | 69.41 | 69.16 | 69.01 | 68.75 | 68.55 | 67.86 | 65.75 | 34 |
| Mar | 69.24 | 68.95 | 68.65 | 68.45 | 68.18 | 67.80 | 66.93 | 35 |
| Apr | 69.43 | 69.09 | 68.89 | 68.70 | 68.41 | 67.87 | 66.27 | 37 |
| May | 69.38 | 69.29 | 69.14 | 68.97 | 68.62 | 67.90 | 64.97 | 38 |
| Jun | 69.82 | 69.73 | 69.63 | 69.34 | 69.03 | 68.45 | 65.20 | 37 |
| Jul | 70.09 | 69.95 | 69.87 | 69.62 | 69.43 | 69.17 | 67.70 | 37 |
| Aug | 70.20 | 70.06 | 69.98 | 69.78 | 69.46 | 69.30 | 68.21 | 36 |
| Sep | 70.33 | 70.19 | 70.08 | 69.86 | 69.55 | 69.16 | 68.61 | 36 |
| Oct | 70.29 | 70.24 | 70.08 | 69.84 | 69.30 | 68.99 | 66.81 | 35 |
| Nov | 70.26 | 70.16 | 69.80 | 69.25 | 68.83 | 68.28 | 67.44 | 35 |
| Dec | 70.18 | 69.66 | 69.32 | 69.03 | 68.70 | 68.05 | 66.10 | 36 |

Statistics Options

View month/year statistics

**Figure 1-13 Water-level data for the USGS/WVDEP long-term monitoring well in Pocahontas County. (Note that the majority of the red measured data points are in the higher percentile classes representing higher levels than average for the year shown)**

Future plans are to maintain the network and continue to move sites from the USGS real-time well network to the CRN after a sufficient period of record is available for statistical analysis of long-term groundwater-level trends.

### 1.3.5 Geophysical Well Log Archiving Project

The DEP has been mandated by the Act to develop a plan to characterize the groundwater aquifers within the state. Unfortunately, there is sparse data on which this aquifer characterization may be based. This is especially true for borehole well-log data from fractured bedrock aquifers within the state. A characterization of aquifers within the state requires a better understanding of the bedding planes, joints, faults and other fractures through which a majority of groundwater flows or is stored.

Numerous geologic and hydrologic investigations have been conducted by the USGS and the DEP throughout the state. Unfortunately, well-log data useful for characterizing fractured rock aquifers within the state is sparse. Older records lack some of the more relevant logs, such as acoustic televiewer and electromagnetic (EM) flow logs, which have recently become standard for characterizing fracture distribution within wells and assessing individual fractures with respect to their capacity to store and or transmit water to wells. To address the issue, the USGS and the DEP have partnered to develop a statewide borehole log archive. The current borehole log archive is comprised primarily of well logs from USGS studies. The archive is maintained by the USGS and is updated as additional logs become available. Detailed results of the geophysical well logging of the state's 16 groundwater monitoring wells are included in Appendix G.

At present, the well log archive is comprised of the following: well logs collected from 11 wells for hydrologic investigations recently completed in the Cambro-Ordovician carbonate bedrock aquifers in the Shenandoah Valley; well logs for seven wells drilled for a recently completed hydrologic investigation of abandoned underground coal mines used as a source of water for public supply in McDowell County; and well logs for 11 wells scattered across West Virginia as part of the joint USGS/WVDEP Groundwater Level Monitoring Network. The current statewide network of 29 wells with logs is at present insufficient for characterization of fracture distribution in the state's major hydrologic settings. However, plans are to add wells to the network as part of on-going USGS/WVDEP cooperative hydrologic investigations.

Data for two complex hydrologic studies has been analyzed and is available. These projects include the Leetown and Elkhorn hydrologic studies. The Leetown hydrologic report, with associated borehole geophysical analysis, is currently available online at the following internet web address:

http://pubs.er.usgs.gov/publication/ofr20071358.

The Elkhorn hydrologic report, with associated borehole geophysical analysis is currently available online at the following internet web address:

http://www.wvgs.wvnet.edu/wvges2/publications/PubCat_MainSearch.aspx,

To access the report, connect to the WVGES website above and search for the report by publication number, which is West Virginia Geological Survey Bulletin B-46.

All well logs collected as part of the project have been archived in the USGS Water Science Center borehole geophysical logs archive. A USGS report was planned for online publication to summarize the well log data, but the project was postponed. Additional funding would have to be allocated to restart the project, collect additional well logs (to warrant a statewide assessment of the borehole log archive) and write a summary report.

Borehole geophysical logs provide information on well construction, location and orientation of fractures, water-producing and water-receiving zones, intervals of vertical borehole flow and stratigraphic sequence that can be used for lithologic correlation. The subsurface information that can be determined by the use of borehole geophysics and the geophysical methods employed are summarized in the following table:

**Table 1-12 Summary of geophysical logs. (A, acoustic televiewer; C, caliper; N, natural-gamma; R, single-point resistance; T, fluid-temperature; F, fluid-resistivity; V, heatpulse flowmeter)**

| Borehole geophysical log | Subsurface information |
|---|---|
| A, C | Location and orientation of fractures and water-producing zones |
| R, T, F | Location of water-producing and water-receiving zones |
| T, F, V | Intervals of vertical borehole flow |
| V | Quantification of borehole flow |
| N, R | Lithologic correlation |
| C, N | Casing length |
| C | Borehole diameter |

The acoustic televiewer is a sonic imaging tool that scans the borehole wall with an acoustic beam. The reflected acoustic waves are recorded digitally on a portable computer and images of transit time and amplitude of the waves are produced. The logs are corrected for magnetic orientation, magnetic declination (true north) and borehole deviation from vertical by the logging software. Fractures are detected by longer transit times and decreased signal amplitudes. Because the returned data is oriented to true north and corrected for borehole deviation from vertical, strike and dip for each fracture or bedding plane can be determined. The acoustic televiewer can be used underwater in 6 to 8 in.

diameter boreholes. Because of magnetic interference, the acoustic televiewer cannot determine fracture orientation within about 6 feet of the bottom of steel casing.

Borehole deviation logs, also called dip-meter logs, record the deviation of a borehole from true vertical. Deviation of boreholes from the vertical is common and deviation logs are used to calculate true vertical depth of features of interest and to correct the strike and dip of fractures, fracture traces, mineralization, or bedding obtained from acoustic televiewer logs.

Caliper logs provide a continuous record of average borehole diameter, which may be related to fractures, lithology, or drilling methods. Caliper logs can be used to identify fractures and possible water- producing or water-receiving zones and to correct other geophysical logs for changes in borehole diameter. They also can be correlated with fluid-temperature logs and heatpulse flow metering to identify additional fractures and water-producing and water-receiving zones.

The natural-gamma or gamma log measures the natural-gamma radiation (photons) emitted from all rocks. The most common emitters of gamma radiation are uranium-238, thorium-232, their daughter elements and potassium-40. These radioactive elements are concentrated in clays by adsorption, precipitation and ion exchange. Fine-grained sediments such as shale or siltstone usually emit more gamma radiation than sandstone, limestone, or dolomite. The gamma log can be collected in or out of water or casing. However, casing does reduce the gamma response. The gamma log is used to identify the stratigraphic sequence which can aid in correlation of geologic units between muliple wells.

The single-point-resistance log records the electrical resistance of a formation between the probe in a water-filled borehole below casing and an electrical ground at land surface. Generally, electrical resistance increases with formation grain size and decreases with borehole diameter, water-producing fractures and increasing concentration of dissolved solids of borehole water. The single-point-resistance log is used to correlate geology between wells and may help identify water-producing zones (Keys, 1988).

The direction and rate of borehole-water movement is determined by the use of a heatpulse flow meter. The heatpulse flow meter operates by heating a small sheet of water between two sensitive thermistors (heat sensors) located the same distance from the heat source. The time it takes for the heated water to move upward or downward past one of the thermistors is recorded. Because the thermistors are located in a channel of fixed diameter, the flow rate can be determined from the time it takes for the peak of the heatpulse to pass one of the thermistors. A flexible diverter is used to block the annular space around the tool to channel all the flow through the measurement channel. The range of flow measurement is about 0.01-1.2 gal/min in a 2- to 10-in.-diameter borehole (Conger, 1996).

Some heatpulse-flow meter measurements may be influenced by poor seal integrity between the borehole and heatpulse flow meter and contributions of water from storage within the borehole. If the seal between the borehole and flow meter is not complete, some water can bypass the flow meter, resulting in measurements of flow that are less than the actual rate. Although the heatpulse flow meter is a calibrated probe, the data are used primarily as a relative indicator to identify water-producing and/or water-receiving zones.

As USGS projects are completed, the well logs for the investigations will be added to the archive to continue to build the database of well logs available for retrospective analyses. The archive at present contains well logs for only 29 wells, so additional wells are needed and will be added as opportunities occur. Plans are for a retrospective analysis of fracture data for water wells in West Virginia, but at least another 20 to 30 wells and funding are needed before such a retrospective analysis would be feasible. For a more detailed description, as well as borehole logs, refer to Appendix G.

### 1.3.6 Spring Inventory

The Springs of West Virginia 50th Anniversary Revised Edition, printed in 1986 by the WVGES, documents over 1,000 springs within the state. This publication needs to be updated and expanded, with emphasis given to the proper spring name (as used by the local communities), the spring's location (again using latitude and longitude), whether the spring is perennial or intermittent, the geological unit the spring is formed in and the estimated or measured spring flow.

This work should be completed in two parts, with the first portion comprised of a literature search of those springs not included in the 1986 publication. The second part should consist of field work using dedicated personnel and equipment to locate additional springs. In addition, because springs are always changing in volume, long-term stage measurements should be made of the largest and most important springs within the state. This will involve surveying the surface across the spring's outlet and then installing flow-measuring equipment in the spring head. The following map shows locations of the springs in our database. The diameter of the dot represents the approximate spring flow in gallons per minute. For complete known spring data (as well as karst springs), please visit the DEP website: http://tagis.dep.wv.gov/WVWaterPlan/

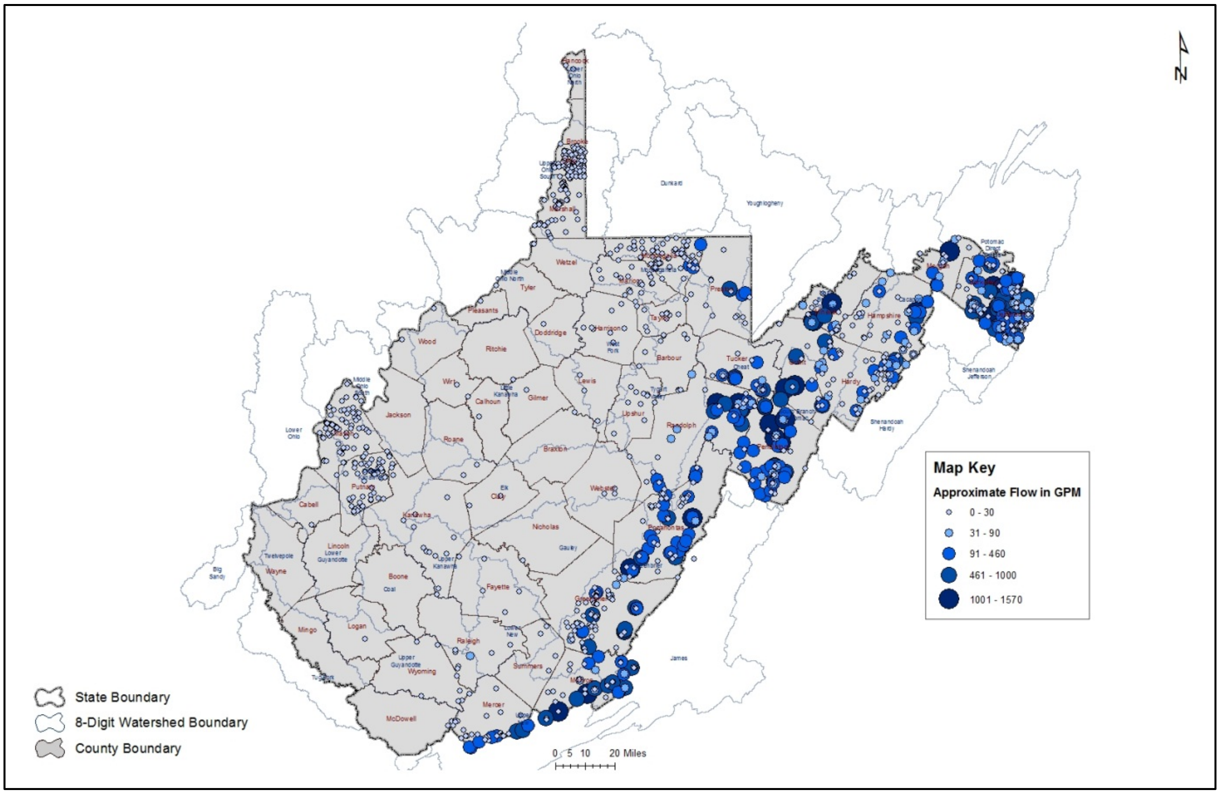



**Figure 1-14 Documented springs of West Virginia and their flow in gallons per minute**

To enhance the spring knowledge in WV, the DEP will be creating an online tool where landowners can self register their spring. As resources allow, the DEP will visit and document the reported springs.

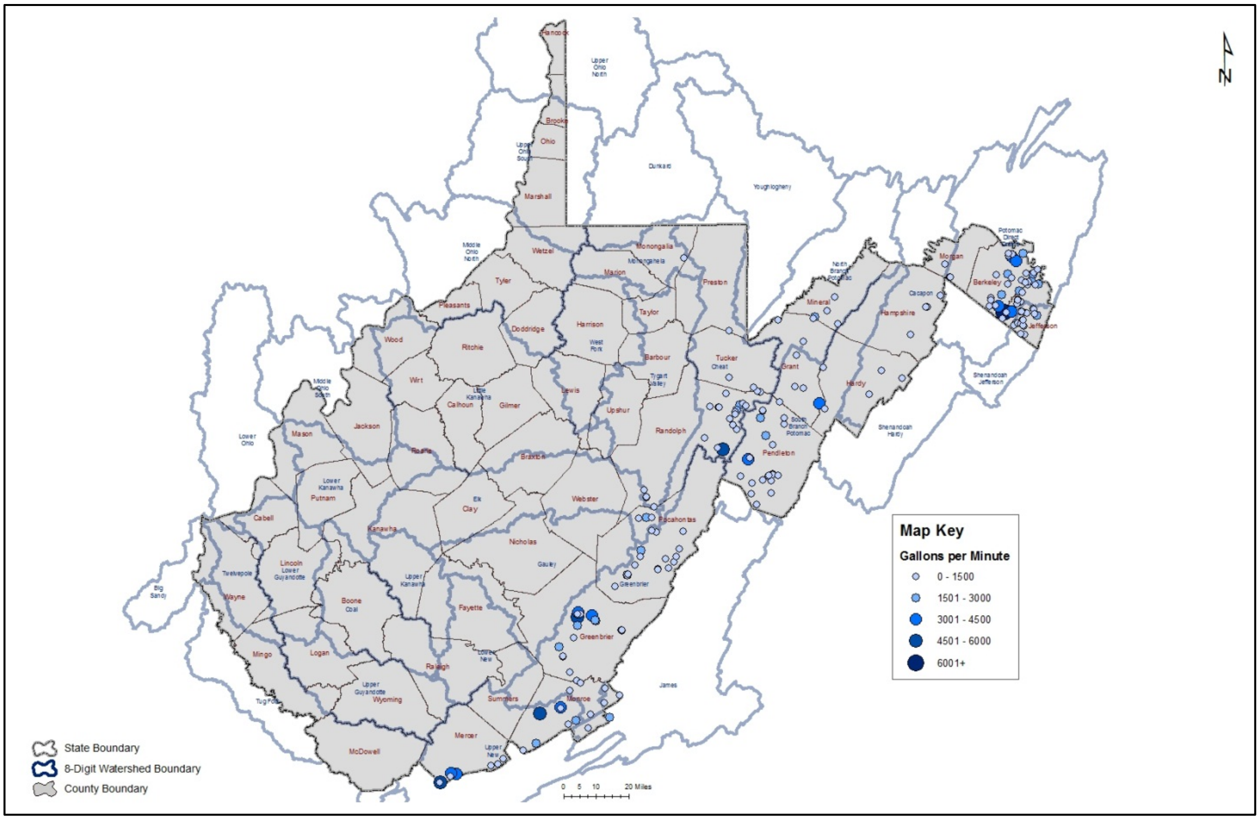



**Figure 1-15 Documented karst springs of West Virginia and their flow in gallons per minute**

### 1.3.7 Dye-Tracing Database

The DEP has recently compiled a GIS database of more than 300 documented dye traces that have been completed within the karst areas of eastern West Virginia. The fields within this database include the input point for the dye, the location where the dye appeared on the surface, the area and county of the trace, who completed the trace, when the trace was done and in what publication this information is documented. More information about the Dye-Tracing project can be accessed on the DEP website:

http://tagis.dep.wv.gov/WVWaterPlan/

This database is critical to determining the groundwater recharge areas within the state's karst regions, as these recharge areas often cross under the divides between the surface water basins. This database should be updated, as required, using both literature searches, contacts within the environmental and caving communities and field work involving volunteers and both state and federal employees. The following map shows locations of the DEP dye tracing studies.

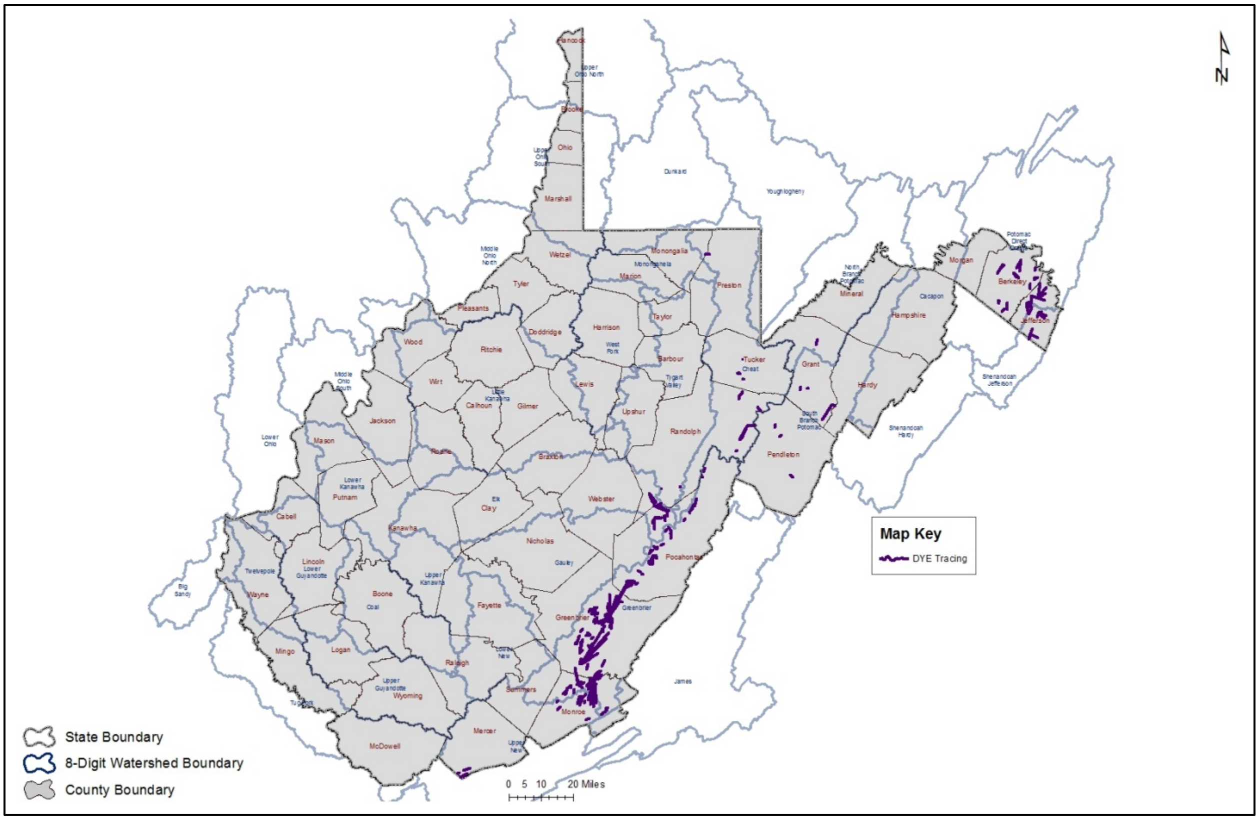



Figure 1-16 The DEP dye tracings locations in the karst regions of West Virginia

### 1.3.8 Groundwater Conclusions

Data has been amassed by various agencies from numerous sources regarding the state's groundwater resources. Past data was collected in localized areas for very specific purposes and typically did not collect data related to the aquifer characteristics required for estimation of the quantity of ground water contained in the aquifers. The previously collected data is insufficient for the purpose of statewide ground water management.

As previously noted, the state has 16 groundwater monitoring wells. States in EPA Region III and those states in Region V that border West Virginia all have more extensive monitoring well networks. Maryland has 668 wells, Pennsylvania 202, Virginia 431, Ohio 160 and Kentucky has 74. The majority of these state programs have also conducted electronic logging of specific wells.

The Water Use Section's website has been constructed so that web users can locate and use the available groundwater data. This website includes links to individual well logs, spring and surface stream data, dye-trace study results, mine-pool data, oil-and-gas information and geological data from various sources.

Gathering the data to evaluate the ground water resources could be accomplished by requiring public water suppliers and commercial well drillers to submit their logs to the DEP. Obtaining the information necessary required for estimation of the quantity of ground water contained in the aquifers will require a long-term commitment by the state. Over time, this would build a body of knowledge about ground water that would help in its evaluation and management.

Any program designed to identify West Virginia's groundwater aquifers should be comprised of several parts. First, precise program strategies should be formulated, which can be modified as environmental, personnel and budgetary constraints demand. Second, the collection of long-term, quality groundwater and surface water data is required. Third, this data must be processed into some type of useable form and lastly, methods must be developed to distribute this information to those persons requiring it. Such a program, with the data collection and the infrastructure required to support it, will involve several strategies, many of which can be implemented simultaneously.

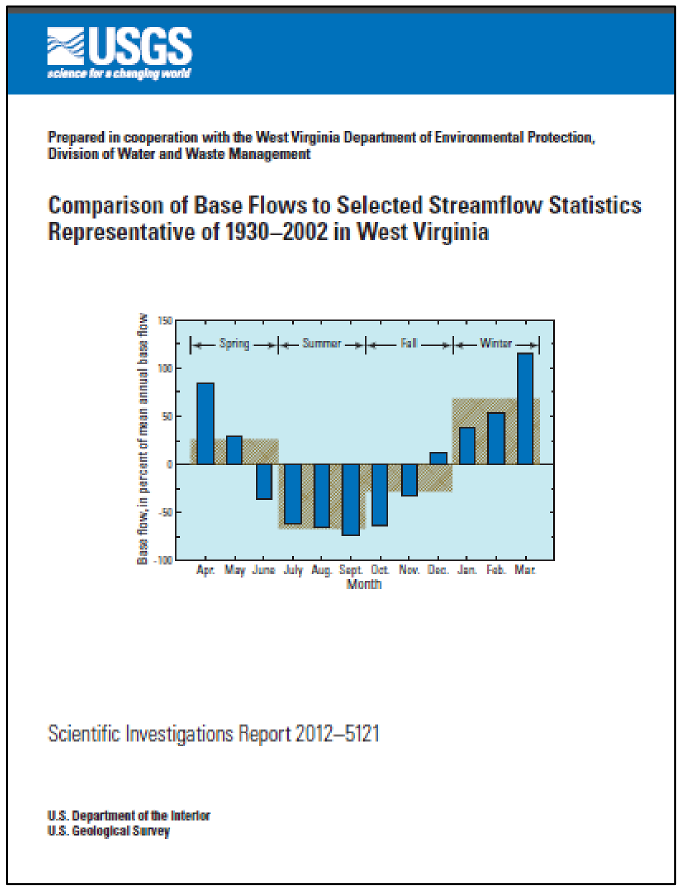
In order to identify and characterize aquifers in the state, the DEP will continue to collect and add all existing groundwater well data into a "Groundwater Database." A private water well reporting portal has been developed for ArcGIS and will soon be adapted for the DEP website. This portal will provide an opportunity for citizens to submit well data that the state may not currently have. Continued efforts will be made to ensure that county health departments require and receive the depth to the groundwater and the latitude and longitude coordinates on all wells that are drilled. The benefits of geophysical well logging have been described above, although they are costly and time consuming.

The DEP will encourage its Groundwater Section to ensure that geographic coordinates are collected in addition to depth to groundwater within the monitoring wells, continue to work with state and county health department to share data and continue collaboration with the USGS in the efforts to identify and characterize the state's aquifers.

## 1.4 Interconnections of groundwater and surface water

The DEP funded the USGS SIR 2012-5121 in order to equate base flow to seasonal stream flow statistics. The Abstract from this study reads:

*"Base flows were compared with published streamflow statistics to assess climate variability and to determine the published statistics that can be substituted for annual and seasonal base flows of unregulated streams in West Virginia. The comparison study was done by the U.S. Geological Survey, in cooperation with the West Virginia Department of Environmental Protection, Division of Water and Waste Management. The seasons were defined as winter (January 1–March 31), spring (April 1–June 30), summer (July 1–September 30) and fall (October 1–December 31).*




*Differences in mean annual base flows for five record sub-periods (1930–42, 1943–62, 1963–69, 1970–79 and 1980–2002) range from -14.9 to 14.6 percent when compared to the values for the period 1930–2002. Differences between mean seasonal base flows and values for the period 1930–2002 are less variable for winter and spring, -11.2 to 11.0 percent, than for summer and fall, -47.0 to 43.6 percent. Mean summer base flows (July–September) and mean monthly base flows for July, August, September and October are approximately equal, within 7.4 percentage points of mean annual base flow. The mean of each of annual, spring, summer, fall and winter base flows are approximately equal to the annual 50-percent (standard error of 10.3 percent), 45-percent (error of 14.6 percent), 75-percent (error of 11.8 percent), 55-percent (error of 11.2 percent) and 35-percent duration flows (error of 11.1 percent), respectively. The mean seasonal base flows for spring, summer, fall and winter are approximately equal to the spring 50-*

*to 55-percent (standard error of 6.8 percent), summer 45- to 50-percent (error of 6.7 percent), fall 45-percent (error of 15.2 percent) and winter 60-percent duration flows (error of 8.5 percent), respectively.*

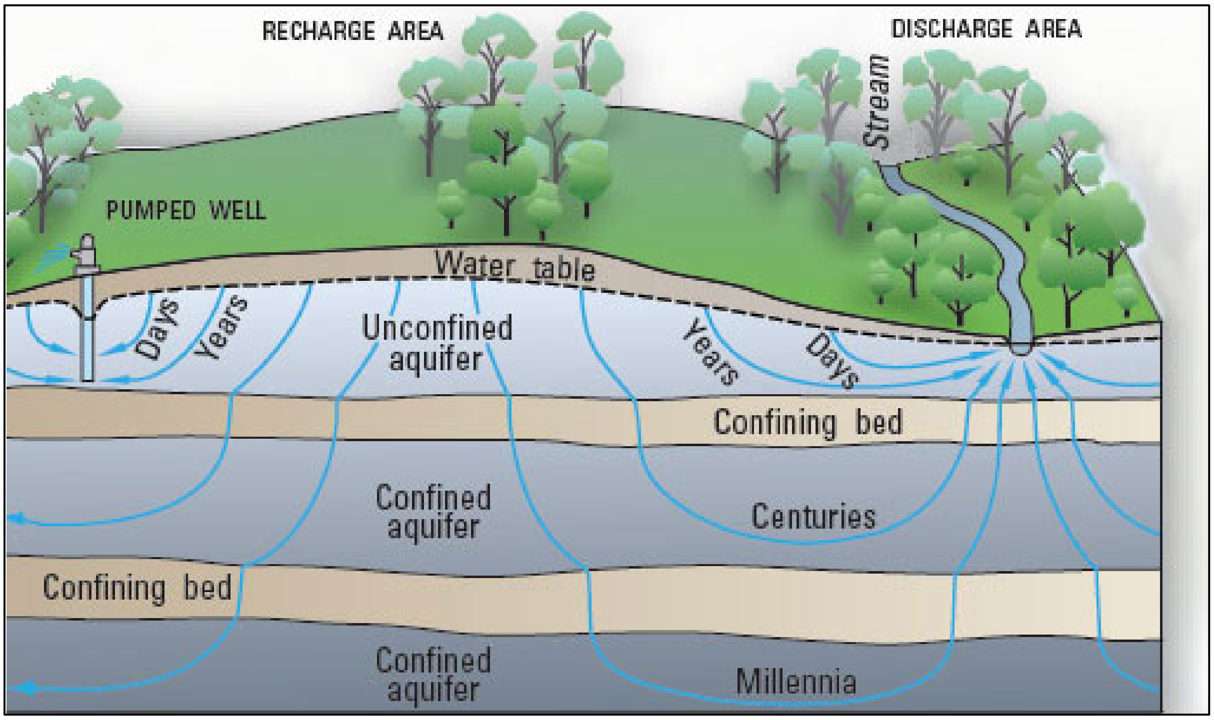
*Annual and seasonal base flows representative of the period 1930–2002 at unregulated streamflow-gaging stations and ungaged locations in West Virginia can be estimated using previously published values of statistics and procedures."*

This report can be downloaded from the following link: http://pubs.usgs.gov/sir/2012/5121/

West Virginia aquifers, streams, lakes and wetlands are sustained by a balancing act between precipitation and these parts of the hydrologic system. In the absence of human intervention, ground water and surface waters exist in a state of approximate equilibrium. A change in one part of the system, whether due to natural climatic variation or withdrawal of surface water or ground water, results in a balancing response in another part of the system. The rate of system response to change is variable, specific to local conditions and much slower for ground water than for surface water (except in karst). In some cases, the system may rebalance itself in response to change (such as additional ground-water withdrawals) within a period of months to years. In other cases, the system may take a significantly longer time period to adjust.

Where the groundwater level is higher than the surface water level, groundwater can discharge into a stream referred to as a gaining stream. Where the surface water level is higher than the groundwater level, the river can leak into the subsurface recharging the groundwater system referred to as a losing stream. The flow of water between the surface water and the aquifer is called the seepage flux. Seepage flux is largely controlled by the hydraulic gradient between the surface water level and the groundwater level and the hydraulic properties of the aquifer, as well as the geological material separating the aquifer from the surface water features.

System response to groundwater withdrawals is most obvious by lowered groundwater levels in local monitoring wells. However, long-term effects may include depletion of wetlands, streams, springs and lakes, as well as ecological or other changes. Use of ground-water resources has long-term impacts beyond the point of withdrawal that future management must consider to minimize impacts on surface-water resources. A long-term approach to groundwater resources management is required in order to minimize impacts on both groundwater and surface water due to the interactions between the two systems.



(http://ga.water.usgs.gov/edu/watercyclegwdischarge.html)

*Coal-fired Electric Power Generation Plant on the Kanawha River*

# CHAPTER TWO
# WATER USE

**WATER USE SECTION** west virginia department of environmental protection

*Golf Course Irrigation*

# Chapter - 2 Water Use

## 2.1 Comparison of Demand Tracking Programs

Many states have implemented water registration and/or permitting programs to track and manage the resource. To better develop the Plan and final recommendations to the Legislature, the DEP researched the information available to the public about the degree of progress regarding water demand programs in surrounding states. Where appropriate, the respective agency representatives were contacted for more information. States bordering West Virginia are most likely to have similar demographics, economics, and environmental conditions, therefore are the most comparable. Furthermore, by evaluating the demands for water use in those states, valuable insight was gained regarding ways to address conditions found in West Virginia. The average annual demand on the state's water resources, organized by Standard Industrial Code (SIC) is available in Table 2-1. Table 2-2 provides a summary of Large Quantity User (LQU) programs in border states. A more detailed discussion of the registration programs and water use analysis can be found in Appendix H. The focus of research regarding programs was for information about the development and progress related to controlling or monitoring the state's water supply and resources. General and specific data were collected and evaluated concerning the implementation of programs and protocols including, but not limited to, the following: councils and planning committees; database development; mapping; plan management and development; delegation and assistance; best management practices for assessing and responding to stormwater and drought conditions; supply planning; withdrawal thresholds for reporting or permitting; and recommendations for future direction.

**Table 2-1 Average Annual Demand for Water Use in West Virginia by SIC category (excluding Hydroelectric: 15,756,375,655,427 gallons/year). *Frac Water was collected from the Frac Water Reporting Tool and is only for withdrawals occurring in 2011**

| Water Use Category (SIC group) | Average Withdraw (gallons/year) |
|---|---|
| Thermoelectric (coal) | 915,256,218,694 |
| Chemical | 168,342,927,475 |
| Public water supply | 69,283,527,985 |
| Industrial | 20,077,779,753 |
| Mining | 13,462,053,653 |
| Agriculture/aquaculture | 5,581,517,720 |
| Timber | 1,233,943,576 |
| Frac Water* | 922,783,143 |
| Recreation | 1,544,771,703 |
| Petroleum | 484,937,415 |
| **Total** | 1,196,190,461,116 |

Currently, with the exception of water management plans for horizontal wells and a limited number of Section 401, Clean Water Act certification conditions, individuals and businesses can withdraw water without restriction. Several of our surrounding states, as shown in Table 2-2, have varying degrees of water withdraw permitting programs. As West Virginia is normally a water rich state with consistent water use over time, the need for a permitting program for all withdrawals has never materialized.

**Table 2-2 Current definitions, exemptions, and requirements for border states regarding Large Quantity Users (LQU) in each state.**

| BORDER STATE | DELEGATION OF RESPONSIBILITY | USERS/EXEMPTIONS | REGISTRATION/REPORTING/PERMIT/FEES | SOURCES |
|---|---|---|---|---|
| KY | Environmental Protection Cabinet<br>Division of Water<br>http://water.ky.gov | All withdrawal, transfer, and diversion >10,000gpd<br>EXEMPT<br>Single household, agriculture(unless impounded), electricity producing plants regulated by KYPSC, UI for O&G | No fee permit limits user to current requirements, may provide protection for others, user must maintain accurate monthly records regarding daily withdrawals | Any surface, ground, or spring including private impoundments |
| MD | Maryland Department of Environment (MDE)<br>http://www.mde.state.md.us | All withdrawal activities regardless of planned amounts<br>EXEMPT<br>Extinguishing a fire, agricultural use <10,000gpd, groundwater users <5,000gpd that are private or outside strategy area | No fee permit must stay within limits and report periodically specific to permit, subject to review every 3years, other requirements relating to testing and analysis as well as approvals from other entities possible | Any of the State's surface and/or underground waters |
| OH | Ohio Department of Natural Resources (ODNR)<br>Division of Soil and Water Resources<br>http://www.dnr.state.oh.us | All users with the *capacity* to withdrawal >100,000gpd AND consumptive uses >2,000,000gpd | Required initial registration and annual reporting of withdrawals and discharges; published as part of online withdrawal atlas .pdf file. Permit required for consumptive uses >2,000,000gpd. | All sources of waters of the state |
| PA | Pennsylvania Department of Environmental Protection (DEP)<br>http://www.pawaterplan.dep.state.pa.us | Public water suppliers and hydropower facilities regardless of withdrawal amount, anyone withdrawing >10,000gpd or transferring >100,000gpd | Required registration and annual reporting as well as 5 year record retention. Public supply and hydropower must meter flows | All sources |
| VA | Virginia Department of Environmental Quality (DEQ)<br>http://www.deq.virginia.gov<br><br>Virginia Marine Resources Commission (VMRC)<br>http://www.mrc.virginia.gov/hmac/hmoverview.shtm | Minor: Crop production >1,000,000gpm, ALL others >10,000gpd, voluntary reporting of lower withdrawals encouraged.<br>Major: >90,000,000gpm of if filling, flooding, or alteration of stream flow occurs.<br>Groundwater: Specified management areas | Required annual online reports of monthly withdrawals are published in Annual Water Resources Report. Permit required for minor withdrawals and encroachment. A joint permit is required for major withdrawals. Permit required for ground-water use in management areas. Applications are submitted to VMRC then distributed to participating agencies to decide separately. Permit fees are determined individually by each agency and subject to change. Permits validity varies based on the project from 3 – 15 year max terms. | Surface and groundwater withdrawals |
| SRBC | Susquehanna River Basin Commission<br>http://www.srbc.net/ | Consumptive users who use an avg. >20,000gpd in 30 days<br>EXEMPT<br>Public Supply and Agriculture (conditionally)<br>Withdrawals from basin that avg. >100,000gpd in 30 days<br>EXEMPT<br>Hydroelectric (conditionally)<br>Diversions out of the basin that avg. >20,000gpd in 30 days<br>EXEMPT<br>Agriculture (conditionally) | Required application for initial use, withdrawals, and diversions as well as increases in uses or withdrawals regardless of proposed increase. No term of approval shall exceed 15 years. Fees and interest are subject to the amount consumed, which are set to meet the requirements of the Commission in order to cover its costs of administering the regulatory program. | Surface and/or groundwater in the basin before or after use/ withdrawal |

### 2.1.1 Water Demand

In order to understand how demand in West Virginia compares to the border states, a water use analysis was completed on each state using USGS estimates. Details of the analysis are available in Appendix H. In general, water use demand is tied to the size of the human population, the political and cultural atmosphere, and the state of the regional economy. Of the total amount withdrawn by West Virginia and its bordering states during 2005, West Virginia's share of use was only about 10% of that total (Figure 2-1). Kentucky is the most comparable to West Virginia in volume, utilizing 9% of the total water withdrawn by the group. However, although comparable in total volume, the population in Kentucky is in excess of twice as much as West Virginia (Figure 2-3). Ohio, Virginia, and Pennsylvania are the highest use contributors to this group using about 24%, 22%, and 20% of the group total, respectively (Figure 2-1). Like West Virginia, Maryland has experienced similar fluctuations in use over time (Figure 2-1 and Figure 2-2). However, Maryland has a population more than three times that of West Virginia, but uses less than twice as much water (Figure 2-2 and Figure 2-3).

> In general, water use demand is tied to the size of the human population, the political and cultural atmosphere, and the state of the regional economy.

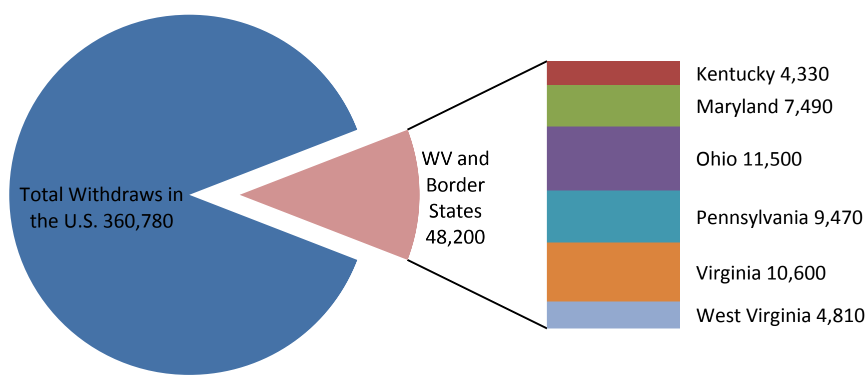



**Figure 2-1 West Virginia and border states' contribution to the USGS estimates of total water withdrawals in the United States in 2005 in Mgal/day**

According to USGS estimates, the majority of water used by Ohio is used for public supply, which, when compared to the steady rise in population, seems to support the steady increase in total withdrawals over the available time intervals (Figure 2-2, Figure 2-3 and Appendix H). Virginia also uses a large portion of its withdrawals for public supply and has seen increases in population. However, Virginia's largest jump in total withdrawals, from 2000 to 2005, may also be attributed to the addition of withdrawals for aquaculture to the overall total in 2005, as well as better recording methods across all categories (Figure 2-2 and Appendix H).

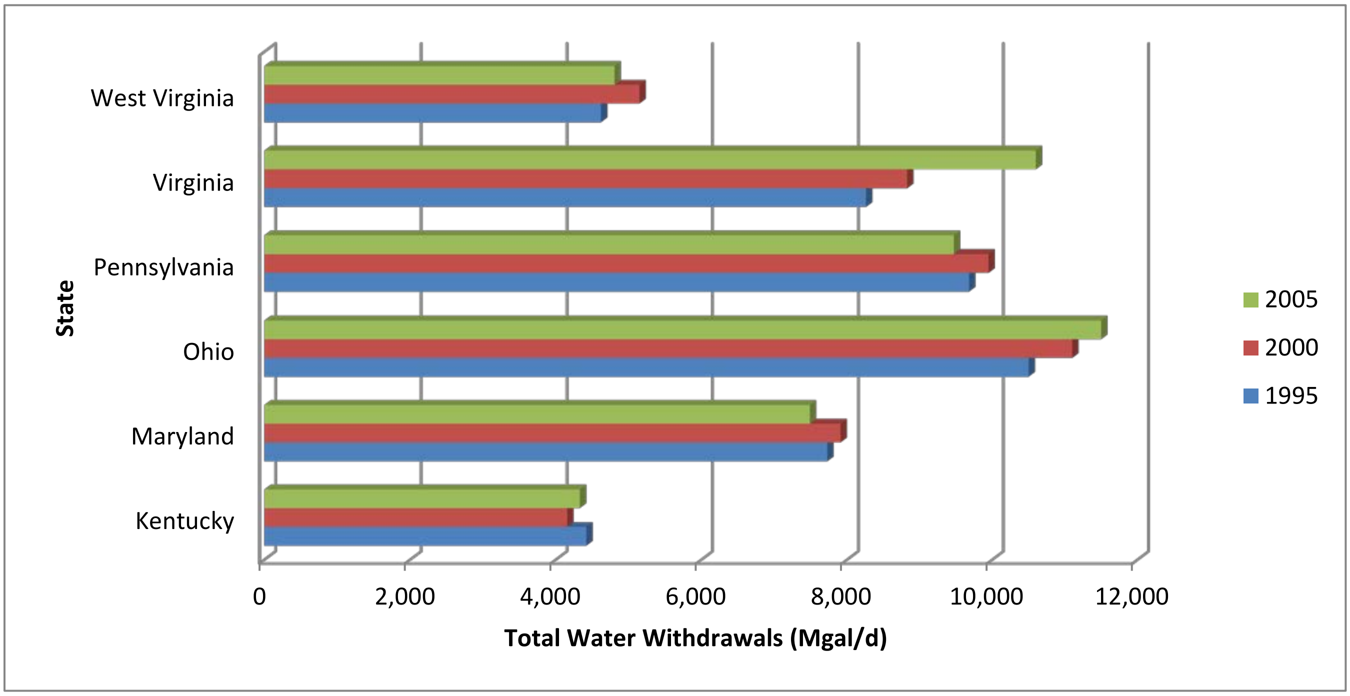
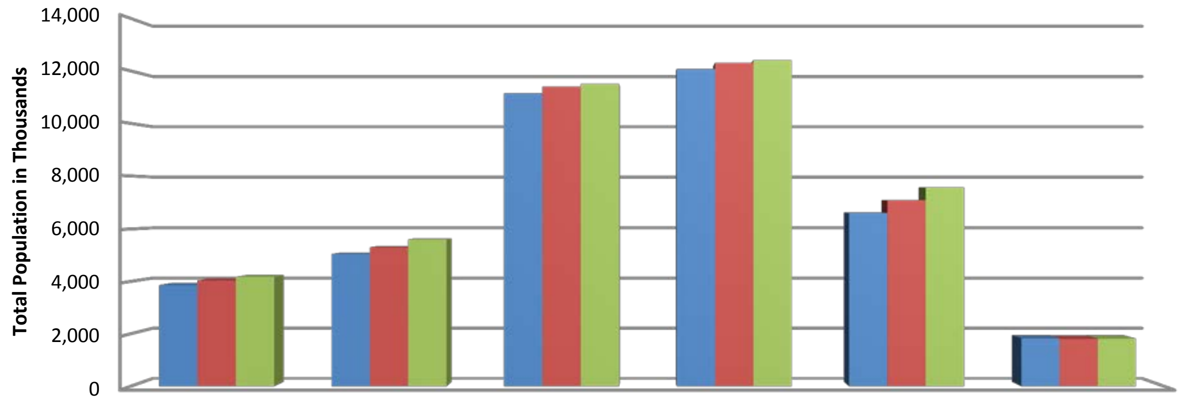



**Figure 2-2 USGS estimates of total water withdrawals by state for five-year Intervals in Mgal/day.**




| | Kentucky | Maryland | Ohio | Pennsylvania | Virginia | West Virginia |
|---|---|---|---|---|---|---|
| 1995 | 3,860 | 5,042 | 11,151 | 12,072 | 6,618 | 1,828 |
| 2000 | 4,040 | 5,300 | 11,400 | 12,300 | 7,080 | 1,810 |
| 2005 | 4,170 | 5,600 | 11,500 | 12,400 | 7,570 | 1,820 |

**Figure 2-3 USGS statewide population estimates for 1995, 2000, and 2005**

Attributing water use estimates in West Virginia to the various factors estimated by USGS differs from its border states in several ways. West Virginia saw a fluctuation in total water use most similar to the fluctuation in Pennsylvania and Maryland which saw the highest use year in 2000 (Figure 2-2). However, unlike Pennsylvania and Maryland, West Virginia was not estimated to have as sharp of an increase in water use for thermoelectric power generation in 2000 (Figure 2-4). Additionally, although West Virginia was the only state in this analysis to see a decrease in the percent change of population from 1995 to 2000 and 2005, as seen in Figure 2-3, the water use estimates for public supply still increased in 2000. Along with the small increase in thermoelectric use, public water supply is the greatest contributor to the total withdrawal increase in the state calculated by USGS (Figure 2-4).

The starkest contrast between West Virginia and its border states is not the total amount of water used per year, the changes in use over time, or even that it is the only state considered to have seen a decrease in population over the intervals of investigation from the initial year. Instead, the greatest difference between West Virginia and the bordering states is seen when comparing the proportion of water withdrawn by the various users in the state (Figure 2-4). In every other state, the greatest single proportion of water used is for the public supply and in some cases such as Ohio, Maryland, and Kentucky, public use accounts for more than half of the proportion of water withdrawn (excluding thermoelectric). In West Virginia, the proportion of public supply is second largest when compared to industrial and chemical uses combined as was done in the latest USGS water use survey (USGS, 2009). The public supply amount in West Virginia is surpassed by the combined chemical and industrial withdrawal estimates, placing it in contrast to all of the surrounding states (Figure 2-4 and Appendix H).

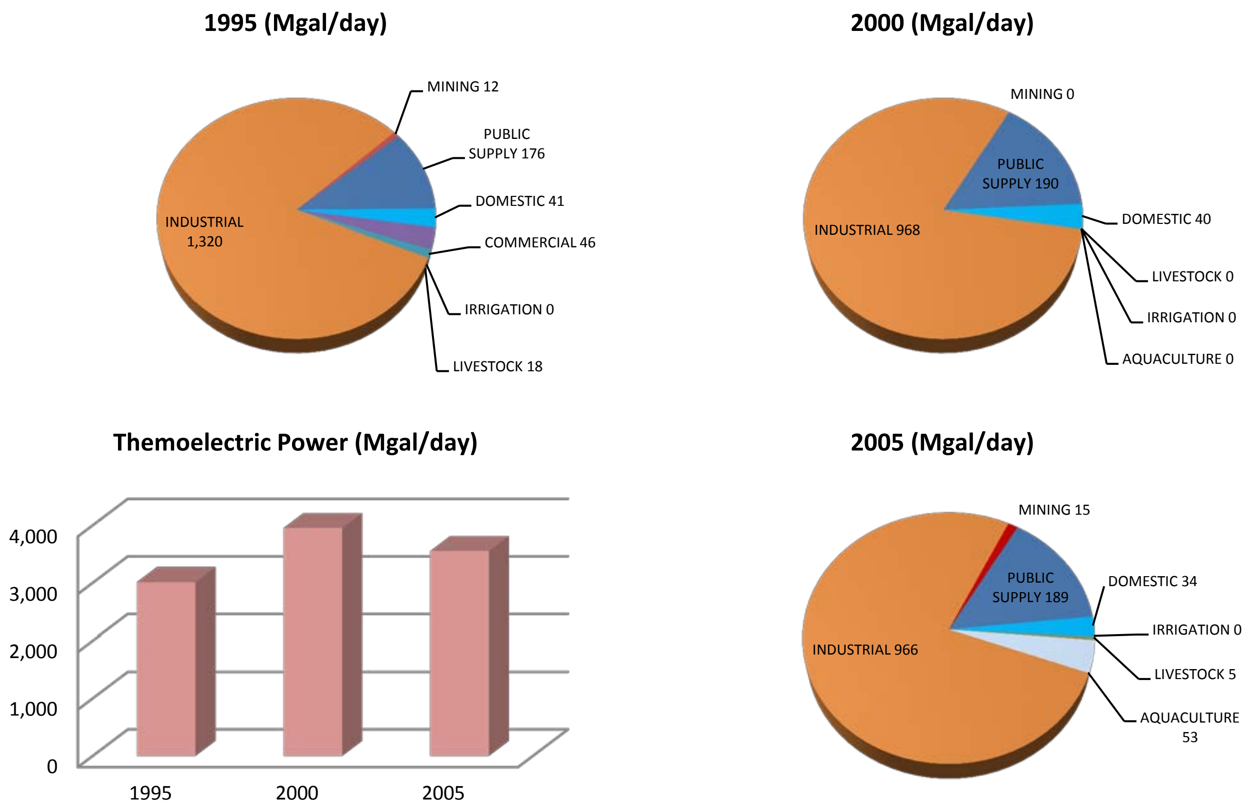



**Figure 2-4 USGS estimate of West Virginia's water withdrawals (Mgal/day) by category of use and year**

## 2.2 Large Quantity Users (LQUs)

As defined in the Act, a Large Quantity User is "any person who withdraws over seven hundred fifty thousand gallons of water in a calendar month from the state's waters and any person who bottles water for resale regardless of quantity withdrawn." With this in mind, a survey was designed to ask users from where they withdrew their water, including: latitude and longitude; stream, river, lake, or spring name; county; and well information. If any water was purchased by a large quantity user, the facility was required to provide the name of the provider and the monthly withdrawal amounts. Details were also requested regarding proposed use and discharge information, specifically whether the discharge was to a wastewater treatment facility, stream, underground injection well/septic system, private reservoir, lake, or other. In each of those categories, the respondent had to give the latitude and longitude, name or description of discharge point, and permit number (if applicable). All the information gathered on water withdrawal data is housed in the DEP's Large Quantity User (LQU) database. This database only contains information on facilities that withdraw more than 750,000 gallons of water in any calendar month from either a surface water or groundwater source defined as waters of the state. Furthermore, water bottlers are not included because they are required to renew permits annually with the West Virginia Public Health Sanitation Division. Because there are only seven facilities operating, none of which qualify as a large quantity user, they have been omitted from the LQU discussion that follows. Companies that bottle water as of June 2013 made available by the Office of Environmental Health Services, Public Health Sanitation Division permit renewal applications, the associated brand names, and annual withdrawal amounts are available in Appendix I. Actual withdrawals by LQUs in 2003, 2004, and 2005 were required to be submitted in the initial survey of 2005. No withdrawal information was collected for 2006 and 2007. Beginning in 2008, LQUs were required to report withdrawal volumes if their withdrawal varied by more than 10% of the last reported value. The most recent data was for 2011. Figure 2-5 is a map that displays the current Large Quantity Users in the state. The information gathered provides West Virginia with valuable insight into the use of water resources. The data will continue to inform future water management decisions. For a description of survey development and data collection in 2003-2005 refer to the 2006 report, which can be viewed and/or downloaded from the DEP's main website.

A Large Quantity User withdraws more than 750,000 gallons of water in a month.

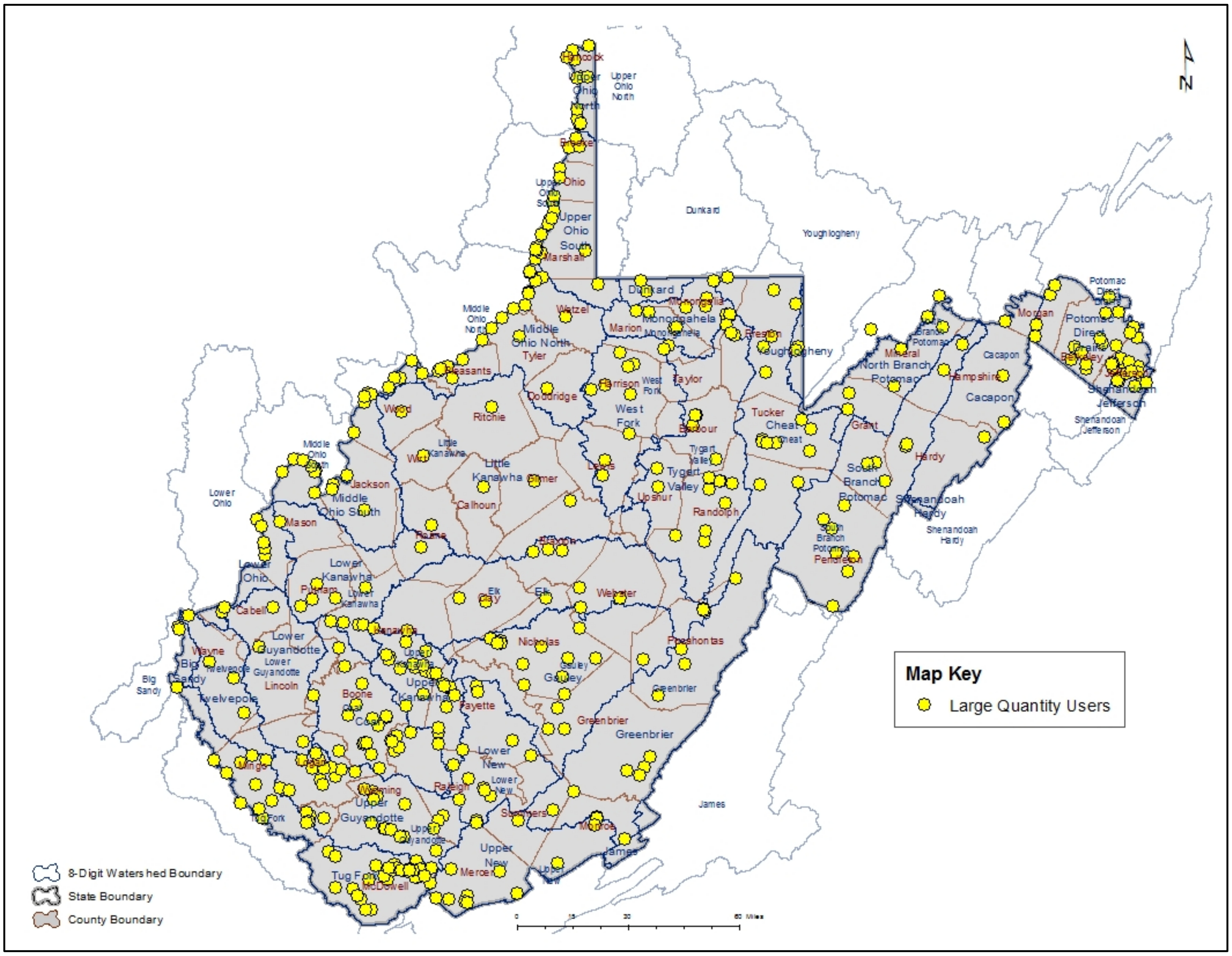



**Figure 2-5 Large Quantity Users registered with DEP after 2011 reporting year.**

### 2.2.1 Survey Testing and Annual Notification of Registration

Beginning in 2008, the Water Resources Protection Act, §22-26-3(b) mandated that the Secretary of the DEP establish a statewide registration program to monitor large quantity users of water resources of this state. Those facilities that completed the 2006 survey were considered to be registered with the DEP. Unregistered users were required to report three years of water use data in order to be registered with the DEP. Hydroelectric users were required to report pass by flows starting in 2009. Currently, registered users are not required to report monthly withdrawals unless the annual amount withdrawn varies by more than 10% from the baseline average [§22-26-3(h)]. The DEP generates a notification letter, including a detailed report of water use, for each Large Quantity User. For instance, if the three-year average from the 2005 report was calculated as 10 million gallons for the 2008 reporting year and the 2008 actual withdrawal amount was between 9 and 11 million gallons, the user was not required to send in a report. Instead, the LQU would be allowed to certify the usage by signing a statement that withdrawal amounts had remained relatively unchanged. A copy of the 2011 surveys for both industrial users and water providers can be found in Appendix J. A list of all current LQU facilities, organized by their SIC code, and including data regarding the percentages of ground and surface water withdrawn as well as the respective county and watershed locations and percentages of total withdraw, and their calculated three-year baseline annual average withdrawal amount can be seen in Appendix K. Any interested party wishing to view the complete data set from the survey should contact the Water Use Section. Due to homeland security concerns, and in consultation with the Department of Military Affairs and Public Safety, geographic location data for public water supply intakes will not be provided.

### 2.2.2 Data Analysis

To evaluate trends over time, annual withdrawal amounts are used. Due to the reporting requirements, blanks were created in the database that needs to be filled in. This was done based on the assumption that withdrawal amounts for the current year are exactly the same as previously calculated by the baseline average. The average of the previous three years of reported monthly data was used to fill in blanks resulting from years where certification of the 10% use range was permitted. If only two previous years of data was available, these were averaged. If there was no other reported withdrawal following either a reported or averaged value, all the following years were set as equal to the last value (reported or averaged). The annual average is the average of the most recent three years of available monthly data. Table 2-3 provides examples of these calculations.

**Table 2-3 Example of the assumptions made to fill in the data gaps in the LQU database and calculate the average annual value from the most recent three-year average. Values in green represent reported values, purple represents averaged values, and blue values are set equal to a previous value. Blanks indicate no withdrawal occurred.**

| | Withdrawal (gallons) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **LQU** | **2003** | **2004** | **2005** | **2008** | **2009** | **2010** | **2011** | **3 Year Average** |
| 1 | **750,000** | **800,000** | **775,000** | **775,000** | **775,000** | **775,000** | **775,000** | **775,000** |
| 2 | | **900,000** | **1,000,000** | **950,000** | **950,000** | **950,000** | **950,000** | **950,000** |
| 3 | | | | | | **850,000** | **850,000** | **850,000** |
| 4 | **750,000** | **800,000** | **775,000** | **775,000** | **775,000** | **850,000** | **812,500** | **812,500** |

Using these assumptions, estimates of water use for each year and an annual average for the state were calculated. The three-year averages are shown by water use type, watershed, and county in the tables in Appendix K. Additionally, only the three water supply brokers currently represented in the Frac Water category are in the LQU database. The DEP collects information on water used in the hydraulic fracturing process to extract natural gas from the Marcellus Shale in the Frac Water Reporting database. All reporting of frac water in this section comes from the Frac Water Reporting database for the year 2011. It was not reasonable to calculate an annual average from that database because of the time of collection. A detailed description of the data analysis of the Frac Water Reporting database is provided in Section 2.5. The water brokers who fall under the large quantity user database definition are excluded from the frac water total to prevent double counting the amount of water reported by them, which is also reported via the Frac Water Reporting Tool by the well operators who purchased the water.

The information provided by LQUs supplies West Virginia with valuable insight into the use of water resources. The data will continue to inform future water management decisions.

It is important to note that no estimates were made in the database for water uses that did not meet the threshold of a LQU. Therefore, the water withdrawal estimates reported do not include such uses as self-supplied water for domestic or agricultural use. These numbers had to be estimated separately and are available in Sections 2.3 and 2.4, respectively. Additionally, those who purchased water in any amount (excluding those covered by a water management plan during the extraction of natural gas from the Marcellus Shale) were not required to report their water use. This leaves gaps in the amount of water being used by any facility using over 750,000 gallons of water in a month that purchases all of its water. The 8-digit HUC watershed and county in which each intake is located is recorded in the database. Figure 2-6 illustrates the state's HUC-8 watersheds. More detailed maps of each watershed are illustrated in the West Virginia Watershed Atlas.

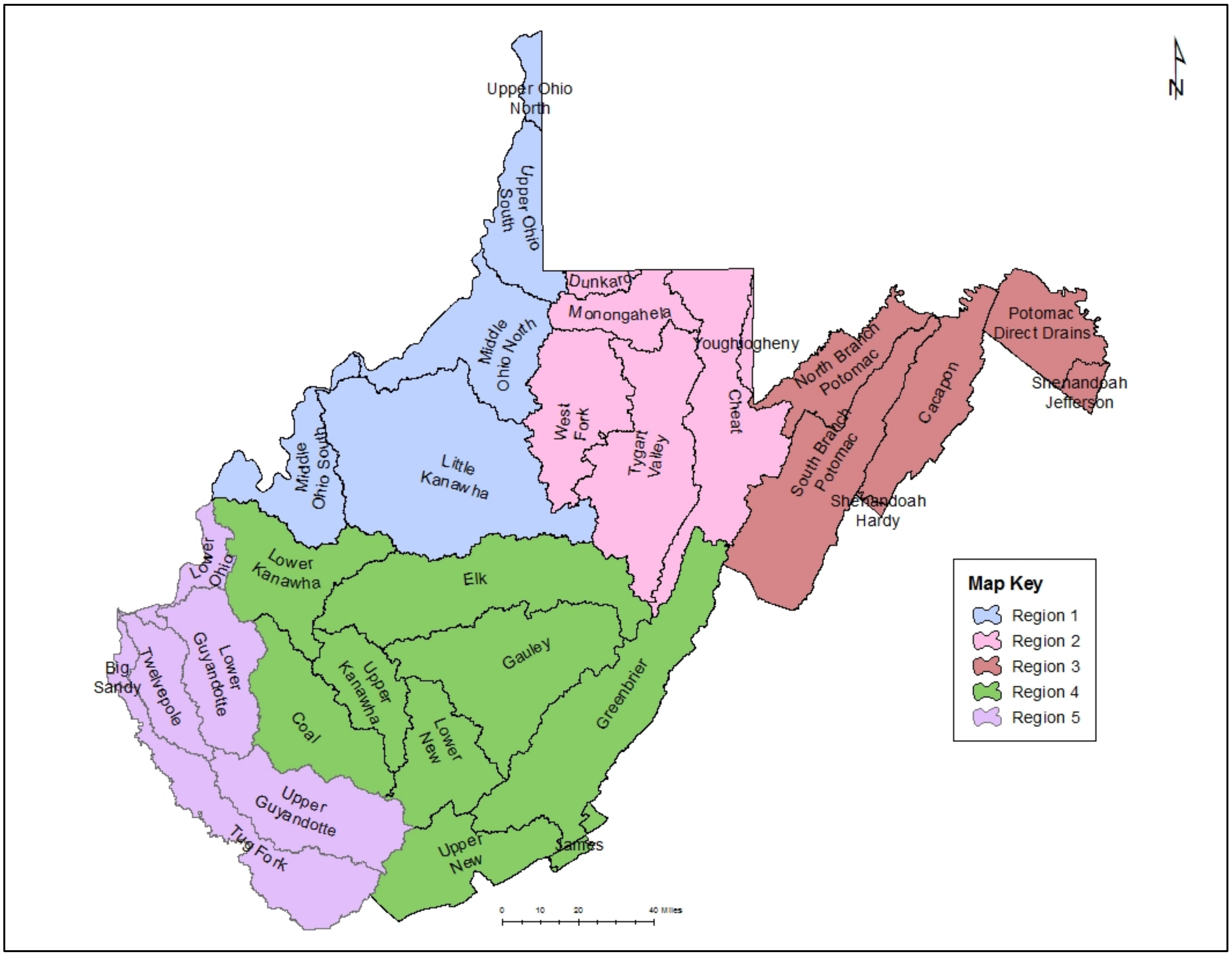



**Figure 2-6 West Virginia has 32 HUC-8 watersheds and are shown divided into five regions.**

The Large Quantity User database has 11 water use categories defined as follows:

- Mining – Coal mining, coal processing plants, quarries, any other type of mining activity where rocks or minerals are removed from the earth.
- Petroleum – Waterfloods. Does not include water used when hydrofracing a well.
- Recreation – Hotels, golf courses, campgrounds, water parks, resorts, etc.
- Timber – Including facilities that manufacture wood products – pulp mills, charcoal manufacturers, dimensional lumber, etc.
- Agriculture/Aquaculture – Irrigation, fish farming, hatcheries, production of feed for farm animals, etc.
- Public Water Supply – Water primarily for human consumption.
- Industrial – General manufacturing other than chemical.

- Chemical – Manufacture of chemicals, chemical compounds, etc., regardless of feedstock source.
- Thermoelectric (coal) – Generation of electric power where heat is the primary motive force and water is used for steam or cooling purposes (i.e. a coal burning plant that boils water creating steam to turn the turbines).
- Hydroelectric – Generation of electric power where water is the motive force. There is little or no consumptive use of the water in the generation process (i.e. a power plant at a dam that uses the water flowing out of the dam to turn the turbine).
- Frac Water – Water withdrawn for commercial resale to the oil and gas industry for purposes of drilling or hydraulically fracturing oil and natural gas wells. Water withdrawn directly by the oil and gas industry for use in such activities is captured in the *Frac Water Reporting Database*. For the purposes of this report, frac water withdrawal data reported herein are provided by that database.

The categories are sorted by the facilities' reported Standard Industrial Classification (SIC), which is defined by the US Department of Labor's Occupational Safety & Health Administration (OSHA). There are 388 LQUs registered with the DEP as of 2011 (Appendix K). The majority of water use in the state, 77%, is withdrawn for thermoelectric energy production. Chemical manufacturing and public water supply are the next largest majority at 14% and 6%, respectively. The other notable use types in the state are industrial and mining using 2% and 1%, respectively. The rest of the SIC categories take up a very low percentage of total use and can be seen below in Figure 2-7. The total statewide withdrawal averages 1,196,190,461,116 gallons annually (excluding hydroelectric). The average totals for each SIC can be seen in Table 2-1 in Section 2.1. It is important to note that the last three years of data may not equal the calculated three year average due to the use of actual monthly data from each facility rather than any filled-in values, independent averaging for percent of withdrawals of a given facility with intakes in multiple watersheds and because closed facilities were excluded from the final three-year average.

> There are 388 Large Quantity Users registered with the DEP who withdraw an average of 1.2 trillion gallons of water annually.

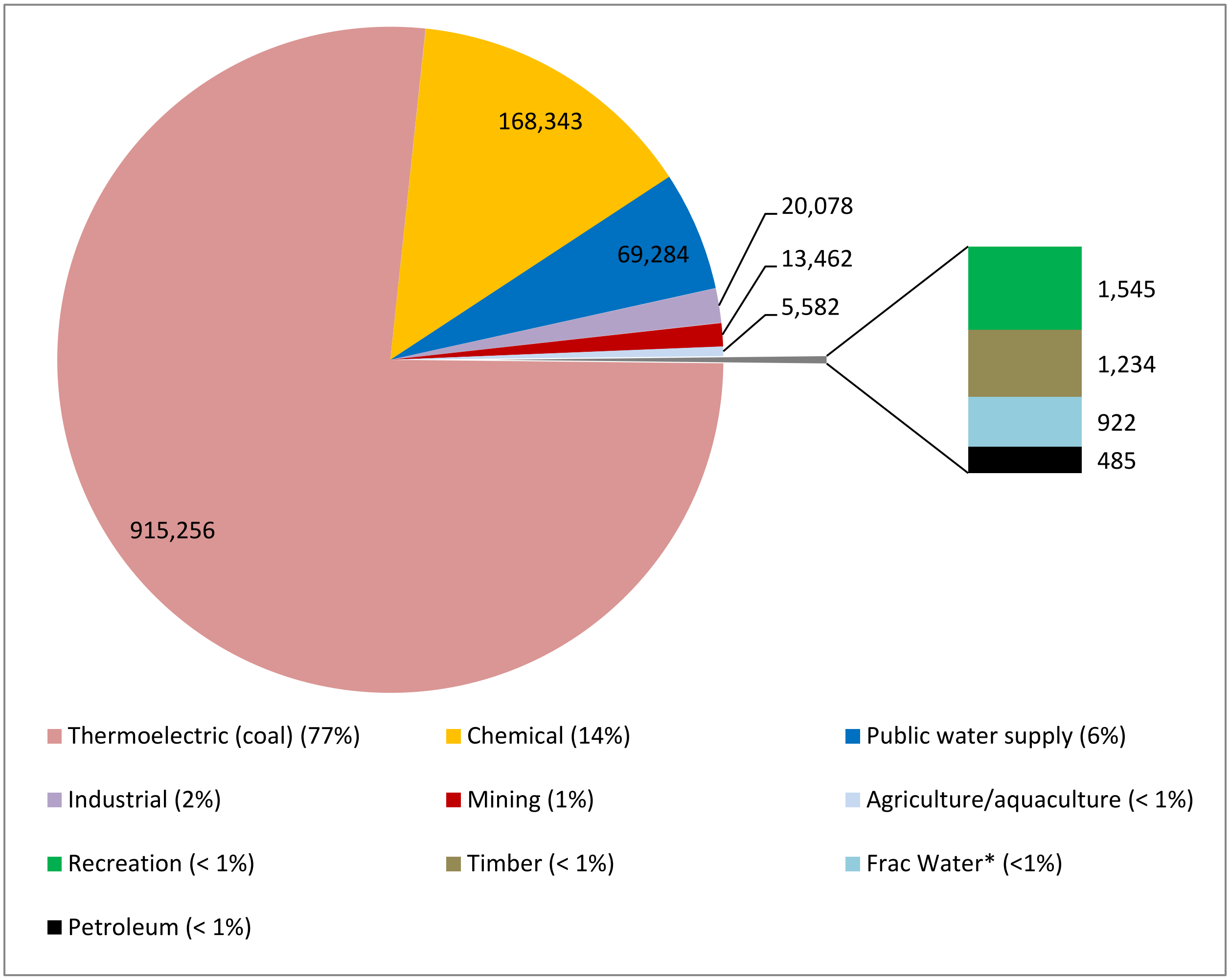



**Figure 2-7 Statewide average annual water withdrawal (in millions of gallons) totals by SIC category. *Frac Water was collected from the Frac Water Reporting Tool and is only for withdrawals occurring in 2011 (hydroelectric is excluded).**

### 2.2.3 Distribution of Withdrawals

To provide a perspective of the distribution of water used by each SIC category across the state, a series of percentage pie charts have been developed from the totals of each facility's three-year average and are shown in Figures 2-9 to 2-19. To interpret these figures, please note that the values descend from left to right and pie slices decrease clockwise. A more detailed explanation of the LQU activity in each watershed can be found in the West Virginia Watershed Descriptions companion report. Each chart represents one SIC use type and presents the percentages of annual average use by each watershed involved. A map of all the LQUs by SIC group can be seen in Figure 2-8.

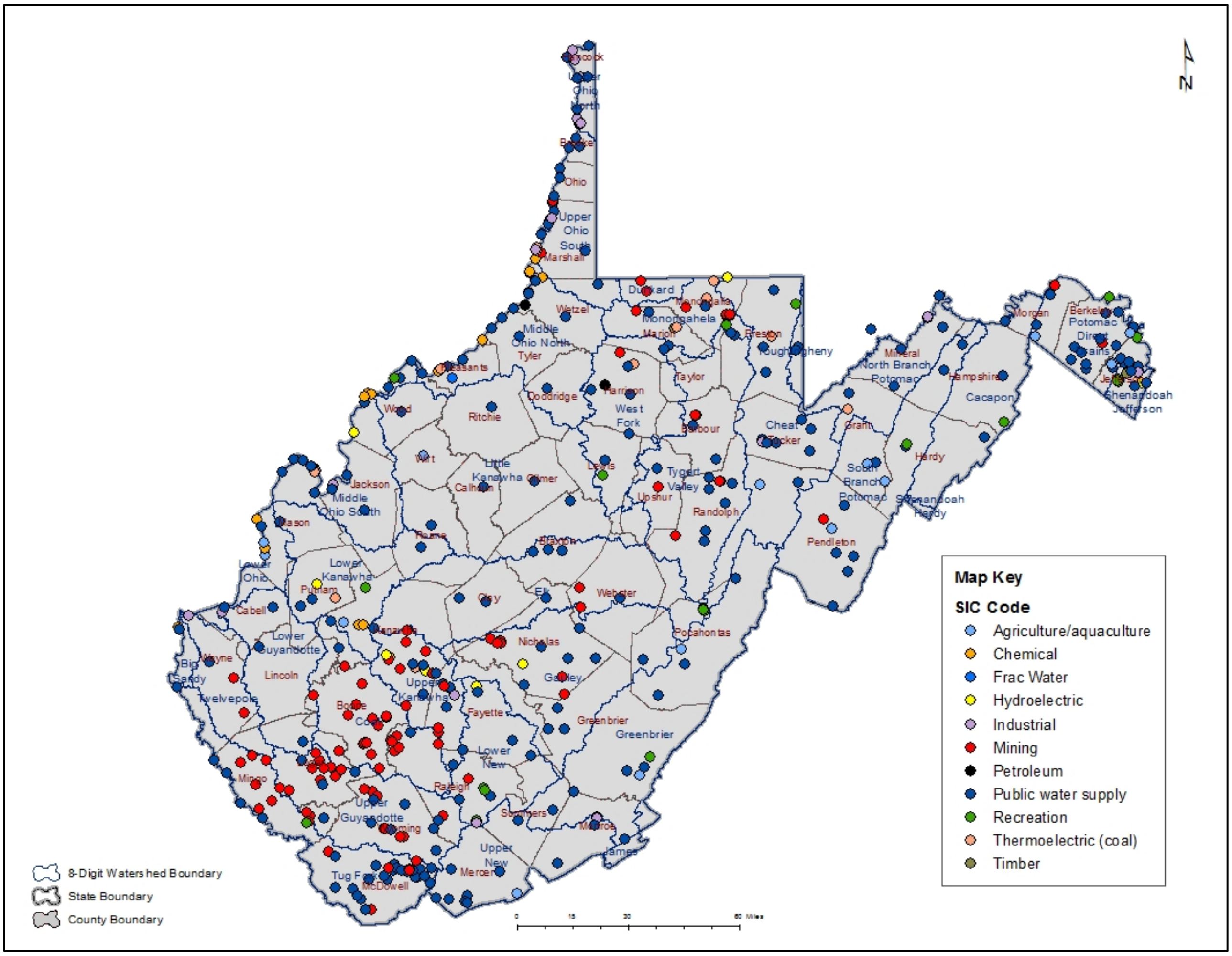



Figure 2-8 Distribution of Large Quantity Users as of 2011, identified by SIC code.

Agriculture/aquaculture and Chemical use types each have seven watersheds with active LQU facilities (Figure 2-9 and Figure 2-10). More than 70% of the total withdrawals for agriculture/aquaculture use occur in the South Branch Potomac and Cheat watersheds, with almost 50% more withdrawals occurring in the South Branch Potomac than in the Cheat. The large amount of withdrawals in the South Branch Potomac is entirely the result of flow through quantities at three hatcheries operated by the West Virginia Division of Natural Resources (DNR). There is only one DNR hatchery in the Cheat Watershed. The remaining watersheds constitute only 30% of the total withdrawals. Additional agricultural water use estimates are described in Section 2.4. Almost 90% of the chemical withdrawals occur in the Lower Kanawha, Middle Ohio North, and Upper Kanawha watersheds. The Lower Kanawha Watershed experiences the most withdrawals for chemical use at 38% of the total in order to operate four different facilities, while the Middle Ohio North, with six chemical facilities, and the Upper Kanawha (one LQU chemical facility) watersheds come in a close second and third, respectively.

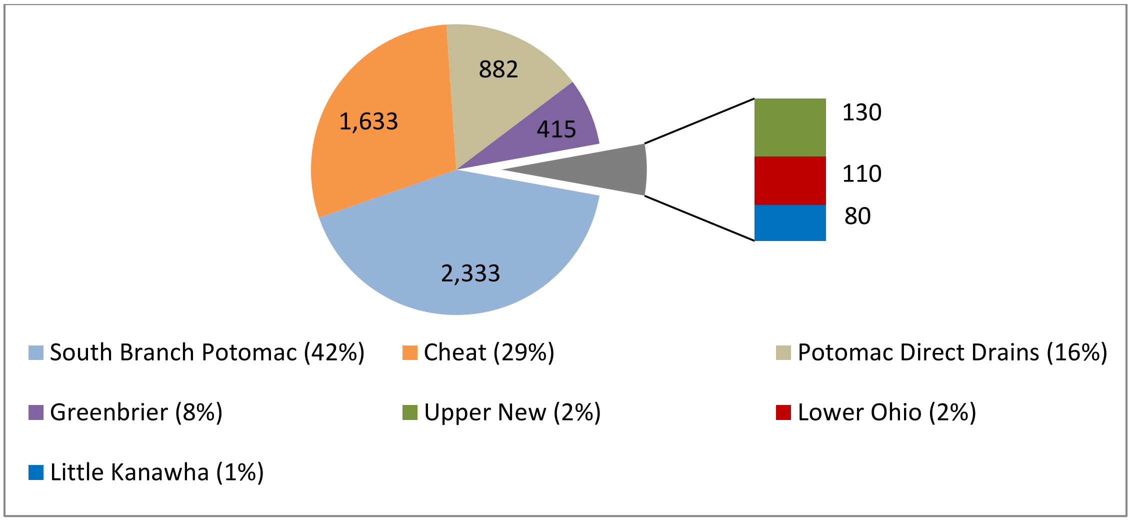



**Figure 2-9 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Agriculture/aquaculture SIC category of use, estimated to be 5,581,517,720 gallons per year.**

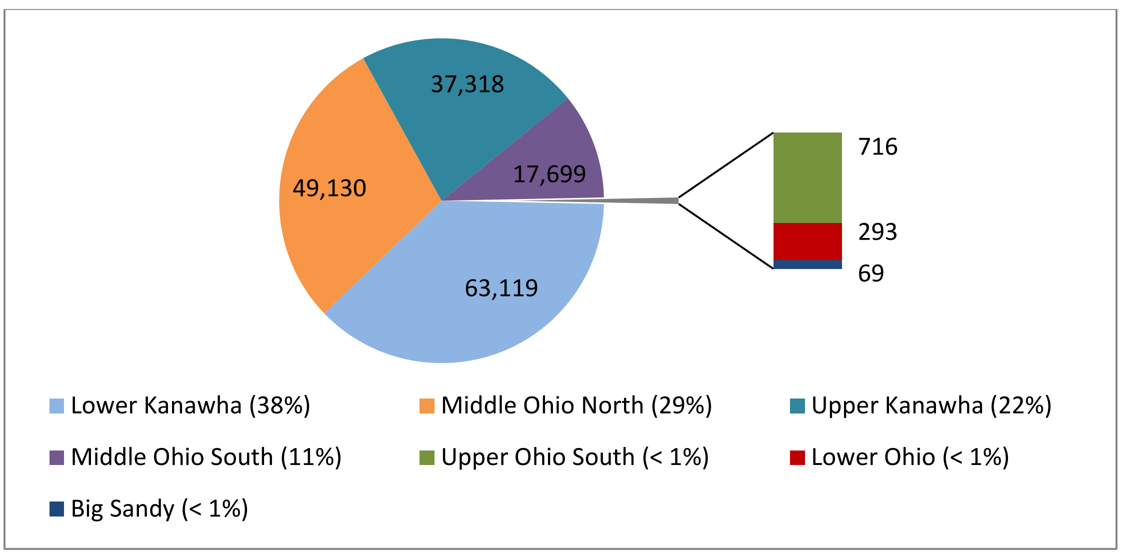



**Figure 2-10 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Chemical SIC category of use, estimated to be 168,342,927,475 gallons per year.**

There are eight watersheds that have active LQU withdrawals occurring for the Hydroelectric and Industrial SIC groups (Figure 2-11 and Figure 2-12). The Middle Ohio South and Middle Ohio North watersheds contribute almost 60% of the total hydroelectric water use in the state from the flow through occurring at two facilities, Belleville Hydroelectric Facility and New Martinsville Hannibal Hydroelectric Plant. Every other watershed with hydroelectric water use has only one active facility, except the Upper Kanawha Watershed which has two; London and Marmet Hydroelectric Projects. Approximately 97% of the total industrial withdrawals occur in three watersheds. The Upper Ohio North Watershed has four active facilities that withdraw significantly more of the total industrial use water (71%) than the Potomac Direct Drains Watershed, which has two LQU facilities withdrawing 15% of the total. The Upper Kanawha Watershed has one facility withdrawing 11% of the total industrial use water in the state.

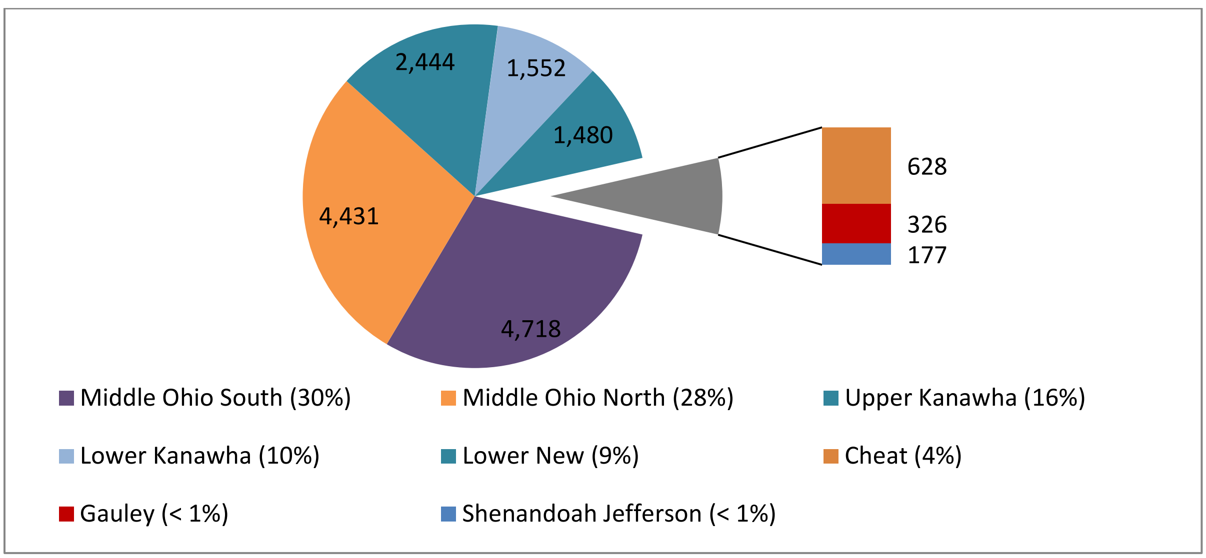



**Figure 2-11 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in billions of gallons for the Hydroelectric SIC category of water use, estimated to be 15,756,375,655,427 gallons per year.**

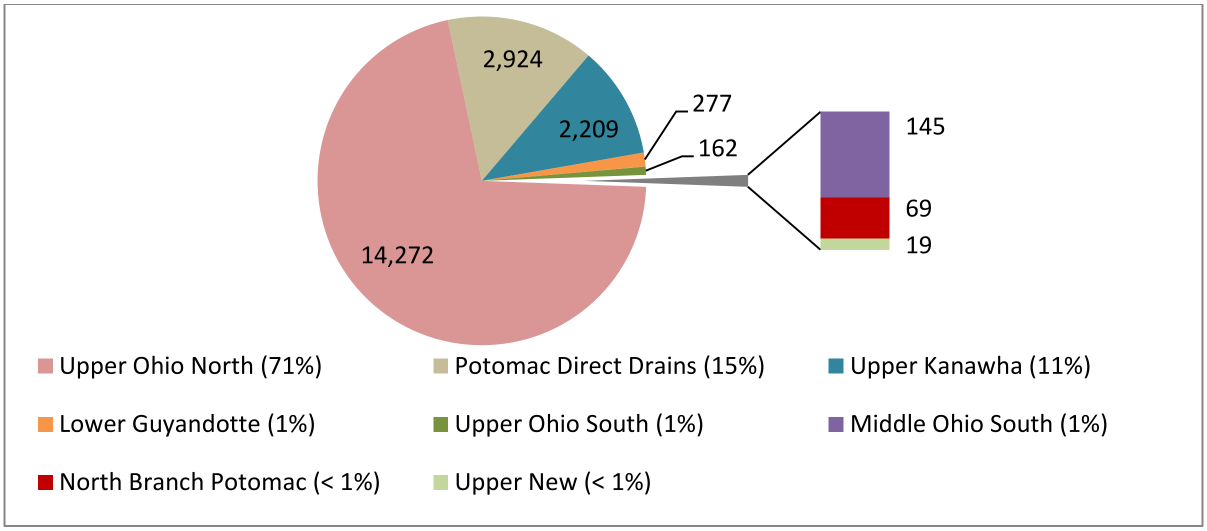



**Figure 2-12 Average annual contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Industrial SIC category of use, estimated to be 20,077,779,753 gallons per year.**

Seventeen watersheds have active LQU withdrawals related to the Mining SIC category (Figure 2-13). The majority of withdrawals for mining (34%) occur in the Coal Watershed which has 18 active LQU facilities. Approximately 45% of the total mining withdrawals occur between four watersheds; Upper Kanawha (19%) with 11 facilities, Upper Guyandotte (10%) with 16 facilities, Upper Ohio South (9%) with two facilities, and Tug Fork (6%) with nine facilities. The remaining 22% of mining withdrawals are split among 25 facilities in 12 watersheds, with shares of the total withdrawals in each remaining watershed ranging from 4% - < 1%.

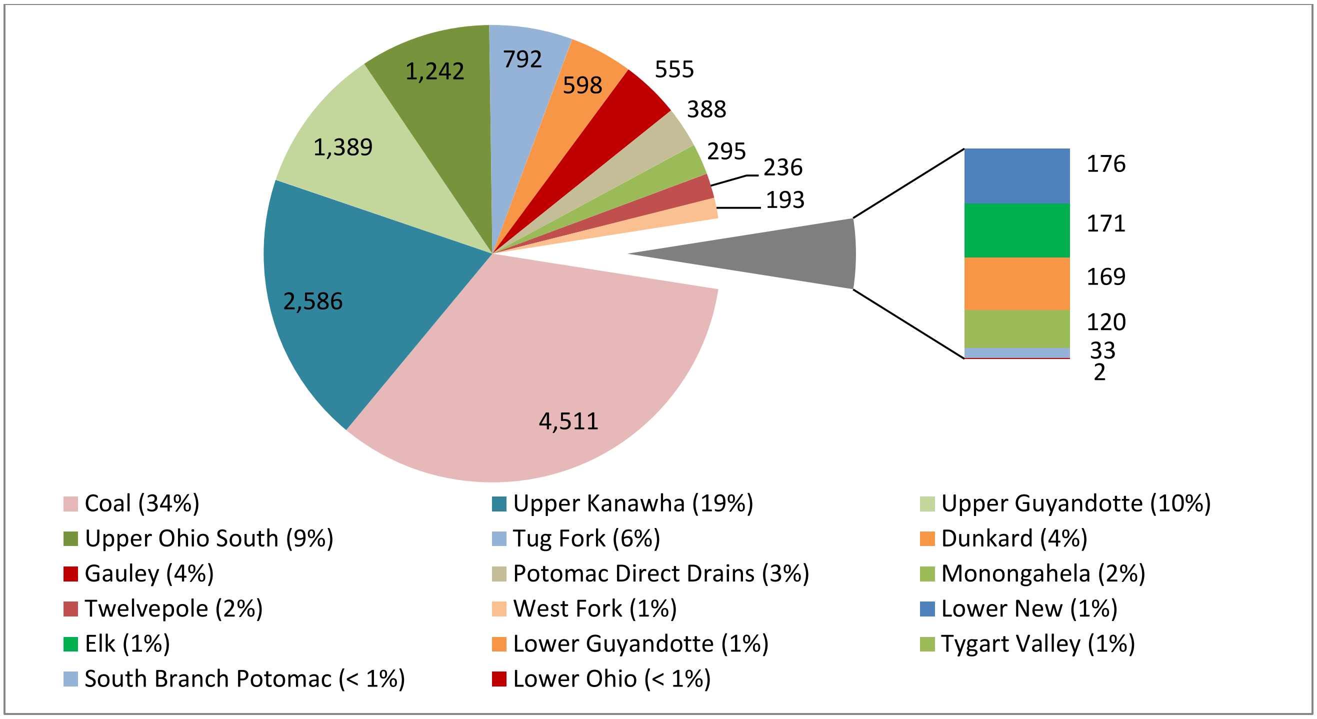



**Figure 2-13 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Mining SIC category of use, estimated to be 13,462,053,653 gallons per year.**

Petroleum has four actively withdrawing watersheds, while the Timber SIC category only has three (Figure 2-14 and Figure 2-15). The four watersheds with withdrawals reported for petroleum use each have only one active LQU facility, except the Upper Ohio North Watershed, which has two facilities and accounts for 67% of the total petroleum withdrawals in the state. The withdrawals for the Timber category occurring at a single facility in the Monongahela Watershed account for 95% of the total timber withdrawals occurring in the state. Three other facilities located in the Shenandoah Jefferson (2) and Cheat (1) watersheds account for the remaining 5% of timber related withdrawals in the state.

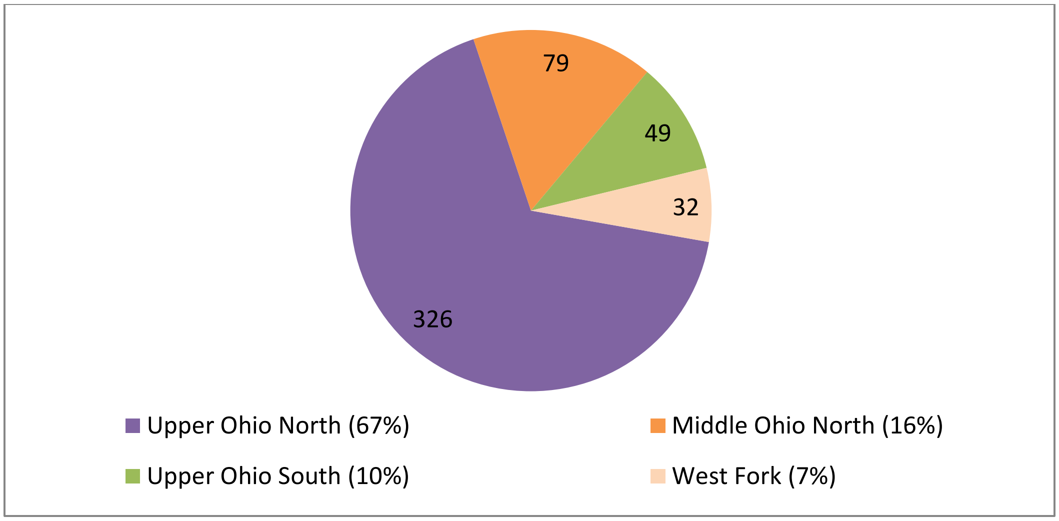



**Figure 2-14 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Petroleum SIC category of use, estimated to be 484,937,415 gallons per year.**

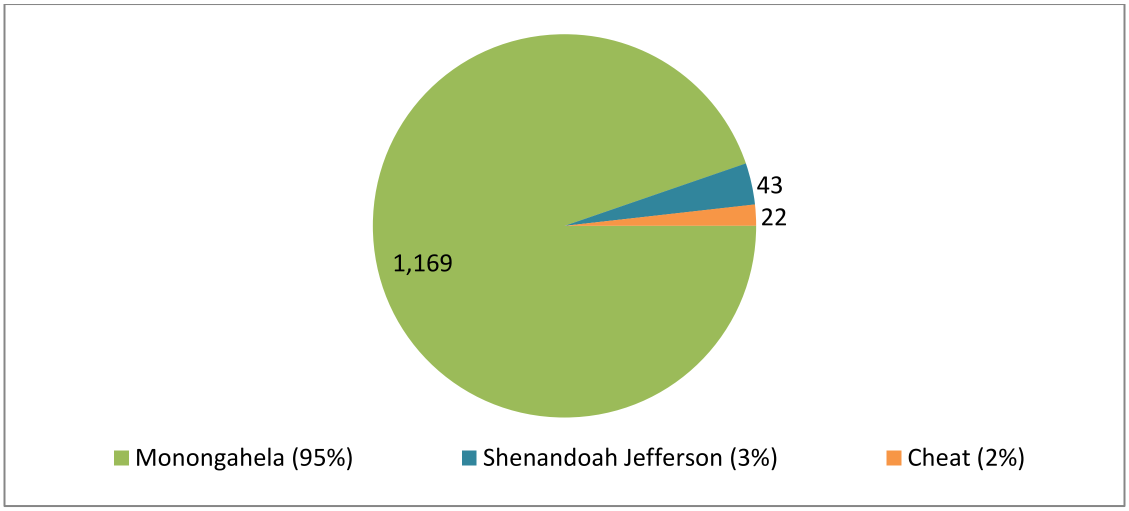



**Figure 2-15 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Timber SIC category of use, estimated to be 1,233,943,576 gallons per year.**

Statewide withdrawals for horizontal well drilling in 2011 occurred in 10 watersheds, but predominately in the Middle Ohio North Watershed, totaling nearly 30% of all related withdrawals (Figure 2-16). The data for horizontal well drilling from the Marcellus Shale is reported and recorded differently from the other Large Quantity Users in the state. A full description of data collection and a detailed discussion of the distribution of water use throughout the watersheds with active Marcellus withdrawals can be found in Section 2.5.

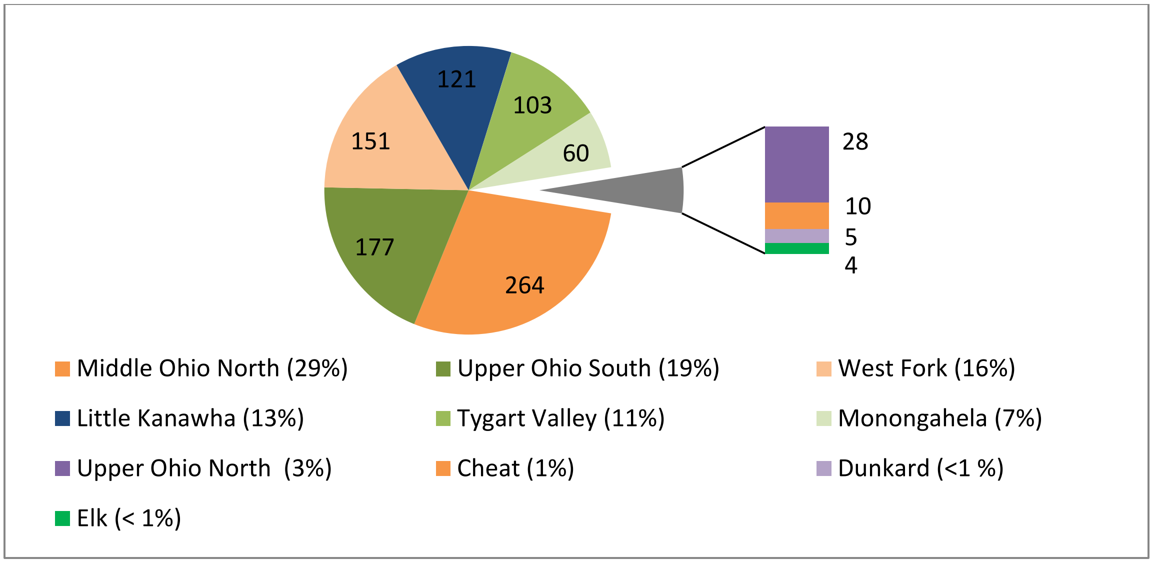



**Figure 2-16 Percent contributions of watersheds to statewide withdrawals and the amount of water withdrawn for the Frac Water SIC category of use from horizontal well drilling in 2011 (from Frac Water Reporting Tool), estimated to be 922,783,143 gallons.**

There are nine watersheds with active LQU withdrawals in the Thermoelectric (coal) category of water use and 14 thermoelectric power plants in West Virginia (see Table 2-4).

**Table 2-4 Thermoelectric (coal) plants in West Virginia**

| Facility ID | Facility Name | Watershed | County | Average Annual Withdrawal (gallons) |
|---|---|---|---|---|
| 2549 | Allegheny Energy - Pleasants Power Station | Middle Ohio North | Pleasants | 5,676,038,175 |
| 2521 | Allegheny Energy Supply - Harrison Power Station | West Fork | Harrison | 13,560,292,200 |
| 3804 | Appalachian Power - Kanawha River Plant | Upper Kanawha | Kanawha | 87,314,848,603 |
| 3805 | Appalachian Power - Mountaineer Plant | Middle Ohio South | Mason | 5,853,907,572 |
| 3806 | Appalachian Power - Philip Sporn Plant | Middle Ohio South | Mason | 199,232,260,160 |
| 3803 | John E Amos Plant | Lower Kanawha | Putnam | 14,411,032,933 |
| 2619 | Monongahela Powe Co - Rivesville Power Station | Monongahela | Marion | 1,175,755,609 |
| 2005 | Monongahela Power Co - Albright Power Station | Cheat | Preston | 843,748,700 |
| 2493 | Monongahela Power Co - Fort Martin Power Station | Monongahela | Monongalia | 3,671,588,650 |

| Facility ID | Facility Name | Watershed | County | Average Annual Withdrawal (gallons) |
|---|---|---|---|---|
| 2600 | Monongahela Power Co - Willow Island Power Station | Middle Ohio North | Pleasants | 11,854,943,333 |
| 3422 | Morgantown Energy Facility | Monongahela | Monongalia | 26,827,340,000 |
| 2699 | Mount Storm Power Station | North Branch Potomac | Grant | 403,202,680,000 |
| 3807 | Ohio Power Co - Kammer Plant | Upper Ohio South | Marshall | 132,394,974,000 |
| 3808 | Ohio Power Co - Mitchell Plant | Upper Ohio South | Marshall | 9,236,808,759 |

Predominately, related withdrawals occur in the North Branch Potomac Watershed (44%) at a single facility (Figure 2-17). Another 50% of the total withdrawals occur among four watersheds. The Middle Ohio South contributes 22% and the Upper Ohio South contributes 15%, each having two facilities. The Upper Kanawha Watershed contributes 10% to the total from one facility while the Monongahela contributes only 3% from three LQU facilities. The remaining four watersheds have one facility each, except the Middle Ohio North Watershed which has two facilities that contribute 2% or less to the total statewide withdrawals for thermoelectric use.

The Recreation SIC category has 14 watersheds contributing to the total amount of annual withdrawals occurring statewide (Figure 2-18). The Greenbrier and Cheat watersheds withdrawal more than 70% of the total recreational water used in the state from four facilities; two located in each. The Lower New has three LQU facilities which account for 11% of withdrawals while the Upper Ohio North has one facility that accounts for approximately 6% of the total. The Potomac Direct Drains and Shenandoah Jefferson watersheds each have two facilities and contribute 3% each to the total recreational use. The West Fork Watershed has one facility that contributes 2% to the total. The remaining seven watersheds with recreational use withdrawals have only one facility a piece and contribute 1% or less to the total annual statewide withdrawals.

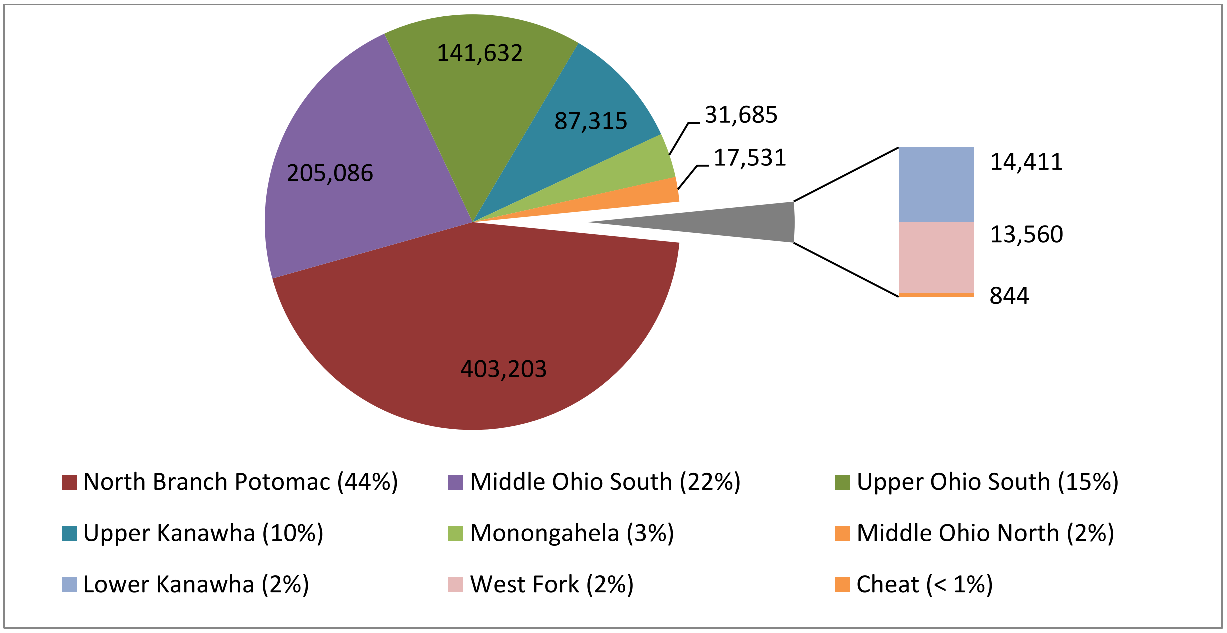



**Figure 2-17 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Thermoelectric (coal) SIC category of use, estimated to be 915,256,218,694 gallons per year.**

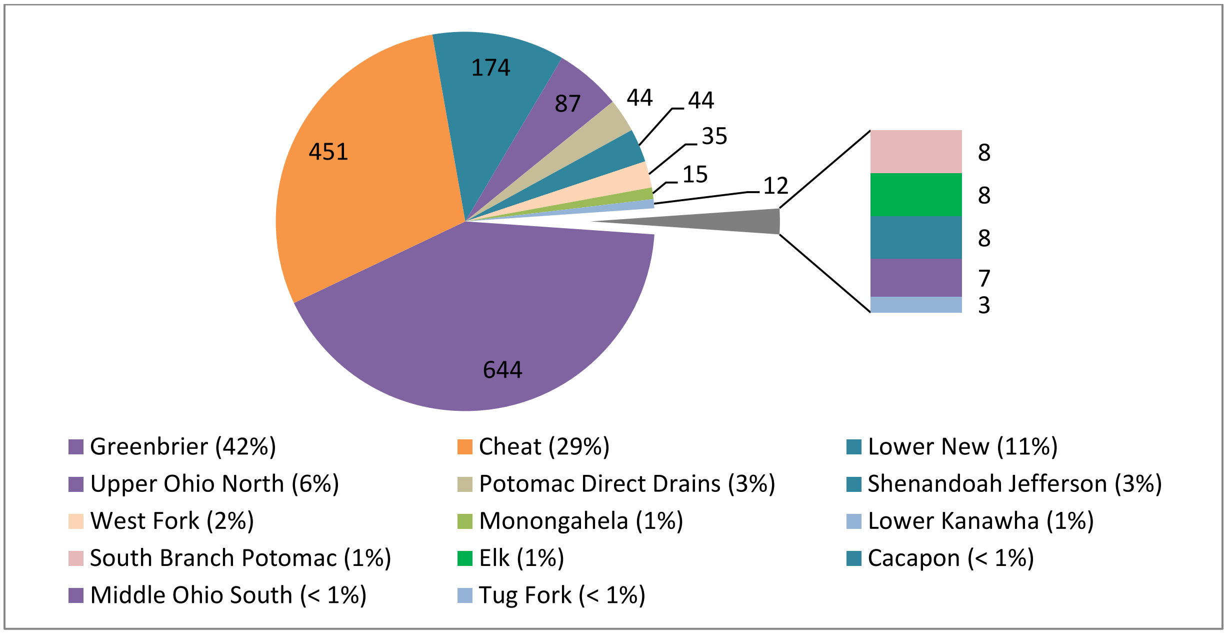



**Figure 2-18 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Recreation SIC category of use, estimated to be 1,544,771,703 gallons per year.**

Every watershed in the state, except the Dunkard, James, and Shenandoah Hardy, has active LQU withdrawals in the Public Water Supply category (Figure 2-19). There are 215 registered LQUs that are actively withdrawing water for the public. It is especially important to remember when considering the number and distribution of LQU public water supply facilities that any facility that is a purchase-only facility is not required to report its water use since that water is already reported by the originating Public Service District (PSD). Withdrawals for the Public Water Supply SIC category are generally well distributed across the state. The largest contribution to the total annual withdrawals occurs due to the activity in the Elk Watershed (17%) which has eight active LQU facilities. Of the eight active facilities, three are operated by West Virginia American Water and serve not only a large residential area and sell water to smaller PSDs but also have a commercial and industrial client base as well, due to location. The Tygart Valley Watershed withdraws the second largest amount of water for public supply (9%) with 13 contributing facilities. The City of Fairmont withdraws the most water of the 13 facilities in the Tygart Valley Watershed, but also serves a large variety of clients (e.g. private domestic, commercial, and industrial) including resale to smaller PSDs. The Middle Ohio South and the Lower Ohio each contribute 7% to the total withdrawals occurring in the state. The Middle Ohio South Watershed has 11 LQU facilities, while the Lower Ohio Watershed has three active facilities, one of which is WV American Water – Huntington. The Lower New Watershed has six facilities while the Upper Ohio South Watershed has 12 facilities, but each contributes 6% to the total annual withdrawals. The Monongahela has four active LQUs while the West Fork Watershed has three active LQUs (the two largest being Morgantown and Clarksburg, respectively,) while the Potomac Direct Drains Watershed has 16 active facilities, but each contributes 5% of the statewide total. The Upper New Watershed has 10 LQU facilities while the Tug Fork Watershed has 28 and each contributes 4% to the total. The remaining 18 watersheds with active LQU withdrawals contribute 3% or less to the total annual withdrawals for public supply.

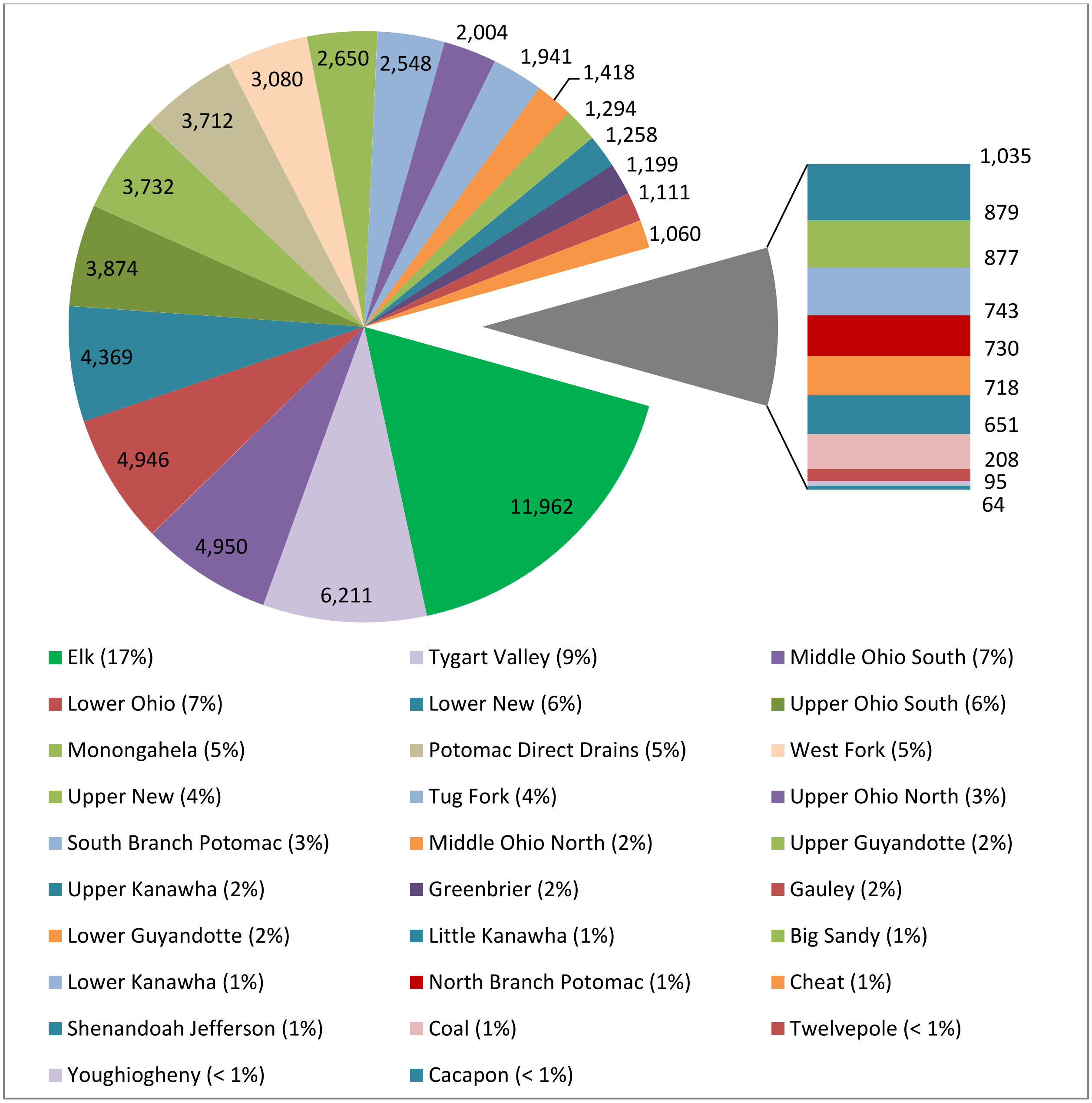
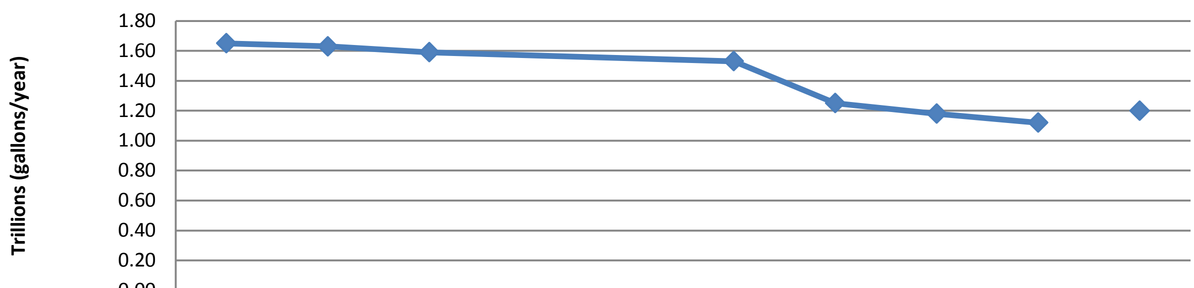



**Figure 2-19 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for Public Water Supply use estimated to be 69,283,527,985 gallons.**

### 2.2.4 Water withdrawal trends over time

Water use rates are directly tied to the size of the human population and the state of the economy. The population in the state has not seen a dramatic change in size over the course of the LQU data collection. It is important to note when reviewing Figures 2-20 to 2-25 that no data was collected in 2006 and 2007. Additionally, the last three years of data may not equal the reported three year average due to the removal of facilities that have closed from the reported three year average. The state of the economy has fluctuated, some due to recessions and recovery periods, but almost all of the SIC categories in the LQU database reported using less water in the most recent reporting year (2011) than in the initial year of data collection (2003). This trend among SIC categories is reflected in the reduction in statewide water use over the reporting period (Figure 2-20).



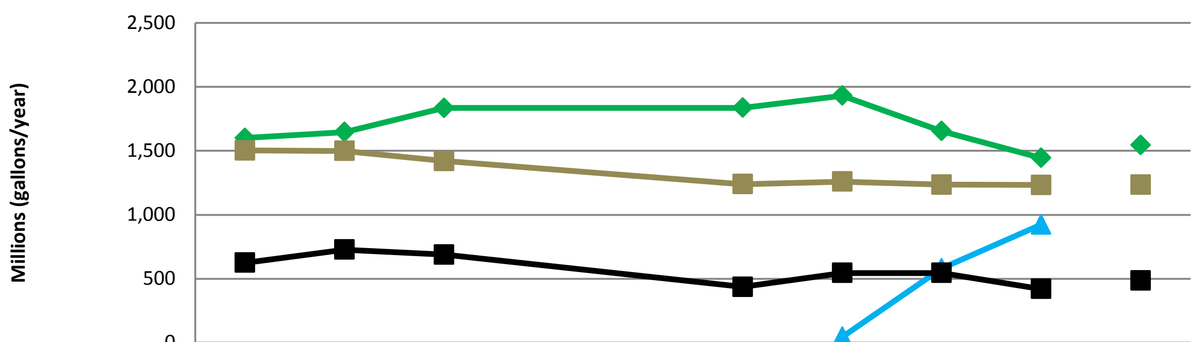

| | 2003 | 2004 | 2005 | 2006 | 2007 | Year | 2009 | 2010 | 2011 | 3 Year Average |
|---|---|---|---|---|---|---|---|---|---|---|
| Statewide | 1.65 | 1.63 | 1.59 | | | 1.53 | 1.25 | 1.18 | 1.12 | 1.20 |

**Figure 2-20 Statewide water withdraw trends over time (excluding hydroelectric).**

The only SIC categories that have seen an increase in water use over time are Public Water Supply, Mining and Frac Water. A detailed list of facilities by SIC category, name, watershed, county, and the average amount of water used each year can be found in Appendix K. Only withdrawals for frac water have seen a steady increase each year of record. Read Section 2.5 for a detailed discussion of the frac water data collection and growth of the industry. The individual watershed sections in the West Virginia Watershed Descriptions companion report contain detailed descriptions of SIC trends.

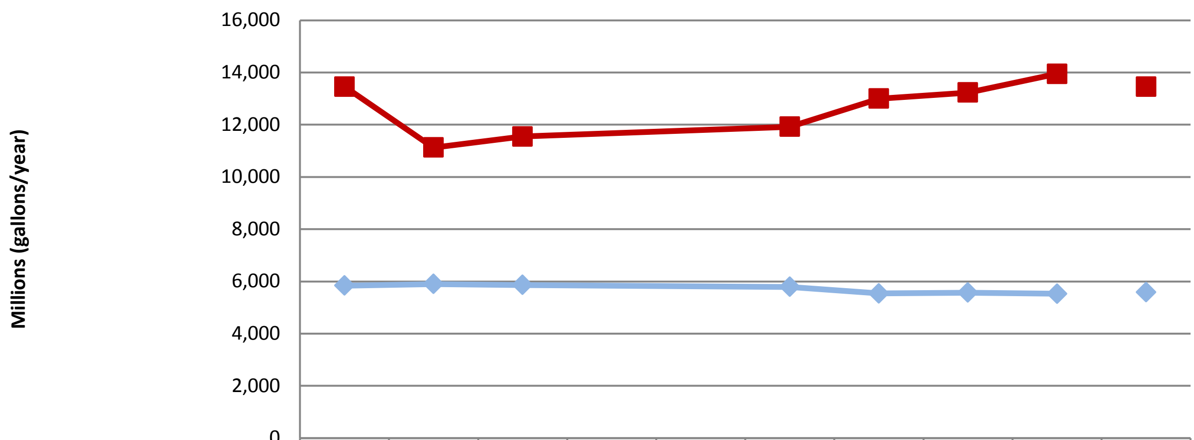
The Timber, Frac Water, Recreation and Petroleum SIC categories reported using the least amount of water annually, ranging only in the 46-1,900 millions of gallons (Figure 2-21). Reductions in overall water use could be a result of economic variations, the implementation of voluntary water conservation practices, facility closures, reduction of withdrawals so that withdrawals fall below the reporting threshold, effectively removing open industries from the reporting data,  or moving from withdrawal operations to purchasing the water needed for operations.

The Mining and Agriculture/aquaculture SIC categories have withdrawal averages ranging from about 5.5 billion to almost 14 billion gallons of water every year (Figure 2-22).  Mining uses more than twice as much water and has seen more fluctuation over time than agriculture/aquaculture uses.  However, there are 12 operating agriculture/aquaculture users in the state and only two facilities have closed since the beginning of the collection period.  Agriculture/aquaculture is almost entirely made up of fish hatcheries or large nurseries that are either set up as mostly flow through operations or are almost entirely non-consumptive otherwise.  There are approximately 90 currently active LQU mining facilities.  Since 2004, 18 facilities have closed with the most (9) occurring in 2009.  Six more facilities closed between 2010 and 2011.  However, 13 new facilities began reporting on or after the 2008 collection year.  Other economic driving forces, such as the market price for coal, are likely to change production levels and therefore the amount of water needed from year to year.




| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 3 Year Average |
|---|---|---|---|---|---|---|---|---|---|---|
| Recreation | 1,600 | 1,646 | 1,834 | | | 1,836 | 1,931 | 1,653 | 1,444 | 1,545 |
| Timber | 1,503 | 1,499 | 1,420 | | | 1,239 | 1,259 | 1,235 | 1,233 | 1,234 |
| Frac Water* | | | | | | | 46 | 581 | 923 | |
| Petroleum | 625 | 727 | 689 | | | 437 | 545 | 545 | 420 | 485 |

**Figure 2-21  Statewide LQU water withdrawal trends for the Recreation, Timber, Frac Water*, and Petroleum SIC categories, measured in millions of gallons per year.  *Frac Water data was collected in a separate database over a different time period.**



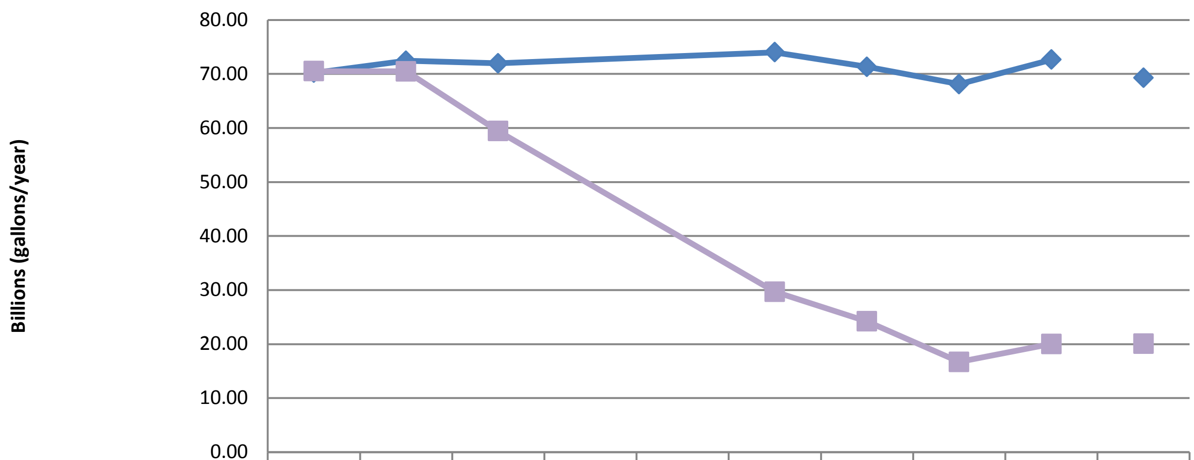

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 3 Year Average |
|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture/Aquaculture | 5,838 | 5,901 | 5,861 | | | 5,793 | 5,539 | 5,572 | 5,528 | 5,582 |
| Mining | 13,462 | 11,125 | 11,548 | | | 11,922 | 13,003 | 13,234 | 13,951 | 13,462 |

**Figure 2-22 Statewide LQU water withdrawal trends for the Agriculture/aquaculture and Mining SIC categories, measured in millions of gallons per year.**

Although the public water supply sector mostly serves residential customers, individual facilities may also have commercial and industrial clients that purchase water. The slight increase in this sector that has occurred since the initial data collection year corresponds to the U.S. Census intercensal estimates, which show a slight increase in population each year of the reporting period. However, the amount of water withdrawn for the public supply has only fluctuated between 68 and 74 billion gallons per year over the reporting period. Other factors contributing to variations in the amount of water used for public supply include annual precipitation, installation of water saving appliances, and economic factors. There are 12 currently operating industrial LQUs. From 2006 to 2009, four of the original 16 closed. The Industrial SIC category has seen an obvious decrease in withdrawals over the reporting period, dropping from 70 billion gallons in 2003 and 2004 down to 17 and 20 billion gallons in 2010 and 2011, respectively. The dramatic reductions could be a result of voluntary conservation practices or a switch to purchasing rather than withdrawing water (Figure 2-23). Reporting

> Reporting water use allows companies to become more aware of the amount of water used, and may lead to increased water conservation.

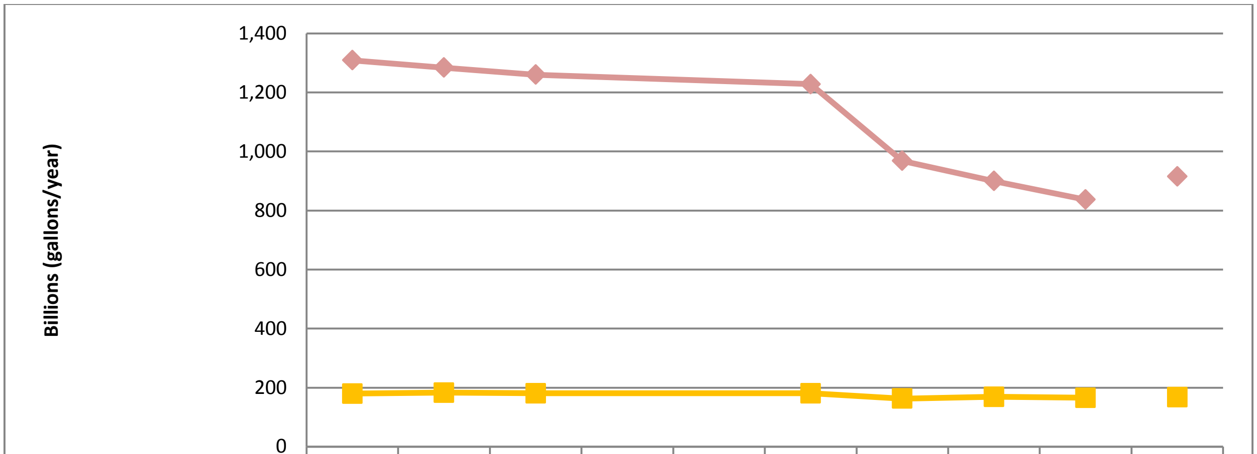
water use allows companies to become more aware of the amount of water used, and may lead to increased water conservation.




| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 3 Year Average |
|---|---|---|---|---|---|---|---|---|---|---|
| Public Water Supply | 70.20 | 72.43 | 71.96 | | | 74.00 | 71.30 | 68.11 | 72.63 | 69.28 |
| Industrial | 70.52 | 70.47 | 59.42 | | | 29.69 | 24.21 | 16.70 | 20.02 | 20.08 |

**Figure 2-23 Statewide LQU water withdrawal trends for the Public Water Supply and Industrial SIC categories, measured in billions of gallons per year.**

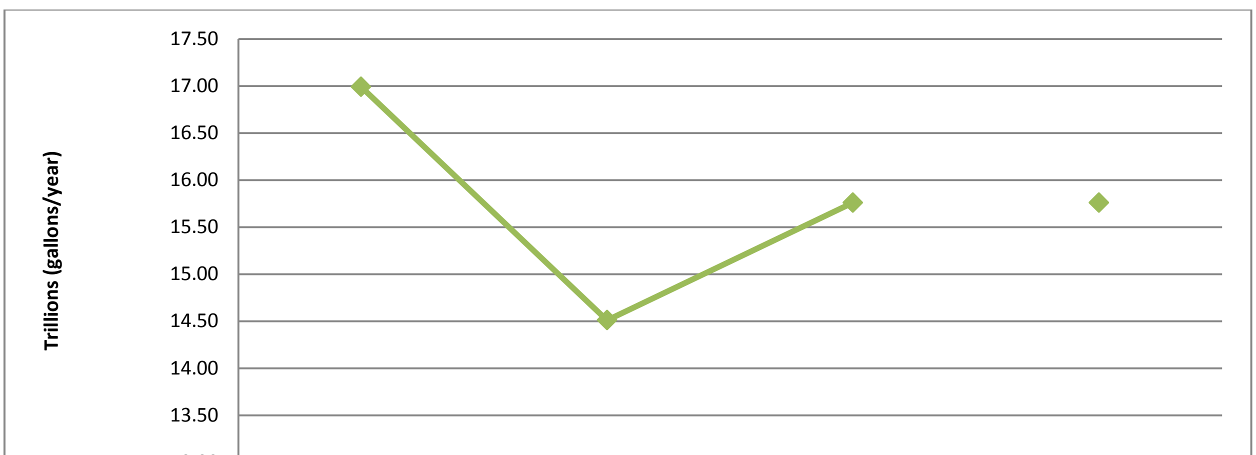
Since 2003, the water reportedly withdrawn by thermoelectric facilities has dropped from approximately 1,300 billion gallons per year to 837 billion gallons a year in 2011 (Figure 2-24). The decline in thermoelectric (coal) production is directly related to a reduction in the amount of energy produced. The reduction in energy production can be attributed to many factors. Economic recessions cause a reduction in energy production. Higher costs for raw materials or less demand for a product can reduce production amounts and therefore the need for energy and finally for water. Climatic changes will have a direct effect on the amount of energy required to heat and cool both residential and commercial buildings. Political factors such as the provision of funding to switch to alternative power sources as well as energy efficient building requirements for new construction, appliances and lighting play a role in the overall reduction. The Chemical SIC category has seen an approximate 15 billion gallon reduction in overall water use since 2003 (Figure 2-24). There were 16 original facilities that registered in 2003 with two closures occurring by 2008 with the 2008 closure being the largest contributor of the two.




| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 3 Year Average |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermoelectric (coal) | 1,309 | 1,284 | 1,260 | | | 1,228 | 968 | 900 | 837 | 915 |
| Chemical | 180 | 183 | 181 | | | 181 | 163 | 169 | 166 | 168 |

**Figure 2-24 Statewide LQU water withdrawal trends for the Thermoelectric and Chemical SIC categories, measured in billions of gallons per year.**

Hydroelectric water use is flow through and considered non-consumptive. Water use data was not originally collected from these facilities. Data collection for hydroelectric facilities began in 2009 (Figure 2-25). There are nine facilities that are currently registered under the Hydroelectric SIC group in the LQU database. Like thermoelectric plants, the fluctuations in water used or passed-by a hydroelectric facility is directly related to the amount of energy needed and the quantity of available water.




| | 2009 | 2010 | 2011 | 3 Year Average |
|---|---|---|---|---|
| Hydroelectric | 16.99 | 14.51 | 15.76 | 15.76 |

**Figure 2-25 Statewide trends in pass by flows occurring in the Hydroelectric SIC category, measured in billions of gallons per year.**

### 2.2.5 Water Sources

Large Quantity Users may withdrawal water from surface sources including streams, rivers, lakes, and springs and from natural groundwater wells or flooded mine pools. The overall average annual results can be seen in Table 2-5 and Table 2-6. The three-year average annual gallons withdrawn was calculated for each individual facility and then summed by SIC category, see Section 2.2.2 for a detailed description of the data analysis. Percentages of ground and surface waters were determined by categorizing the source and then calculating the average contribution of each intake type reported by facilities to the overall withdrawal. The general locations of LQUs utilizing surface and groundwater sources can be seen in Figure 2-26. Water withdrawn for domestic and agriculture use does not fall under the reporting requirements and had to be estimated separately Sections 2.3 and 2.4, respectively.

From the tables below we can see that every LQU withdrawals more surface water than groundwater except for withdrawals for the petroleum industry. The Petroleum SIC category withdraws, on average, approximately 24% of its total water from surface water sources, and has the most balanced water withdrawal approach of all the LQU industries. Mining withdraws the second highest percentage of groundwater and has the next most balanced withdrawal approach, with an average of approximately 78% of its total water being from surface sources. The Industrial, Public Water Supply and Recreation SIC categories all withdraw approximately 80% of their total water use from surface water sources. However, it is important to remember when considering withdrawals for public supply that this is only for PSDs that withdraw enough water to be considered a LQU; it is likely that smaller PSDs use a larger percentage of groundwater than surface water to supply the public. The remaining industries all withdraw greater than 90% of their water from surface sources. The thermoelectric industry withdraws the greatest percentage of surface water used in the state, while hydroelectric use is 100% flow-through and has no groundwater intakes (Figure 2-27). This distribution of annual surface water used in each watershed by the each SIC categories can be seen in Figure 2-28.

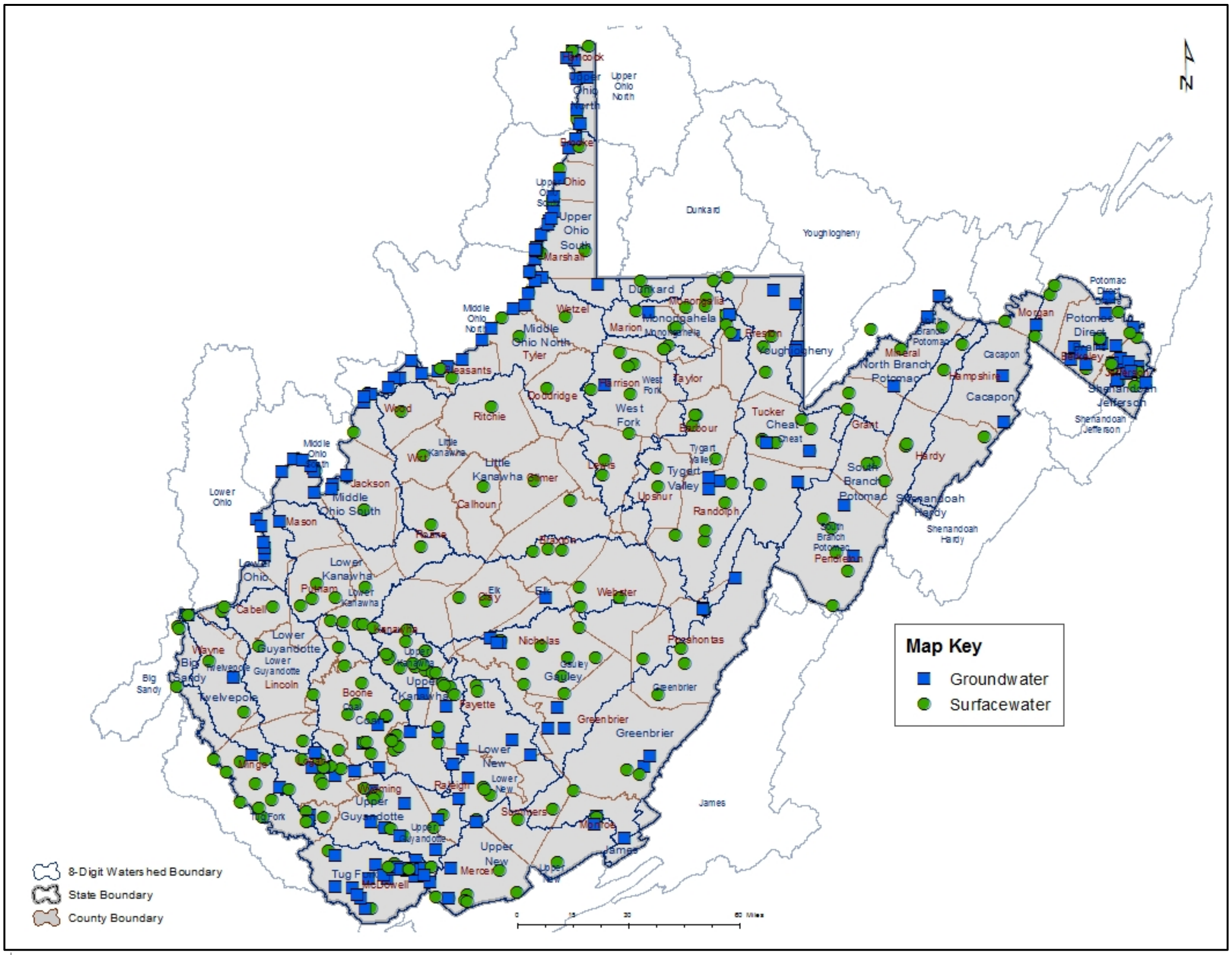



Figure 2-26  Distribution of Large Quantity User groundwater and surface water withdrawals.

Although the Public Water Supply SIC category withdraws 19% of its total water use from groundwater sources, it uses the greatest percentage of overall groundwater withdrawn by LQUs in the state (Figure 2-29).  Of the 215 currently registered and operating public water supply LQUs, approximately half utilize groundwater intakes for their supply.  The Chemical SIC category withdraws 6% of its total water from groundwater sources and its' share of total groundwater use in the state is 32%.  A relatively small number of chemical facilities use a large amount of the groundwater withdrawn in the state.  There are 14 chemical facilities registered as LQUs that are currently operating and of those, nine utilize groundwater intakes for their supply.

**Table 2-5 Total annual average gallons withdrawn in the state and the corresponding percentages of groundwater and surface water, separated by SIC code. *Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool, which all horizontal well operators who hold a water management plan as part of the Oil and Gas permit are subject to report all related withdrawals to. Values may not sum exactly due to individual rounding.**

| LQU | Sum of 3 Year Annual Average | % GW | % SW |
|---|---|---|---|
| Agriculture/aquaculture | 5,581,517,720 | 4.95 | 95.05 |
| Chemical | 168,342,927,475 | 6.18 | 93.82 |
| Frac Water* | 922,783,143 | 0.12 | 99.88 |
| Hydroelectric | 15,756,375,655,427 | 0.00 | 100.00 |
| Industrial | 20,077,779,753 | 17.71 | 82.29 |
| Mining | 13,462,053,653 | 22.55 | 77.45 |
| Petroleum | 484,937,415 | 76.37 | 23.63 |
| Public water supply | 69,283,527,985 | 18.75 | 81.25 |
| Recreation | 1,544,771,703 | 16.37 | 83.63 |
| Thermoelectric (coal) | 915,256,218,694 | 0.04 | 99.96 |
| Timber | 1,233,943,576 | 0.59 | 99.41 |
| **Total annual LQU withdrawals** | 16,952,566,116,543 | **<0.01** | **>99.99** |

**Table 2-6 Total annual average gallons withdrawn in the state and the corresponding percentages of groundwater and surface water, separated by SIC code. *Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool, which all horizontal well operators who hold a water management plan as part of the Oil and Gas permit are subject to report all related withdrawals to. Values may not sum exactly due to individual rounding. Hydroelectric totals are excluded.**

| LQU | Sum of 3 Year Annual Average | % GW | % SW |
|---|---|---|---|
| Agriculture/aquaculture | 5,581,517,720 | 4.95 | 95.05 |
| Chemical | 168,342,927,475 | 6.18 | 93.82 |
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| Public water supply | 69,283,527,985 | 18.75 | 81.25 |
| Recreation | 1,544,771,703 | 16.37 | 83.63 |
| Thermoelectric (coal) | 915,256,218,694 | 0.04 | 99.96 |
| Timber | 1,233,943,576 | 0.59 | 99.41 |
| **Total annual LQU withdrawals** | 1,196,190,461,116 | **2.63** | **97.37** |

The industrial and mining sectors contribute 13% and 9%, respectively, to the total amount of groundwater withdrawn annually. Two percent of groundwater use comes from both the recreation and petroleum industries, while the remaining industries contribute 1% or less to the annual withdrawals. This distribution of annual groundwater used in each watershed by the each SIC categories can be seen in Figure 2-30.

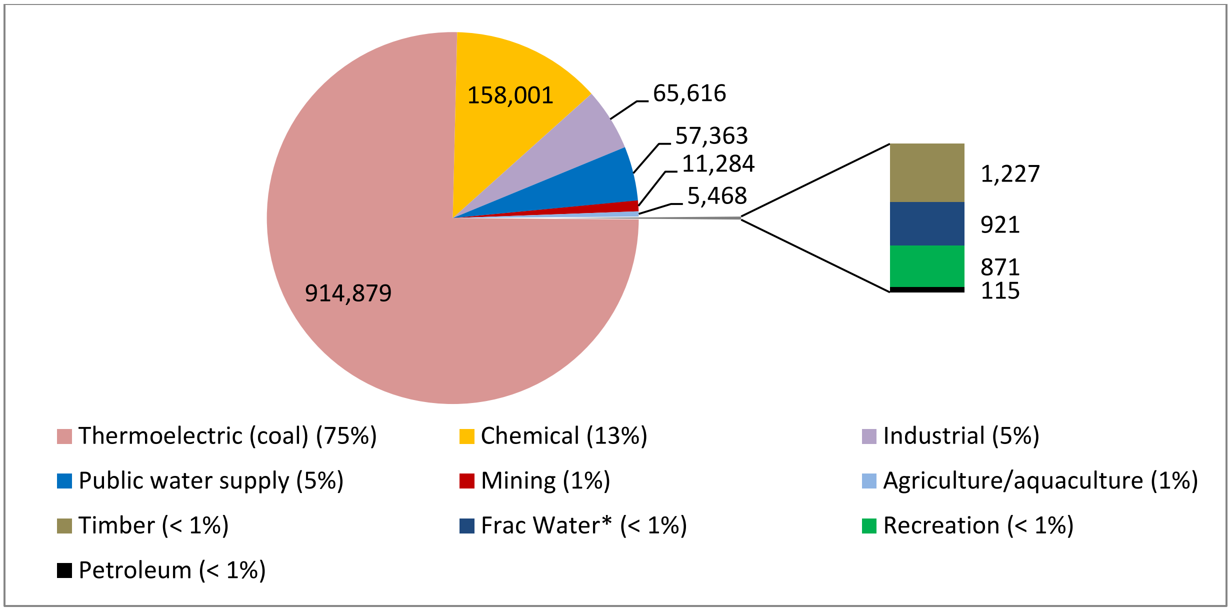



**Figure 2-27 Statewide distribution of average annual amount of water withdrawn by LQUs from surface water sources (excluding Hydroelectric). * Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool.**

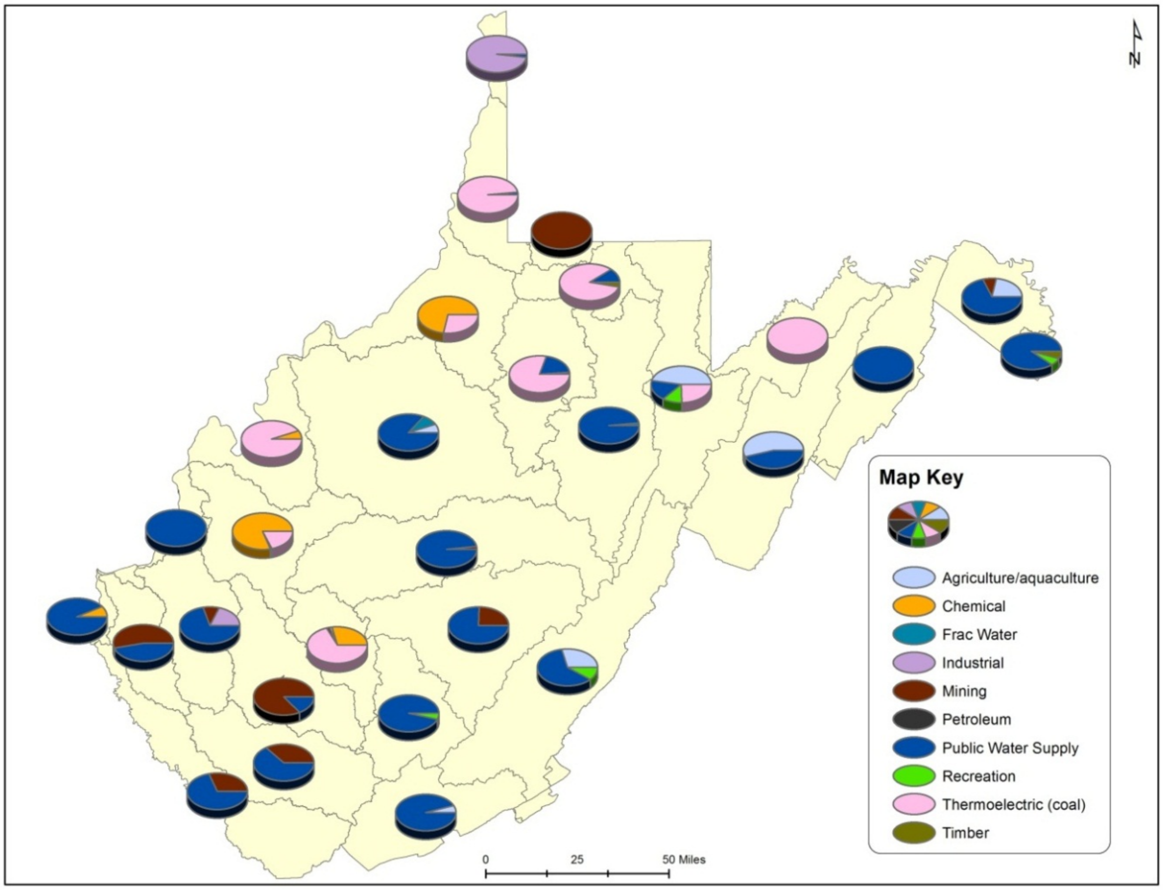



Figure 2-28 Distribution of average annual amount of water withdrawn by LQUs from surface water sources (excluding Hydroelectric) in each watershed. Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool.

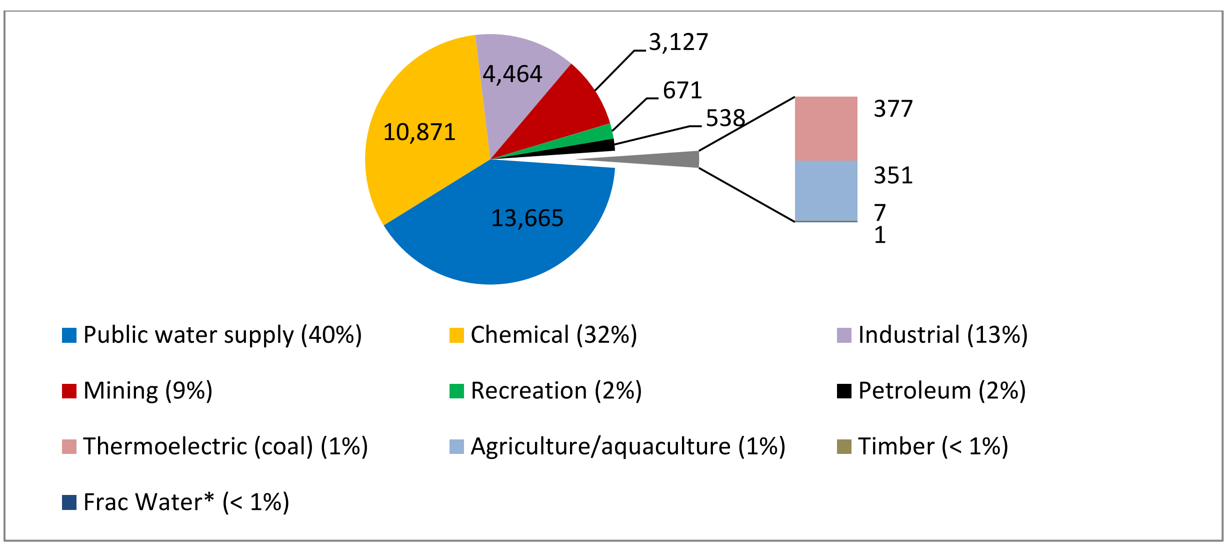



Figure 2-29 Statewide distribution of average annual amount of water withdrawn by LQUs from groundwater sources (excluding Hydroelectric). * Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool.

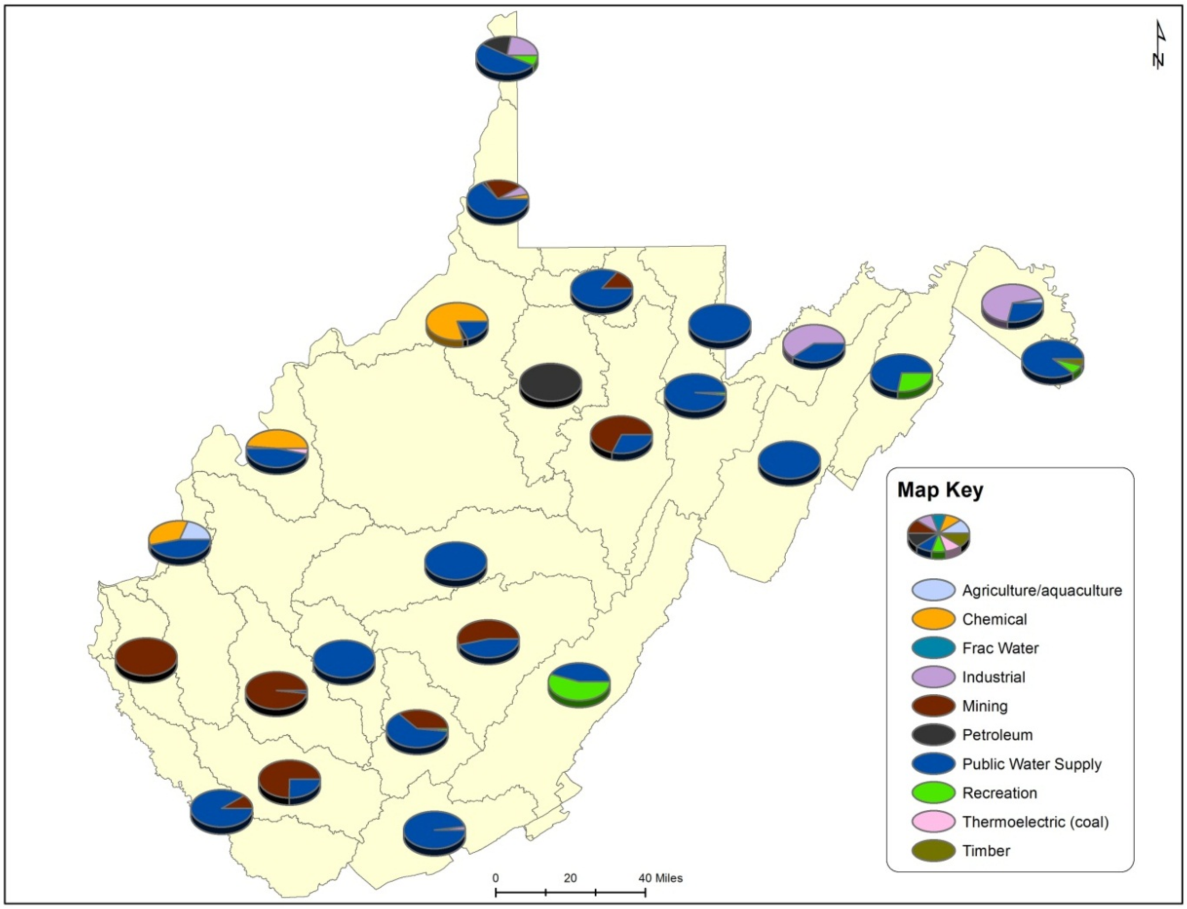



Figure 2-30  Distribution of average annual amount of water withdrawn by LQUs from groundwater sources (excluding Hydroelectric) in each watershed.  Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool.

## 2.2.6 Interbasin Transfers

As defined in the Act, 22-26a, interbasin transfers result from the permanent movement of water from one hydrological unit to another.  These transfers are considered a consumptive use from the originating watershed. Based on data availability, the following discussion is limited to the consideration of the movement of water between HUC-8 watersheds occurring due to the activity of Large Quantity Users in the state.   Approximately 8 billion gallons of water are withdrawn by facilities that utilize intakes in multiple HUC-8 watersheds.  However, this is not completely indicative of the amount of water actually transferred because some of the water withdrawn may be discharged back to the originating watershed. Table 2-7 provides the facilities that withdraw from multiple watersheds and the total average water withdrawn from each originating watershed.

**Table 2-7 Large Quantity Users with activities resulting in withdrawals from multiple watersheds. The annual average withdrawal amount from each watershed is provided. *The facility has reported withdrawal locations but has not reported any withdrawals.**

| Facility ID | Facility Name | Watershed | Average Annual Withdrawal (gallons) |
|---|---|---|---|
| 1945 | Point Pleasant Water Works | Middle Ohio South | 303,221,446 |
| | | Lower Ohio | 151,383,421 |
| 2075 | Kanawha River Terminals – Ceredo Dock | Lower Ohio | 1,887,506 |
| | | Twelvepole | 7,953,505 |
| 2904 | Bayer Material Science LLC | Upper Ohio South | 19,199,790 |
| | | Middle Ohio North | 716,424,361 |
| 3034 | ICG Eastern – Birch River Operation | Gauley | 107,377,222 |
| | | Elk | 10,775,531 |
| 3077 | Beckley Water Company | Upper Kanawha | 344,896,552 |
| | | Lower New | 2,924,265,081 |
| 3414 | Consol Energy – Loveridge | Dunkard | 15,724,589 |
| | | Monongahela | 233,476,504 |
| 4161 | Arch Coal – Coal-Mac, Inc. | Tug Fork | 61,286,135 |
| | | Upper Guyandotte | 36,117,131 |
| 4454 | Hobet Mining – Hobet21 Mine | Coal | 743,881,779 |
| | | Lower Guyandotte | 170,427,192 |
| 4564 | Cobra Natural Resources – Mountaineer Mine & Plant | Upper Guyandotte | 156,677,487 |
| | | Tug Fork | 1,870,871 |
| 4639 | Snowshoe Mountain | Cheat | 451,505938 |
| | | Elk | 7,995,322 |
| 4685 | Catenary Coal Company – Samples Mine Complex | Coal | 49,069,468 |
| | | Upper Kanawha | 53,286,536 |
| 5082 | Cheat Mountain Water Company | Cheat | 7,952,188 |
| | | Elk | 2,959,157 |
| 5128 | Cress Creek Country Club | Shenandoah Jefferson | 0* |
| | | Potomac Direct Drains | 13,735,000 |
| 10070 | City of Vienna | Middle Ohio North | 37,154,164 |
| | | Middle Ohio South | 392,870,880 |
| 10103 | Wolf Run Mining- Sentinel Complex | Tygart Valley | 81,152,653 |
| | | West Fork | 56,847 |

Interbasin transfers can result from a variety of activities. Initially a facility must obtain water from either a withdrawal point or as purchased water from another facility. Large Quantity Users report water withdrawn from surface and/or groundwater sources and water purchased from other facilities. The location of the source may or may not be located in the same watershed of the facility itself or the watershed where the water is later discharged. Additionally, the location of a facility from which water may be purchased for use could require piping from a long distance, and resultantly come from a different watershed than the one where it is used and later disposed of. For example, large PSDs could pipe water across watersheds to domestic or industrial users not attached to public sewer leaving the water in the transferred location. Once water is obtained by a facility and used, it may be disposed of in numerous ways that could result in additional interbasin transfers. Discharges to surface waters, publicly owned treatment works (POTW), underground injection control wells (UIC), private reservoirs, public lakes, and others are also reported by Large Quantity Users. Discharges classified as 'Others' include but are not limited to the following types: irrigation, snowmaking, and dust suppression. Large Quantity Users that are classified as public water suppliers do not report any discharges because the water that is withdrawn for public water supply is either discharged by residential customers to POTWs or to a local septic system. Industrial and commercial customers may discharge the water from public water suppliers to any of the potential discharge locations listed above. Any of these customer uses have the potential to result in interbasin transfers. When a Large Quantity User has multiple intake and discharge locations it becomes impossible to determine exactly how much water from each specific source ends up in each final discharge location because the water generally gets combined and is not traced separately throughout the in-house processes. Understanding the exact amounts of water transferred is further complicated by the lack of or inability to meter discharges. In order to gain an adequate understanding of the interbasin transfers occurring due to the operation of an individual facility, a site specific study would be required.

In order to gain an adequate understanding of the interbasin transfers occurring due to the operation of an individual facility, a site specific study would be required

Interbasin transfers resulting from the activity of Large Quantity Users (LQUs) such as the example of the transfers out of the Elk Watershed illustrated below (Figure 2-31) are described in the respective regional breakdowns in the West Virginia Watershed Descriptions companion report. It is important to note the limitations listed above and that each facility transfers were considered under only three potential transfer mechanisms; 1) surface or groundwater withdrawals to stream discharge, 2) surface or groundwater withdrawals to public owned treatment facility (POTW) discharge, and 3) purchased water to stream or POTW discharge. The following graphic (Figure 2-31)is meant to serve as an example of the limitations of the data collected from LQUs and why a site specific approach needs to be considered. To get a picture of water that is transferred as a result of withdrawals from surface and groundwater vs. discharges to streams (Stream_DRP) or POTWs (POTW_DRP) refer to the blue circle set. Approximately 12 billion gallons are withdrawn annually from the Elk Watershed by 13 facilities. Of that water, approximately 18.7 million gallons are reportedly transferred out of the Elk by the operations of two facilities. One facility reportedly discharges 190 million gallons into the Gauley Watershed via stream discharges while the second facility discharges 8.5 million gallons into the Cheat Watershed via

POTW discharges. The larger amount being discharged into the Gauley Watershed by one facility than what was withdrawn by two indicates that there are more factors at play that are not clearly defined by the reported amounts alone. This situation is further compounded when considering purchased water transfers as is depicted by the orange circles. The complete list of detailed explanations regarding the reported LQU withdrawal amount and source, as well as the discharge locations and amounts that result in interbasin transfers throughout the state can be seen in Appendix L.

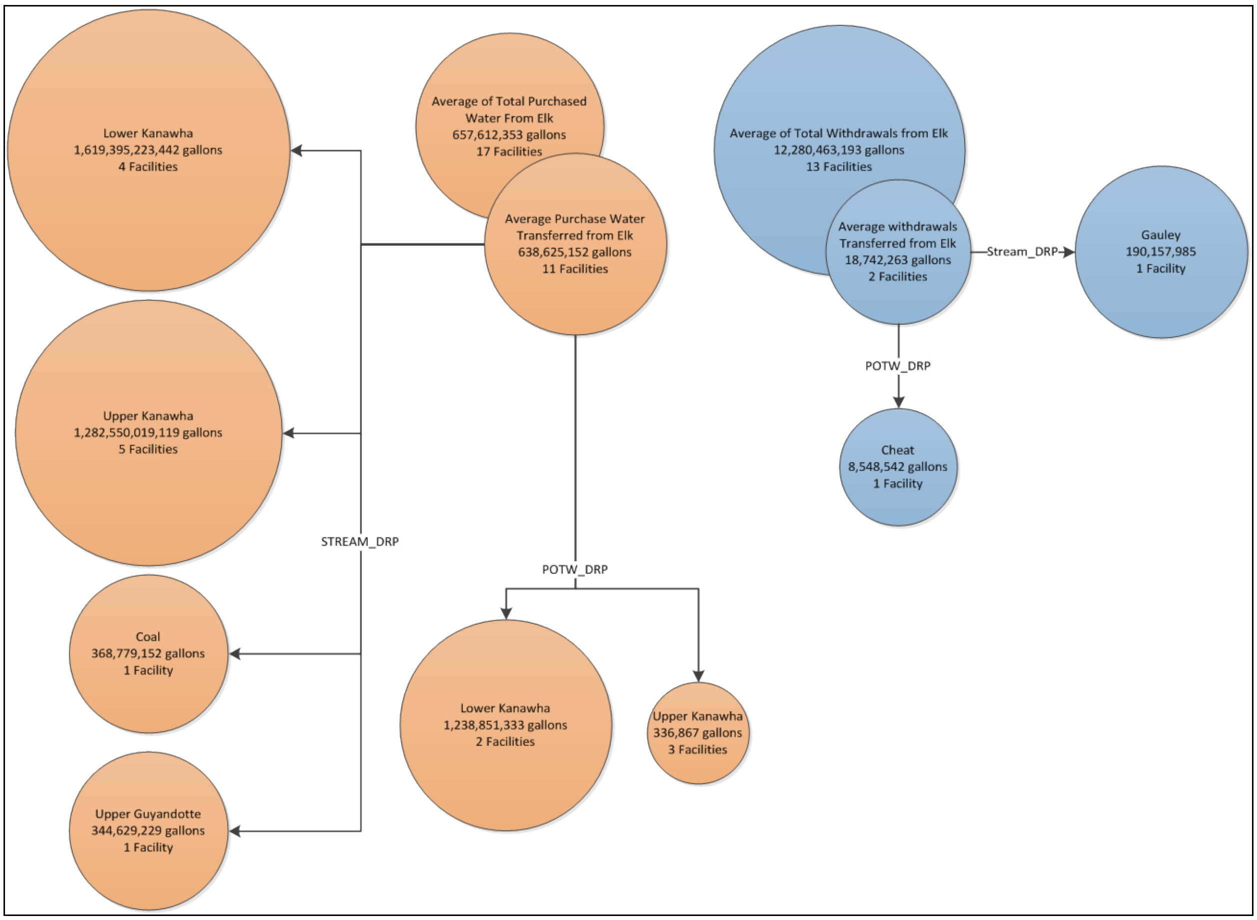



**Figure 2-31 Activity in the Elk River Watershed resulting in water transfers to other watersheds (interbasin transfers). The sizes of the balloons represent the proportions of water and serve to illustrate the difficulty in understanding the actual occurrence and resulting impact of interbasin transfers.**

### 2.2.7 Consumptive Use

Estimating the amount of water consumed is an essential component of a water resources plan for West Virginia. As per the Act, consumptive use is defined as any withdrawal of water that returns less water to the water body than is withdrawn. Water managers need to know how much water is removed from the water system to evaluate the potential impact on downstream users and the environment. As an example, in 2011 approximately 6% of the total water withdrawn in West Virginia was considered to be consumptive. A detailed explanation of the methods of calculation as well as a discussion of limitations is available as part of the future consumptive use projections presented in Chapter - 4. High and low scenarios of consumptive use were developed from LQU withdrawal data and use coefficients from the 2007 Shaffer and Runkle study for past withdrawals in order to make future projections. Past consumptive use by watershed is discussed here, while consumptive use on the county level is available in the Chapter 4 Appendices P-T.

In order to make past consumptive use estimates, as well as withdrawal and consumptive use projections for this analysis, water use categories had to be combined. Withdrawals and consumptive use were not projected for two of the LQU database water use categories. Both hydroelectric and aquaculture uses are considered to be non-consumptive. The reasons for this are explained in Chapter - 4. The categories used for consumptive use are:

- Mining and Petroleum (LQU database categories - Mining and Petroleum)
- Manufacturing (LQU database categories - Industrial, Chemical, and Timber)
- Public Water Supply
- Recreation
- Thermoelectric
- Marcellus Shale/Hydraulic Fracturing

Table 2-8 is an excerpt from the Chapter - 4 explanation of water use coefficients and was also used to calculate past consumptive use. The consumptive use estimate for each year (2003-2005, 2008-2011) was determined by multiplying each facility's estimated or recorded withdrawal by the corresponding consumptive use coefficient.

Table 2-8 Low and High scenario consumptive use rates for the recombined water use categories (Shaffer & Runkle, Consumptive Water-Use Coefficients for the Great Lakes Basin and Climatically Similar Areas, 2007).

| Water Use Category | Consumptive Use Rate (percent) | |
|---|---|---|
| | Low Scenario | High Scenario |
| Public Water Supply | 15 | 20 |
| Manufacturing | 10 | 13 |
| Thermoelectric | 2 | 4 |
| Recreation | 55 | 56.5 |
| Mining and Petroleum | 14 | 20 |
| Marcellus Shale/ Hydraulic Fracturing | 91 | 100 |

The results from creating the Mining and Petroleum and Manufacturing categories are shown in Chapter 4 tables and in Appendix P. The withdrawals by reorganized use types and the associated consumptive use high and low estimates are displayed in Figure 2-32 and Figure 2-33. The figures show that the Thermoelectric sector is the largest withdrawer of water, followed by the Manufacturing sector. Chapter 4 Appendices P-T summarizes estimates of past consumptive use in West Virginia using the coefficients discussed in this section and in greater detail in Chapter 4 (except for Marcellus Shale which is described entirely in Chapter 4).

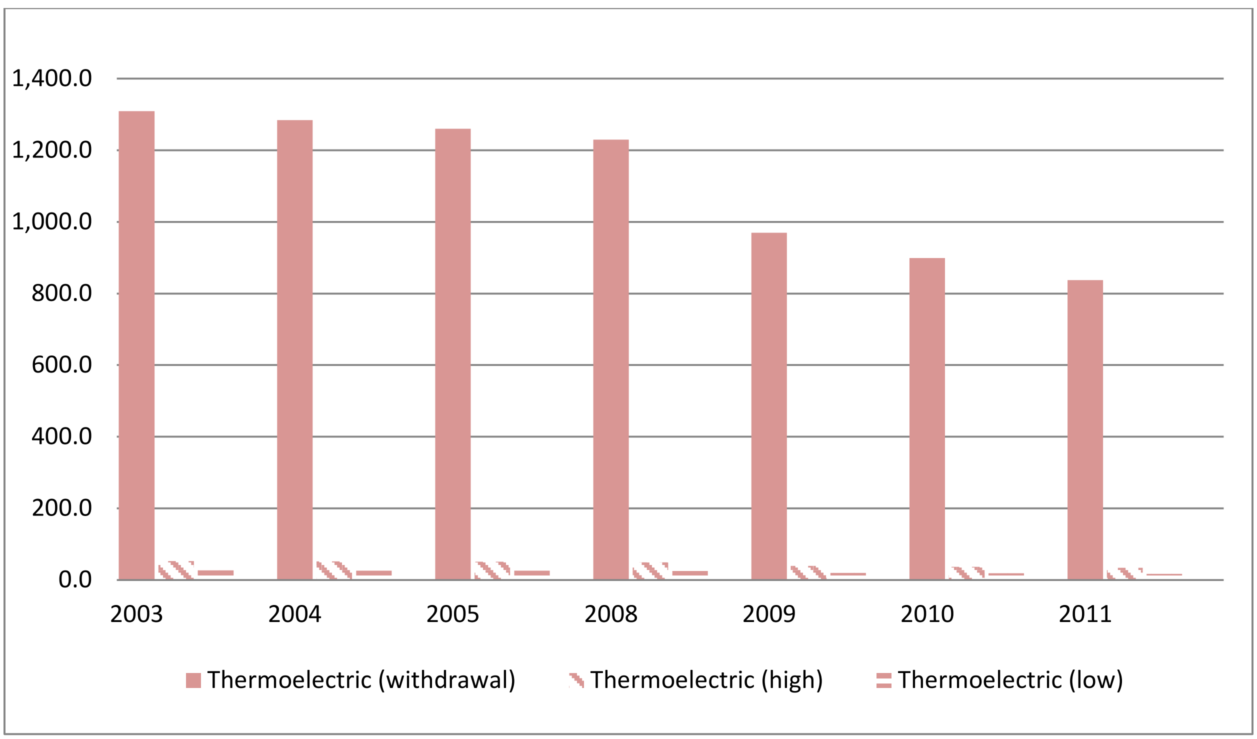



Figure 2-32 Annual withdrawals from the LQU database for the (amended) Thermoelectric* group as well as the high and low consumptive use estimates for those years (based on the Shaffer and Runkle consumptive use coefficients) in billions of gallons. *Shown separate due to scale.

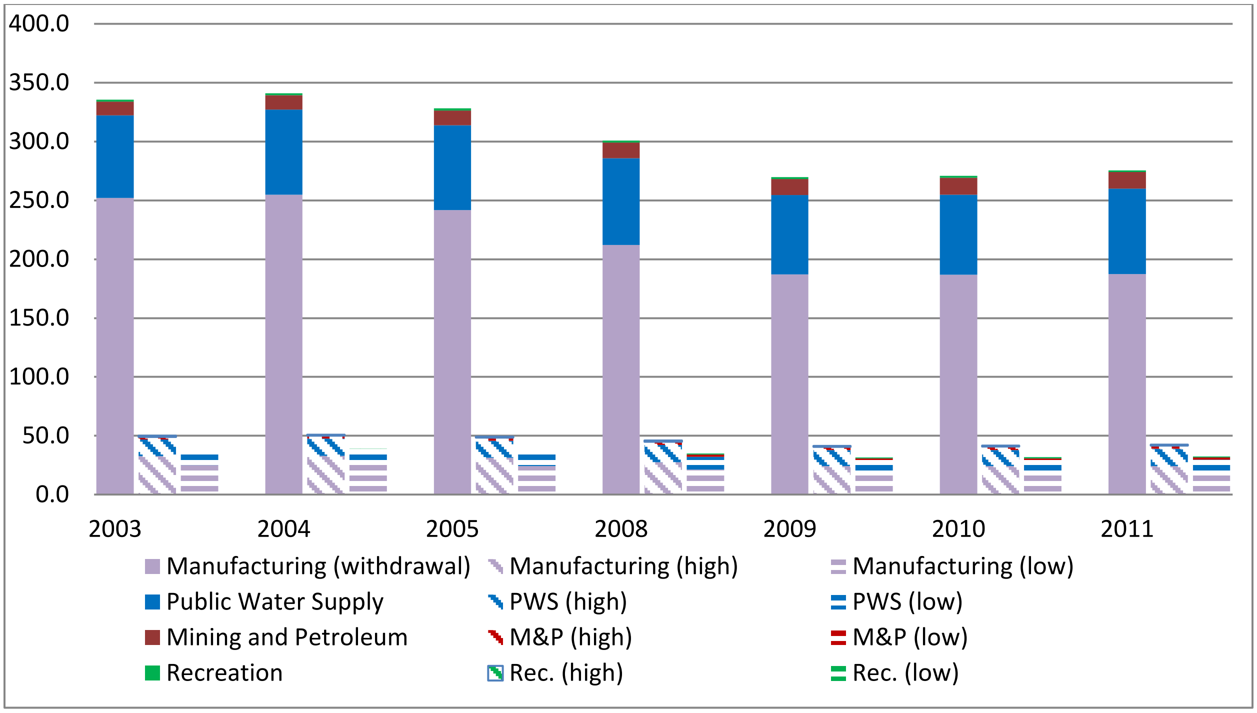



**Figure 2-33 Annual withdrawals from the LQU database for (amended) groups as well as the high and low consumptive use scenario calculations (based on the Shaffer and Runkle consumptive use coefficients) in billions of gallons.**

Furthermore, Figure 2-32 and Figure 2-33 indicate that the Thermoelectric and Manufacturing sectors consumptively use the most water. Total consumptive use is driven by large withdrawals in the Thermoelectric sector despite low consumptive use coefficients (Figure 2-32). However, it is important to note that the effects of installing scrubbers at thermoelectric plants in West Virginia on the consumptive use coefficient may require recalculation in the future (see Section 4.5 for more discussion). The Manufacturing sector has a high consumptive use rate that leads to high consumptive use totals even with the lower withdrawal totals.

> Approximately 6% of the total water withdrawn in West Virginia in 2011 was considered to be consumptive use.

Marcellus Shale withdrawals are not shown here because data was not collected over the same time period. For the Marcellus Shale use category, a low scenario consumptive use rate of 91 percent was calculated from the Frac Water Database. This rate was calculated as the average difference between the amount of water withdrawn and the amount of flowback water returned from a fractured well. For the high scenario, a consumptive use rate of 100 percent was used to reflect that the flowback water is essentially wastewater and is removed from the water cycle entirely. The calculated consumptive use coefficients, when applied to the 2011 Frac water withdrawal data, suggest that the total consumption of water statewide was between 840 and 923 million gallons. These data are grouped by watershed in Table 2-9.

**Table 2-9 Marcellus Shale withdrawals and consumptive use estimates by HUC. Data were provided by DEP outside of the LQU database.**

| HUC8 | Frac Water Withdrawals and estimated consumptive use (2011) (Mgal) | | |
|---|---|---|---|
| | Withdrawal | HIGH Consumptive | LOW Consumptive Use |
| Tygart Valley | 102.7 | 102.7 | 93.5 |
| West Fork | 150.9 | 150.9 | 137.3 |
| Monongahela | 60.4 | 60.4 | 55.0 |
| Cheat | 10.1 | 10.1 | 9.2 |
| Dunkard | 4.6 | 4.6 | 4.2 |
| Upper Ohio North | 28.4 | 28.4 | 25.8 |
| Upper Ohio South | 176.9 | 176.9 | 161.0 |
| Middle Ohio North | 263.5 | 263.5 | 239.8 |
| Little Kanawha | 121.3 | 121.3 | 110.4 |
| Elk | 3.8 | 3.8 | 3.5 |
| TOTAL | 922.6 | 922.6 | 839.7 |

### 2.2.8 Limitations and Improvements

While analyzing the information to prepare this chapter, several data and programmatic deficiencies were discovered. Several of the facilities did not accurately provide all requested information in the initial surveys. For example, some of the survey respondents provided latitude and longitude that mapped outside of the state. Some inaccurately calculated their water withdrawals. Compounding the problem of inaccurate water use calculations is the fact that many facilities do not meter their water intakes or discharges. Additionally, contact information became outdated during certification years, complicating data collection efforts. It became apparent that often the individual completing the survey was not familiar with the details of the facility's operation. Ensuring that qualified representatives complete the survey would improve data integrity. Given that the DEP must manually review and enter the reported data to assure the validity of the information prior to drawing conclusions, future surveys may be submitted electronically. Reporting actual use would minimize data-related problems and improve the accuracy of the Large Quantity User information. The Act currently requires the Large Quantity User to certify "…that the amount withdrawn in the previous calendar year varies by no more than 10% from the user's baseline average." This was initially intended to make it easier for the water users to report; however, in reality it has resulted in a potential 20% error in calculation of total statewide water use. This wide discrepancy complicates database calculations and results in less-than-desirable survey accuracy, which hampers the DEP's efforts to study, develop and protect the state's water resources. Revising the code (*See*, W. Va. Code § 22-26-3(d)) to eliminate the ±10% variance would increase survey accuracy.

Reporting actual use would minimize data-related problems and improve the accuracy of the Large Quantity User information.

In addition to having estimated withdrawals instead of metered withdrawals, complicated by insufficient discharge data, there is currently a limited understanding of the movement of water occurring post withdrawal at most facilities. In other words, the brief description provided by each LQU regarding the purpose and planned use for the water withdrawn does not afford an in depth understanding regarding uses by purchasers or potential transfers that may be occurring. Having this information would improve the understanding of consumptive use and interbasin transfers.

The DEP, with assistance from USGS, has attempted to identify all potential large water users. Going forward, a review of all public providers registered with the Public Service Commission (PSC) and the Department of Health and Human Services (DHHR), as well as businesses registered with the Secretary of State's office, to ensure all Large Quantity Users are compliant, plus tracking the percentages of water sold to the various categories of end users, will improve our understanding of use in the state and ability to interpret and use the data collected. Additionally, as suggested in several Legislative committee meetings, reducing the reporting threshold from 750,000 gallons/month to 300,000 gallons/month would increase the completeness of data related to the water being used and make West Virginia consistent with neighboring states' reporting thresholds. A study completed by CEGAS estimates 785 additional facilities and 2.4 billion gallons of water withdrawn annually would be captured if the reporting threshold were lowered. Lowering the threshold would aid in the planning for water resources management, oil and gas water management plans, better equip decision makers should drought-driven withdrawal or conservation restrictions become necessary and allow us to capture groups of smaller water users that are not currently required to register. Lowering the threshold to 300,000 gallons/month was recommended by the Legislative Auditors of the Performance Evaluation and Research Division in their report dated November, 2011 (PE-11-11-500). To accomplish this, a change to the definition of a Large Quantity User in the Act (§22-26-2) would be necessary. The CEGAS study is included in Appendix M. The following is a list from the CEGAS study of the facility types that would potentially report if the threshold is lowered.

- Golf Courses (Some or most may need to be reporting with current levels)
- Nursing homes/Retirement facilities
- Mobile home parks
- Public water supplies
- Farms (For Irrigation)
- Campgrounds
- Jails/Correction facilities
- Schools
- Resort hotels
- Parks
- Courthouses
- Cemeteries
- Nurseries
- Lumber facilities
- Chemical plants
- Paper plants
- Ammunition plants
- Concrete plants
- Pet food producers (from animal and food waste)
- Meat processors
- Industrial parks
- Furniture makers
- Highway Rest Stops

## 2.3 Estimating Domestic Use: Self-Supplied vs. Public Water Supply

There are several possible methods for estimating the amount of water withdrawn for domestic use. Generally, it would be possible to get an estimate of self-supplied water by calculating the amount of water withdrawn from the difference in the number of people served in the state by Large Quantity Users and the U.S. Census estimated total population using the 2005 USGS per capita rate in West Virginia (100.7 gal/capita/day). However, this does not account for the population that may be served by smaller public service districts or by those PSDs that purchase water while the per capita rate accounts for all estimated domestic use both delivered and self-supplied. Additionally, the U.S. Census estimates are limited to the accuracy of the most recent decennial census and current data collection efforts, while the USGS estimates are becoming dated. Instead, the DEP chose to work in concert with efforts underway by the West Virginia Water Development Authority (WDA) to calculate the population currently using well water by county.

The WDA used the SAMB dataset of digital structure images to estimate the percentage of unserved structures by overlaying the maps of known water lines. The percentage of unserved structures was then combined with the number of households estimated by the U.S. Census to calculate an estimated number of unserved households. The average household size was then applied to determine an estimated amount of water used by the unserved population. The DEP then used an adjusted per capita use rate to calculate the average water withdrawals from wells for self-supplied domestic use. The 2005 USGS per capita water use rate for West Virginia was determined to be 100.7 gallons/day, which was calculated from total domestic use that year and population estimates. However, for the determination of current self-supplied domestic use, a per capita rate of 90 gallons/day was chosen. This reduction is intended to account for recent changes in water use standards for new household appliances and new trends in voluntary reductions of water used at home since 2005. Although the use of this GIS data and methodology used is intended to account for some of the considerations for other estimations mentioned above, these estimates still have some caveats of their own:

- Structure data is from the SAMB dataset and includes all structures (homes, businesses, public buildings, barns, etc.) and is not coded to remove useless data.
- Served/Unserved estimates are based on a distance of 500’ from a known existing water line.
- Not all water lines have been provided to WDA and so estimates of unserved structures may run high.
- Does not account for business use, but businesses make up a smaller percentage of the rural areas that remain unserved.
- Does not consider possible agricultural use of water for livestock or irrigation.

**Table 2-10 Average annual amount of water supplied by Large Quantity Users to each county and estimated annual self-supplied amounts in gallons.**

| County | Public Supply | Self-Supply | County | Public Supply | Self - Supply |
|---|---|---|---|---|---|
| Barbour | 1,190,542,333 | 227,887,494 | Mineral | 0 | 434,157,403 |
| Berkeley | 3,904,895,047 | 2,834,254,604 | Mingo | 1,367,233,109 | 220,817,663 |
| Boone | 56,110,053 | 122,337,959 | Monongalia | 3,618,309,333 | 2,653,449,187 |
| Braxton | 371,706,673 | 286,369,498 | Monroe | 349,971,273 | 310,427,880 |
| Brooke | 1,987,124,587 | 192,066,451 | Morgan | 172,097,671 | 498,117,505 |
| Cabell | 4,849,095,171 | 118,965,512 | Nicholas | 1,007,428,307 | 486,081,998 |
| Calhoun | 117,677,133 | 192,853,515 | Ohio | 2,474,253,234 | 1,363,057,615 |
| Clay | 166,710,033 | 183,928,616 | Pendleton | 134,104,382 | 206,834,468 |
| Doddridge | 56,309,000 | 234,049,811 | Pleasants | 287,180,125 | 219,645,737 |
| Fayette | 1,979,400,088 | 432,354,389 | Pocahontas | 167,104,362 | 218,883,925 |
| Gilmer | 224,960,667 | 139,922,360 | Preston | 636,277,528 | 715,070,769 |
| Grant | 373,592,104 | 217,871,221 | Putnam | 829,426,333 | 278,186,841 |
| Greenbrier | 1,106,452,303 | 753,606,914 | Raleigh | 3,394,446,353 | 723,996,949 |
| Hampshire | 209,725,520 | 638,751,292 | Randolph | 1,187,713,292 | 503,180,670 |
| Hancock | 325,213,200 | 262,319,828 | Ritchie | 0 | 246,223,222 |
| Hardy | 1,350,741,254 | 347,989,241 | Roane | 265,644,353 | 295,503,246 |
| Harrison | 2,647,853,667 | 597,485,978 | Summers | 1,012,213,653 | 296,266,481 |
| Jackson | 652,080,137 | 456,579,374 | Taylor | 0 | 175,819,704 |
| Jefferson | 1,005,820,950 | 1,115,326,374 | Tucker | 263,953,622 | 177,671,540 |
| Kanawha | 12,286,973,515 | 151,027,044 | Tyler | 173,505,085 | 195,823,443 |
| Lewis | 431,777,333 | 233,916,107 | Upshur | 781,452,937 | 252,111,780 |
| Lincoln | 127,566,000 | 400,063,453 | Wayne | 1,186,825,438 | 119,896,814 |
| Logan | 1,396,126,951 | 287,177,976 | Webster | 118,313,467 | 208,460,660 |
| Marion | 3,081,451,235 | 614,207,130 | Wetzel | 665,097,895 | 260,473,178 |
| Marshall | 1,144,502,950 | 400,657,100 | Wirt | 0 | 110,462,286 |
| Mason | 1,190,148,820 | 864,418,788 | Wood | 4,436,548,840 | 501,259,959 |
| McDowell | 1,139,975,298 | 308,411,733 | Wyoming | 556,224,115 | 385,864,278 |
| Mercer | 1,542,097,312 | 748,642,822 | **TOTAL** | 70,001,954,044 | 25,421,187,783 |

Berkeley, Jefferson, Monongalia, and Ohio counties were estimated to withdrawal the greatest amount of water for self-supplied use. Kanawha, Cabell and Wood counties reported having the largest withdrawals by Large Quantity Users for the public water supply. County totals for total public water supply and for total gallons withdrawn for self-supply are available in Table 2-10. The same information is displayed in Figure 2-34. The pie charts represent proportional breakdowns of the total amount of surface and groundwater provided by LQUs and the total amount of water withdrawn by the unserved population for self-supply.

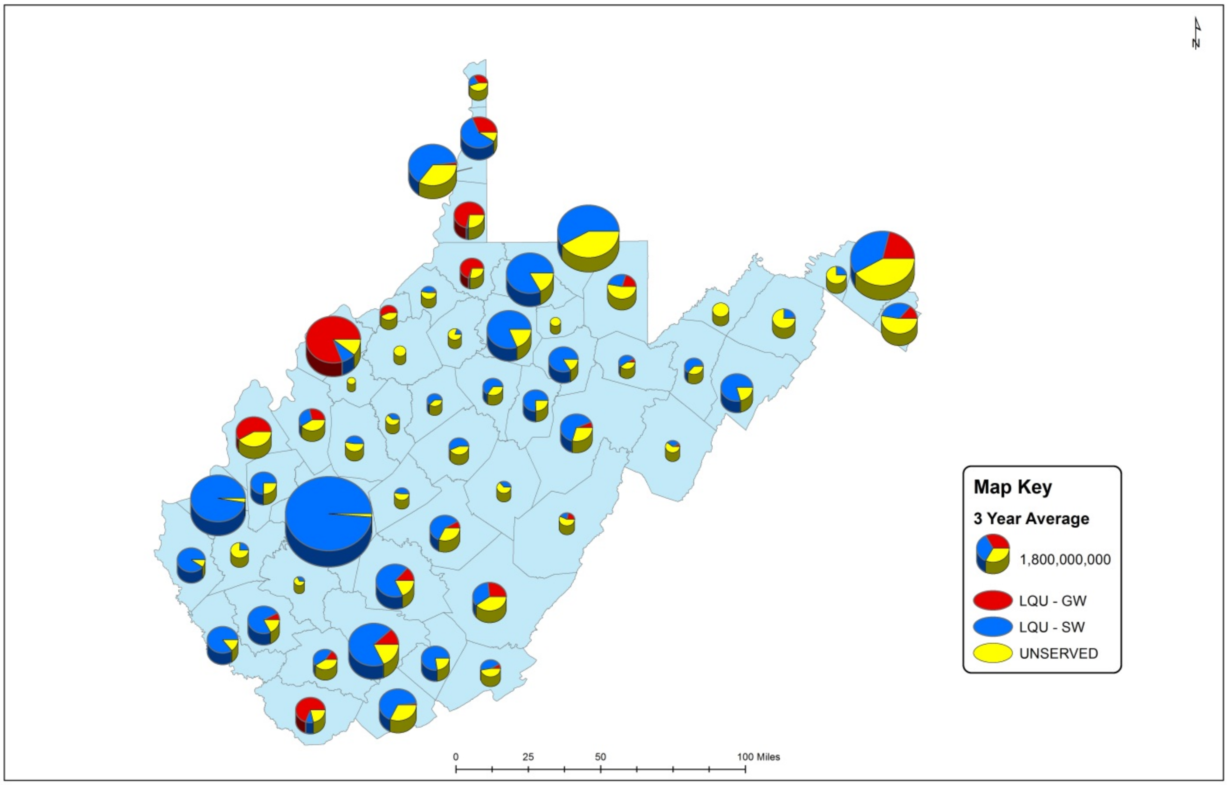



**Figure 2-34 Distribution of average annual gallons of water withdrawn by LQUs in each county from groundwater and surface water sources for public supply and the estimated amount withdrawn by the unserved population for domestic use.**

## 2.4 Estimating Agricultural Use

The United States Geological Survey has estimated the water used in the United States every five years since 1950, taking into consideration both the source and category of use (Kenny, et al., 2009). The results of its 2005 estimates are the most recent data available. Due to restrictions in the law, data from individual farms may not be reported. Data was aggregated by county for various types of livestock and poultry. Water use related to livestock includes meeting the operation requirements and the watering and feedlot needs of cows, cattle, sheep, goats, hogs, horses and poultry. Very little water is used for irrigation by farmers in the state, so that statistic is not collected. All of the water use reported is for livestock and poultry. Appendix N lists 2005 agricultural water consumption by county. Figure 2-35 displays the same information on a state county map.

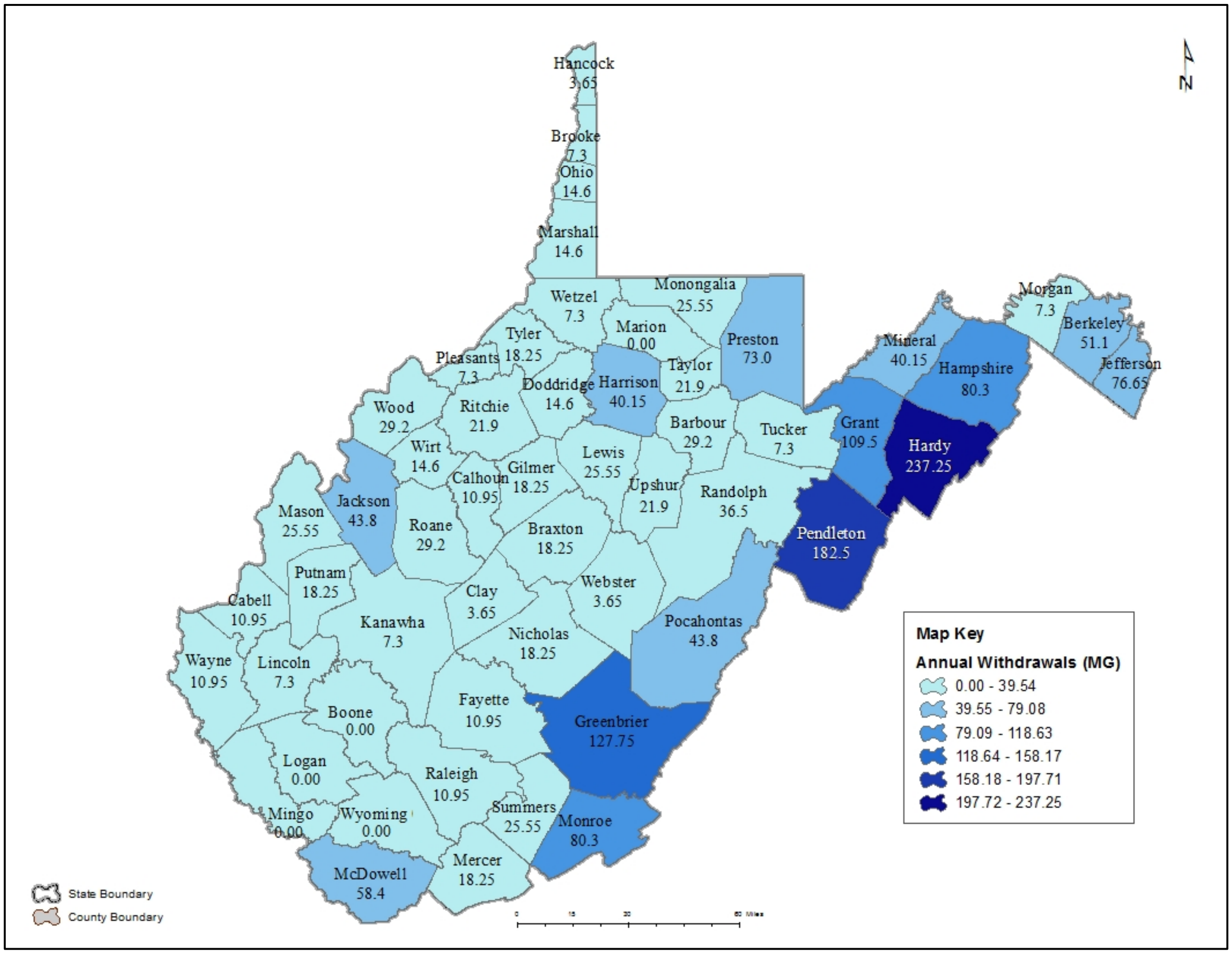



Figure 2-35 USGS Estimates of 2005 agriculture withdrawals for livestock and poultry.

As provided, the agricultural data cannot be used for detailed water use assessment and evaluation. For example, the total withdrawal estimates for 2005 is equal to about one third of the average water reported by LQUs for agriculture/aquaculture use, which is calculated from the most recent three years of data (see Table 2-1). Additionally, there is no location data for the withdrawals. The water could be from one stream, several streams, or multiple wells at multiple depths. Without this information, it is impossible to evaluate the data for competing sources, conditions that exacerbate flooding and drought, or any other comparative statistic. To develop a water management program that reflects the range of competing uses, everyone must work together to devise a program that will provide the water use data needed, while maintaining the confidentiality of agricultural information. Evaluating counties with agricultural output on a regional scale will provide the greater detail needed to manage the resource for the benefit of all.

## 2.5 Marcellus Shale water use

Prior to 2009, the term “Marcellus Shale” was virtually unknown in regard to water resources management in West Virginia. Today, oil and gas exploration in the state has dramatically increased due to technological advances in directional drilling and hydraulic fracturing. These approaches allow unprecedented access to gas-rich geologic formations, specifically the Devonian-age and older shale, which underlie the majority of the Appalachian Basin from New York to West Virginia. As shown in Figure 2-36, the Marcellus formation, a Devonian-age shale, extends throughout West Virginia at depths typically ranging from 3,000-9,000 feet below the surface before ultimately outcropping in the Eastern Panhandle. The thickness of the shale varies from 0 – 250 feet. These factors contribute to the overall economic feasibility of gas exploration across the state and have directly led to highly regionalized growth. To date, in West Virginia, horizontal drilling and hydraulic fracturing techniques have been primarily centered in northwestern and central counties.

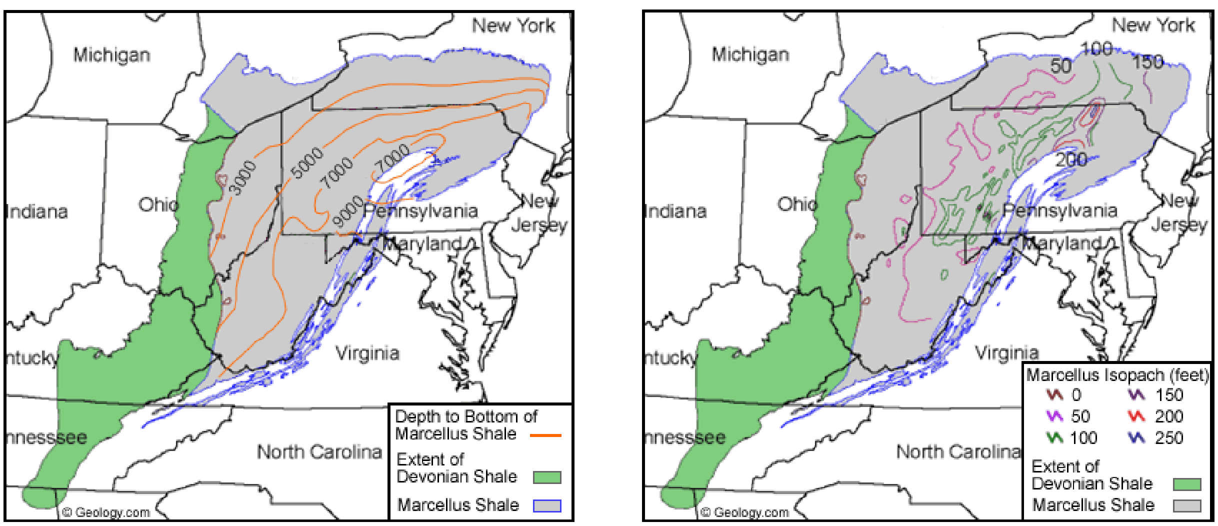



**Figure 2-36 Extent, depth and thickness of Marcellus Shale in West Virginia**

The combined techniques of horizontal drilling and hydraulic fracturing, generalized in Figure 2-37 below, illustrate the procedures utilized to extract oil and/or gas from formations such as the Marcellus Shale. These techniques involve precise drilling of a gradually-angled turn to transition from a vertical to a horizontal well bore, thus allowing for greater access to a geologic formation known to contain oil and/or gas reserves. Once the well bore is drilled, cased and cemented, it is perforated and hydraulically fractured. Perforation is done by inserting a perforation "gun" into the well bore, which detonates charges along various segments or "stages," creating dendritic fissures into the formation. After fracturing, a chemically-enhanced water and sand mixture is pumped into the well under high pressure creating a greater network of fissures. Sand is used as a proppant to keep these tiny fissures open and allow the desired gas to flow out of the well. After all stages of perforation and hydraulic fracturing are complete, a portion of the water used, "frac water," is returned to the surface. This waste water is then stored until disposal or re-use. Ultimately, the gas that has been accessed by this process flows out of the well and is sold.

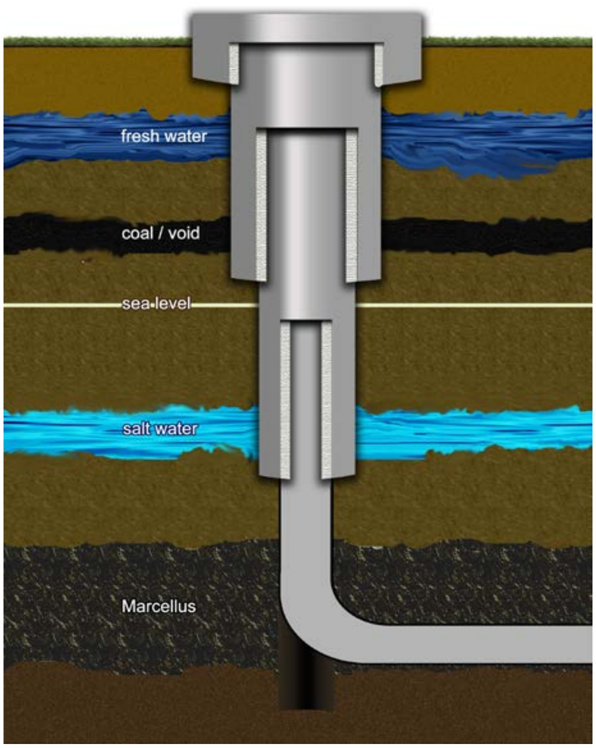



**Figure 2-37 Generalized horizontal drilling**

### 2.5.1 Environmental Impacts

With the economic benefits of a resurgent oil and gas industry come potential environmental impacts, especially with respect to water use, if not properly managed. Based on data reported to DEP, these methods currently require approximately five million gallons of water per well. As Marcellus Shale exploration expanded into West Virginia, public concern over such large scale water withdrawals led to the creation of the DEP's *Water Withdrawal Guidance Tool*, published in November 2009. While not regulatory in nature, this tool was designed to provide withdrawal guidance to the oil and gas industry, as well as the public, based on real-time flow information. By dividing the state into regions of similar climatology (referred to as "polygons") which reference the existing USGS Stream Gaging Station network, current local flow conditions could be compared against chosen baseline stream statistics, thus allowing a determination to be made regarding the suitability of water withdrawals. Within each polygon, the user would receive one of three messages depending on the current conditions of the assigned reference gage. If real-time stream flow exceeded 40% of the 10 year average annual flow, the user would be advised that conditions anywhere in that region would likely be adequate for withdrawals. If the current conditions were less than 10% of the 10 year average annual flow, the user would be alerted that withdrawals were inadvisable. Between the two thresholds, the user would be advised to only withdrawal from a select group of pre-defined streams/rivers within that polygon.

Despite the fact that the Water Withdrawal Guidance Tool was never intended to be a regulatory device, it found widespread usage among the oil and gas industry and public. The WWT should be known and used as suggested by the Legislative Auditors of the Performance Evaluation and Research Division in their report dated November, 2011 (PE-11-11-500) but should not be made mandatory without further development and legislative approval. Since the initial publication, the tool has been revised several times. New polygons have been added. Some polygons were additionally referenced to a secondary gage to provide better accuracy when considering regions influenced by multiple stream classes. This tool is still in service, but has evolved to be primarily a tool for public use because the Horizontal Well Control Act enabled DEP to create specific flow requirements, which must be monitored using the USGS Stream Gaging network. The most recent change to the tool was to update the flow statistic used to determine the minimum flow requirements. After the passage of the Horizontal Well Control Act, which will be discussed later in Section 2.5.5, the tool needed a major update to bring the flow threshold minimums in line with those used to determine pass-by flow requirements.

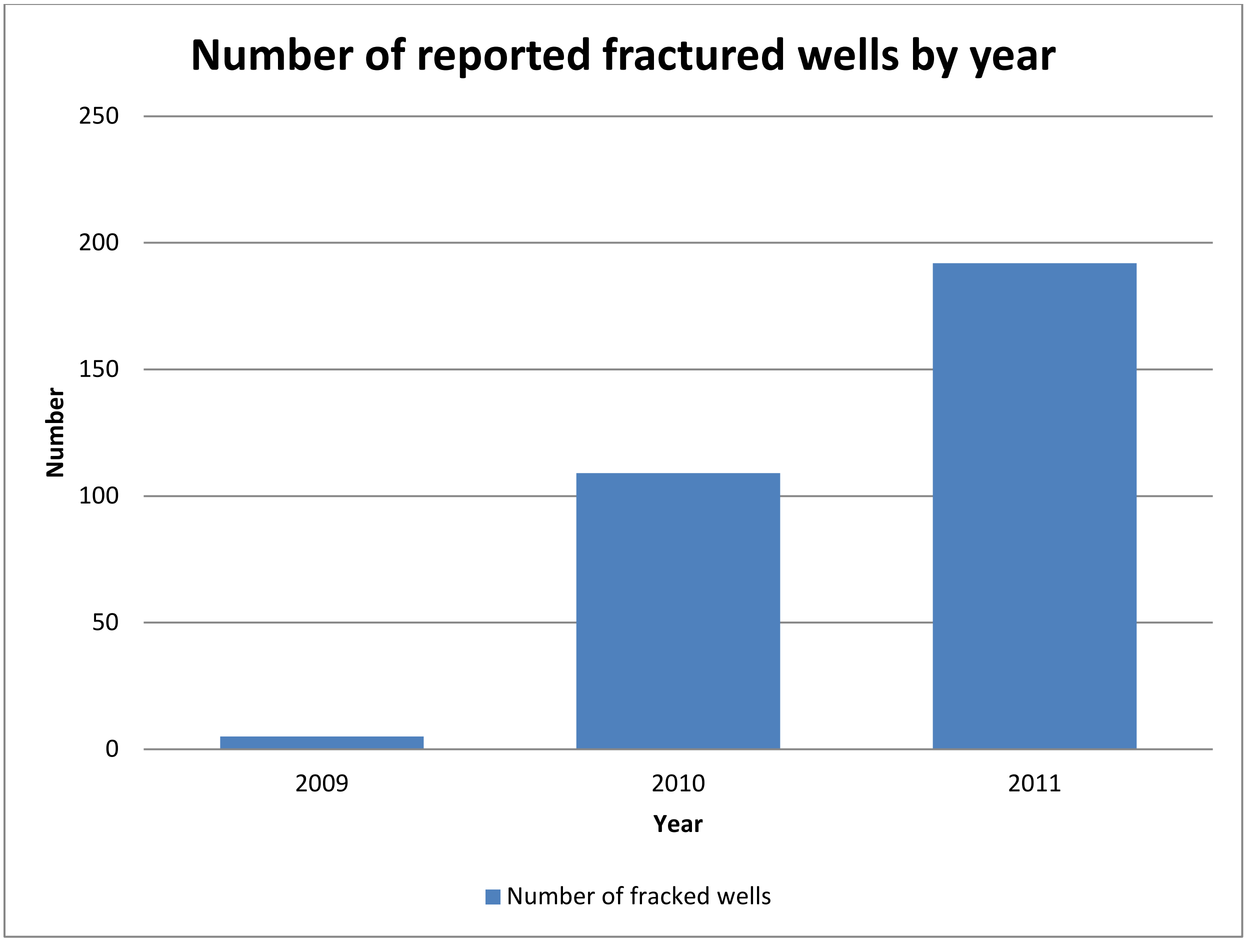
With expansion of Marcellus drilling a large increase in withdrawals via pumping trucks has occurred in the last five years. To protect the resource, DEP has developed water management plans associated with the oil and gas permit and the water withdraw guidance tool. Despite these processes, DEP has found that communication of withdraw concerns do not always filter down to the actual truck driver conducting the withdrawal. Further individuals withdrawing water not affiliated with drilling activities may have limited or no knowledge of recommended minimum stream flow values, the guidance tool or measures that may be taken to eliminate invasive species transfer. For example, drivers affiliated with construction companies, hydro-seeders, and hydrostatic pipeline testers withdraw waters from streams without oversight or training. To improve protection of the resource the DEP, in cooperation with the Division of Natural Resources and other appropriate agencies, intends to develop a guidance document describing the appropriate procedures for protection against spread of invasive species and other best management practices relative to water withdrawals.

### 2.5.2 Water Use

The nature of hydraulic fracturing requires large quantities of water, which means that in most cases, oil and gas operators will qualify as Large Quantity Users. However, water acquisition for well work related to horizontal drilling doesn't lend itself to the annual certification that other industries are required to complete. Water use for a singular well is a one-time need, which ends once the well is placed into production. If each well were treated as a facility in the traditional sense, none would be operational long enough to calculate baseline annual water use. As a solution to this dilemma, the DEP published its *Frac Water Reporting Tool.* This web-based interface allows operators to enter water source and disposal data on a per-well basis, without being required to file an annual certification. An operator must enter water source and disposal data for each well no later than one year after well completion. Required data include: withdrawal source location, total volume, and date; injection and recovery volumes and dates; and disposal locations and dates.

Since 2009, DEP has been collecting water use data associated with horizontal drilling activities, as summarized below. It should be noted, however, that there have been substantial barriers to the data collection process. The greatest challenge in ensuring that reporting requirements have been met has been identifying wells that used enough water to qualify as Large Quantity Users. Until the Horizontal Well Control Act was passed in December 2011, newly issued horizontal well permits were not identified as such by the Office of Oil and Gas. Moreover, each issued permit has a shelf-life of two years before expiration. Due to the one-year window to report water use through the *Frac Water Reporting Tool*, there may be up to a three-year time span from permit issuance to water use reporting. For example, a well work permit for a horizontal well issued in 2010 could be drilled in 2012, and not be required to report water use until 2013. Despite these challenges, DEP has collected water withdrawal and disposal data for 306 horizontal wells hydraulically fractured between 2009 and 2011. Table 2-11 shows that in 2009, just five wells were reported to have been fractured. That number grew to 109 in 2010 and 192 in 2011. Reporting for wells fractured in 2012 is ongoing, and should be complete by December 31, 2013.

Table 2-11  Number of reported fractured wells per year




The following annual data are presented for the years 2009, 2010 and 2011. As shown in Table 2-12, the amount of water used in association with hydraulic fracturing has significantly increased since 2009. While the total water demand has increased with the number of wells, the per-well water demand has decreased from approximately 11.4 million gallons per well in 2009 to 5.3 million gallons per well in 2011. This decrease in per-well demand is likely a result of an increase in efficiency in operations.

Table 2-12 Statewide annual reported water withdrawals for horizontal wells (2009, 2010 and 2011) by source type in gallons

| Source Type | | | | | | |
|---|---|---|---|---|---|---|
| Year | Commercial Broker | Ground-water | Lake/Pond/ Reservoir | Recycled Frac Water | Stream/River | Grand Total |
| 2009 | -- | -- | 1,680,000 | 10,961,457 | 44,347,507 | 56,988,964 |
| 2010 | 103,952,562 | -- | 11,965,142 | 35,052,994 | 464,786,339 | 615,757,037 |
| 2011 | 241,087,495 | 1,083,744 | 78,537,376 | 88,003,933 | 602,074,528 | 1,010,787,076 |
| **Grand Total** | **345,040,057** | **1,083,744** | **92,182,518** | **134,018,384** | **1,111,208,374** | **1,683,533,077** |

In the data years reported to the WVDEP, operators have utilized various types of water sources which are defined below:

- *Commercial broker* – water purchased from a vendor explicitly for use by oil and gas operators for activities related to horizontal wells. This water is typically sold by public utilities or industries with the existing infrastructure necessary to withdrawal quantities of water suitable for horizontal well development. Commercial brokers are generally already registered Large Quantity Users who report water use through the annual certification process
- *Groundwater* – water supply wells used in support of horizontal well development
- *Lake/Pond/Reservoir* – impounded water. May be publicly or privately owned.
- *Stream/River* – free flowing water
- *Recycled frac water* – water resulting from the fracturing of a previously drilled well

As shown in Figure 2-38, the primary water source utilized by the oil and gas industry is streams/rivers. Annually, these sources account for about 65% of total water use for activities related to horizontal drilling. The majority of the remaining water is purchased from a commercial supplier (20%). Pre-treated water is often the preferred choice for cementing and well-casing programs because it reduces the potential for the introduction water-borne bacteria which may compromise the integrity of the well casing over time. Lakes, reservoirs, and pond water represent about 5% of sourced water. Often these sources are privately owned farm ponds not considered to be state waters. Less than 1% of the water used from 2009-2011 for horizontal well activities has originated as groundwater. The remainder of the reported water use, approximately 10%, is recycled frac water.

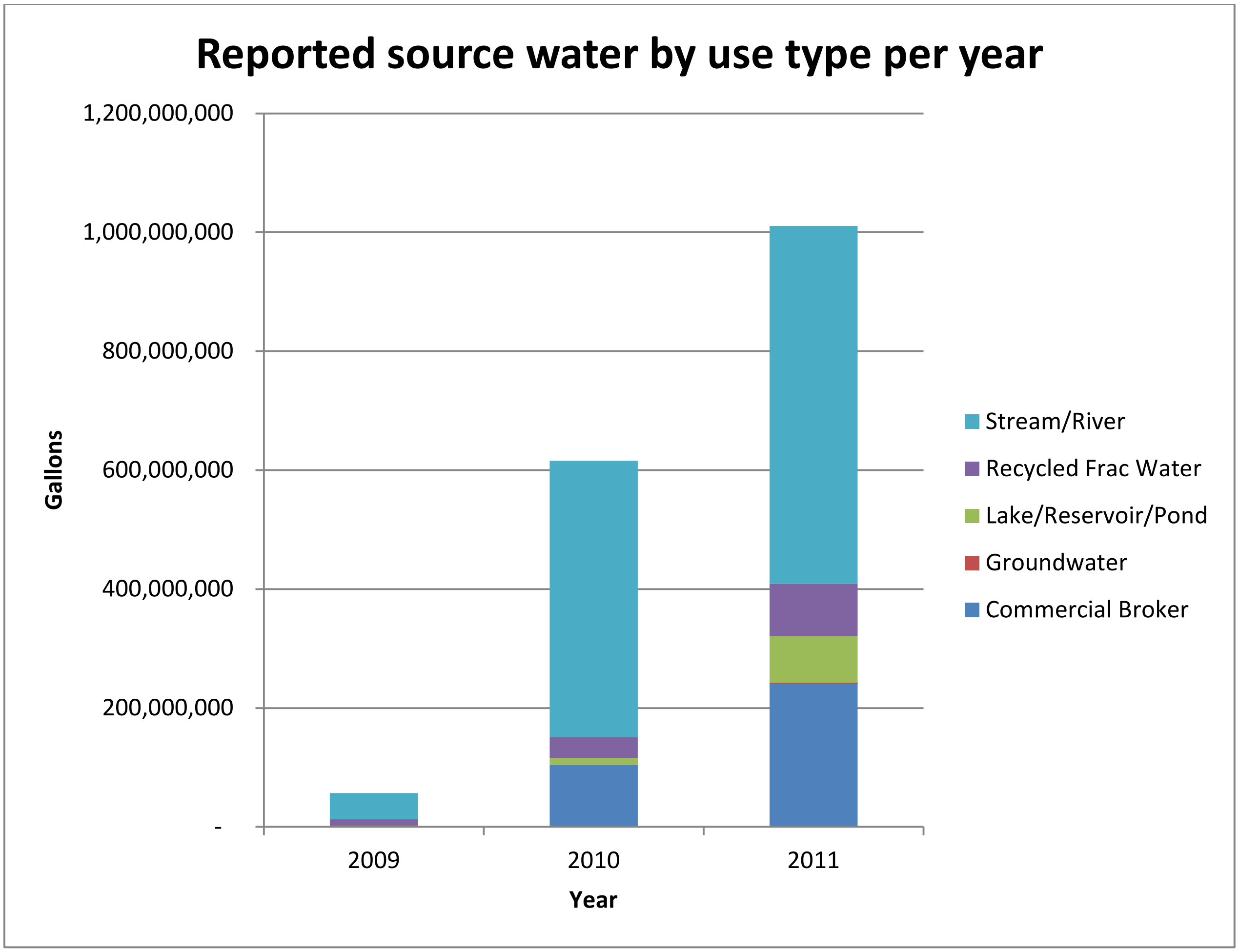



**Figure 2-38 Reported horizontal drilling source water by type per year in gallons**

As detailed in Table 2-13, nearly half (49.6%) of the water used for horizontal well development and exploration in West Virginia is withdrawn from the Middle Ohio North and Upper Ohio South watersheds. The West Fork and Tygart Valley watersheds supply an additional 30.9% of frac-related water. That these regions together provide approximately 80% of all reported water used for hydraulic fracturing is not surprising, given the location of these watersheds in relation to the areas most involved in Marcellus Shale development. Water withdrawals for hydraulic fracturing related activities are described in Appendix O.

Table 2-13 Water use for horizontal drilling activities by watershed in gallons

| | Year | | | |
|---|---|---|---|---|
| **Watershed** | **2009** | **2010** | **2011** | **Grand Total** |
| Cheat | | 12,959,856 | 10,164,840 | 23,124,696 |
| Dunkard | | | 3,038,634 | 3,038,634 |
| Dunkard (PA) | | | 1,576,700 | 1,576,700 |
| Elk | | | 3,780,000 | 3,780,000 |
| Little Kanawha | | 56,461,094 | 121,339,875 | 177,800,969 |
| Middle Ohio North | | 151,609,193 | 263,549,243 | 415,158,436 |
| Middle Ohio North (OH) | | 2,103,192 | | 2,103,192 |
| Monongahela | | | 60,411,110 | 60,411,110 |
| Tygart Valley | 3,273,606 | 108,820,988 | 102,655,760 | 214,750,354 |
| Upper Ohio North (PA) | | | 28,419,128 | 28,419,128 |
| Upper Ohio South | 34,755,546 | 141,948,872 | 176,902,790 | 353,607,208 |
| West Fork | 7,998,355 | 106,800,848 | 150,945,063 | 265,744,266 |
| **Grand Total** | **46,027,507** | **580,704,043** | **922,783,143** | **1,549,514,693** |

Given the nomadic and relatively short-term nature of water withdrawals for the horizontal gas industry and the lengthy reporting window after the completion of operations, the DEP believes it would be easier for both the industry and the agency if water use associated with horizontal drilling was reported within 90 days of well completion activities. This 90-day reporting requirement would improve and ensure data integrity.

### 2.5.3 Out-of-state transfers

One unanticipated effect of the Marcellus Shale industry is out-of-state transfer, or water withdrawn in West Virginia for use in out-of-state drilling operations. While it is true that any person withdrawing water surpassing the LQU reporting threshold for any reason is required to report their water use data, identification of such users is increasingly difficult where the withdrawals are nomadic and the water is transferred across state lines. That said, approximately 704 million gallons of water originating in West Virginia have been reported for use in support of wells in Pennsylvania since 2010 (Table 2-14). All of this reported water originated from the Upper Ohio South Watershed. It is difficult to estimate the actual volume used.

**Table 2-14 Transfer of water for hydraulic fracturing to neighboring states**

| | Year | | |
|---|---|---|---|
| **Watershed** | **2010** | **2011** | **Grand Total** |
| Upper Ohio South | 562,684,474 | 141,315,048 | 703,999,522 |
| **Grand Total** | **562,684,474** | **141,315,048** | **703,999,522** |

Similarly, water originating from Ohio and Pennsylvania has been used to support West Virginia horizontal well work operations. 2.1 million gallons of water were transferred from Ohio for use in West Virginia wells in 2010. All of this water originated in the Middle Ohio North Watershed. In 2011, approximately three million gallons of water from Pennsylvania areas within the Monongahela Watershed and 54 million gallons from the Upper Ohio North Watershed were used in West Virginia (Figure 2-14).

Table 2-15 Transfer of water for hydraulic fracturing from neighboring states to West Virginia

| | Year | | |
|---|---|---|---|
| **Watershed** | **2010** | **2011** | **Grand Total** |
| Middle Ohio North (OH) | 2,103,192 | | 2,103,192 |
| Dunkard (PA) | | 3,153,400 | 3,153,400 |
| Upper Ohio North (PA) | | 54,493,446 | 54,493,446 |
| **Grand Total** | **2,103,192** | **57,646,846** | **59,750,038** |

With the passage of the Horizontal Well Control Act, which will be discussed later in Section 2.5.5, DEP established an informal agreement with the Pennsylvania Department of Environmental Protection to require operators to seek agency approval from the neighboring state if water from that state will be transported across state lines. Going forward, DEP may find it necessary to solidify this agreement with a formal memorandum of understanding between West Virginia and all the neighboring states. Such an agreement would allow for a greater understanding of the impacts of horizontal drilling and hydraulic fracturing and prevent water being transported out of state without regulatory oversight. Alternatively, the Legislature could consider altering the Horizontal Well Act to specify any water withdrawn from West Virginia and used in another state for hydro-fracturing must acquire and adhere to a West Virginia Water Management Plan. Currently, only wells with a West Virginia permit are required to have an enforceable Water Management Plan.

### 2.5.4 Waste Disposal

The use of recycled frac water as source water for future wells is routine among oil and gas operators in the state. The data shows that approximately 75% of frac water is reused in future wells (Figure 2-39). Although not currently active, two frac wastewater treatment facilities are being developed. Until these facilities are approved for treatment and/or discharge, the most feasible options for disposal of these wastes are reuse in future wells or disposal in an underground injection control (UIC) well. UIC well disposal currently represents about 25% of frac water disposition. It is important to note that West Virginia does not permit land application of waste water originating from hydraulic fracturing activities.

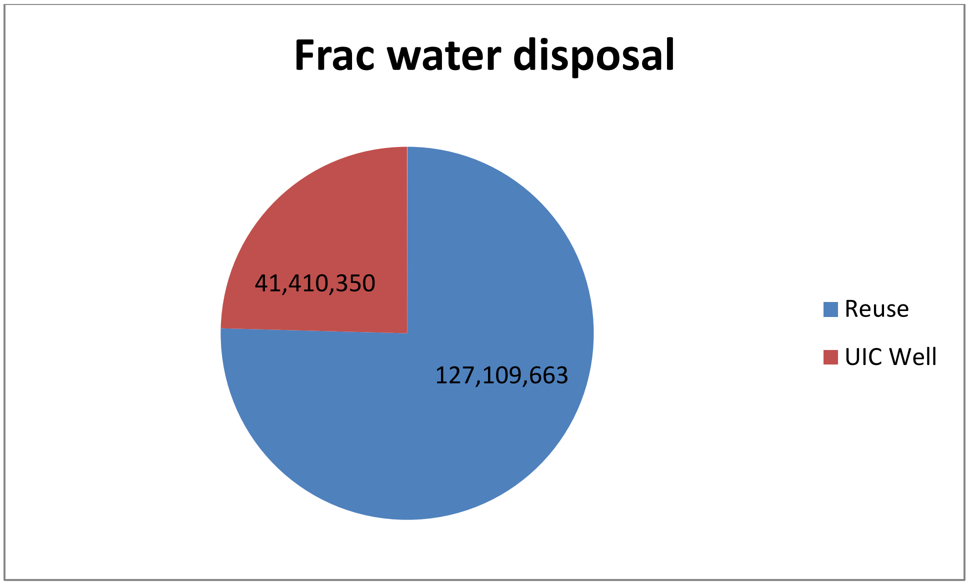



Figure 2-39  Frac water disposal data.

### 2.5.5 Horizontal Well Control Act

In December 2011, West Virginia passed the Horizontal Well Control Act, §22-6A, which established requirements for the creation of Water Management Plans for any well using more than 210,000 gallons in any one month period. The water management plan must identify the type of water source, such as surface or groundwater, the location of each source to be used, the anticipated volume and date range for each water withdrawal. Additionally, current and existing water uses must be identified. This includes any public water intakes within one mile downstream of the withdrawal location.

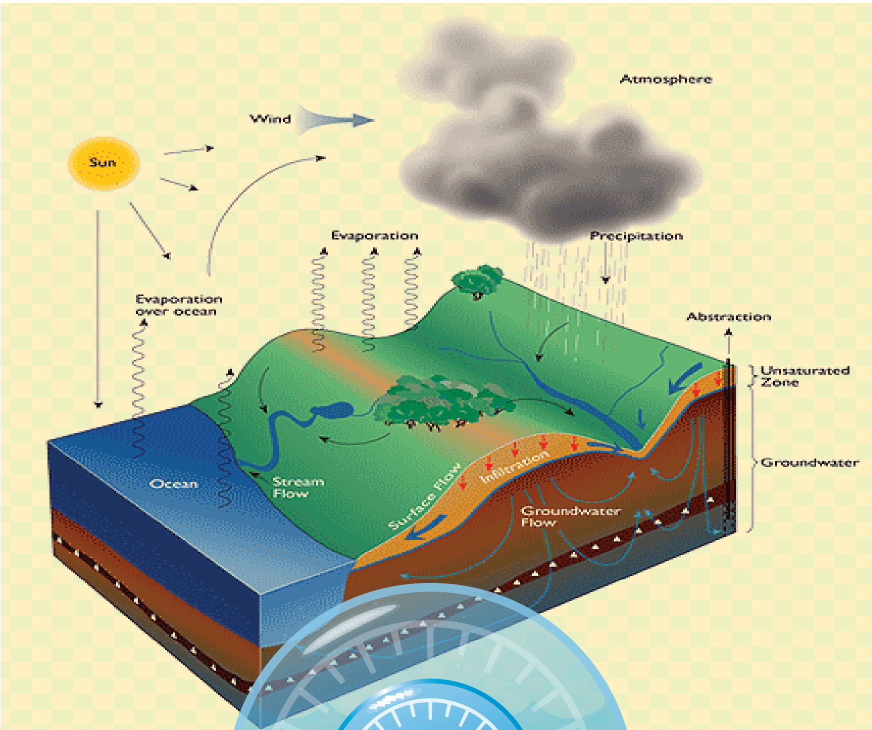
In addition to identifying all potential water sources, the operator must demonstrate that adequate in-stream flow shall be available immediately downstream of the intake while it is in use. The DEP's preferred method of ensuring adequate downstream flow is adherence to the following minimum flow criteria:

A) Minimum flow at a specified USGS Stream Gaging Station
B) Minimum flow at the withdrawal site

The latter ensures that the local environment has a minimum quantity of water necessary to support aquatic life, while the former ensures that the watershed as a whole can adequately support life as well.

In order to determine withdrawal limits, DEP has adopted the "base-flow" approach. During normal-flow conditions, stream flow can be separated into discharge from overland runoff (e.g., precipitation) and discharge from groundwater aquifers by use of hydrographic separation modeling. The portion of stream flow originating from the groundwater is the base-flow. When overland runoff decreases during low-flow conditions, most or all of the flow within the stream may be considered base-flow. As aquatic life has adapted to these low-flow conditions, typically observed in summer, water withdrawals below the base-flow threshold would be deemed detrimental to aquatic life.

In cooperation with the DEP, the U.S. Geological Survey undertook a study to quantify the base-flow threshold and relate it to calculated stream flow statistics (Wiley, Comparison of Base Flows to Selected Streamflow Statistics Representative of 1930-2002 in West Virginia, 2012). By performing a hydrographic separation analysis of historic flow data (1930-2002) from 15 USGS stream gage stations, the USGS discovered that summer base flows most nearly approximated the annual $75^{th}$ percentile flow duration statistic. Based on this project, DEP has incorporated the $75^{th}$ percentile flow duration as the minimum withdrawal threshold on all unregulated state streams and rivers. To transfer this threshold from the representative stream gage to proposed surface water intake points, the base-flow threshold is scaled by the ratio of the drainage basin areas. Safety factors are incorporated if the withdrawal location is on an ungaged stream or located far from the gage.




# CHAPTER THREE
# WATER BUDGET

**WATER USE SECTION** west virginia department of environmental protection

# Chapter - 3 Water Budget

## 3.1 Introduction

Managing West Virginia's water resources is critical to ensuring the availability of dependable water supplies now and into the future. The Act instructs the DEP to determine the quantity of available water in each of the watersheds and provide an estimate of the safe yield of such sources for consumptive and non-consumptive uses during periods of normal conditions and drought. There is no one accepted definition of safe yield, and due to the dynamic nature of surface water, the term "safe yield" is more applicable to groundwater systems that are more static. In an effort to quantify the available water in this state, a seasonal water budget has been calculated. By calculating a water budget, incorporating both consumptive and non-consumptive demands on the total system, we have determined the remaining available water in each watershed. The surface water budget number can be useful for numerous water planning exercises including infrastructure, supply and economic development. As mentioned in Chapter 1, safe yield is relevant to groundwater. However, due to the complexity of the stratigraphy in West Virginia, it would entail multiple localized studies for its determination. In other words, West Virginia lacks large, regional aquifer systems similar to the Floridian or Ogallala aquifers.

## 3.2 West Virginia's Water Budget

As described, it is necessary to develop a water budget for each of the 32 eight-digit Hydrologic Unit Code Watersheds (HUC-8 WS) within West Virginia. The ultimate goal of this water budget is to estimate the quantity of water available for use in a system beyond the amount necessary to sustain aquatic life. Since West Virginia's precipitation, base-flow, and evapotranspiration rates vary seasonally, water budgets were developed to reflect these changes.

To develop a seasonal water budget, it is first necessary to determine the average seasonal precipitation rates of the area. For this study we used monthly "normal" precipitation data provided by NOAA that was derived from "PRISM" climate data developed at Oregon State University. The 30-year monthly normal precipitation values were derived using data from 1981-2010. According to NOAA, the data "are considered the most detailed, highest-quality spatial climate datasets currently available" (http://water.weather.gov/precip/about.php). This data was downloaded as ESRI ASCII grids, overlain by the HUC-8 watershed boundaries and the data grids within the HUC-8 watersheds were extracted for each month. The monthly data was then averaged for the four seasons for each of the HUC-8 watersheds. The seasons were defined in USGS SIR 2012 5121 as winter (January 1–March 31), spring (April 1–June 30), summer (July 1–September 30) and fall (October 1–December 31).

The charts below show the average seasonal inches of precipitation across each of the 32 HUC-8 watersheds, the maximum and minimum inches of precipitation per grid point in the watershed and the total number of grid points within each watershed. These tables are available on the web-interface tool.

**Table 3-1 Winter and spring HUC-8 watershed precipitation totals per grid point**

| **WINTER** | | | | | **SPRING** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **HUC8** | **Avg (in)** | **Max (in)** | **Min (in)** | **No. in HUC8** | **HUC8** | **Avg (in)** | **Max (in)** | **Min (in)** | **No. in HUC8** |
| Big Sandy | 9.61 | 9.69 | 9.55 | 10 | Big Sandy | 12.04 | 12.26 | 11.82 | 10 |
| Cacapon | 8.11 | 9.89 | 7.11 | 125 | Cacapon | 10.75 | 12.28 | 9.99 | 125 |
| Cheat | 11.71 | 15.64 | 9.12 | 203 | Cheat | 14.70 | 16.90 | 12.11 | 203 |
| Coal | 10.32 | 12.02 | 9.32 | 137 | Coal | 13.29 | 15.15 | 11.64 | 137 |
| Dunkard | 9.88 | 10.27 | 9.43 | 17 | Dunkard | 12.71 | 13.14 | 12.23 | 17 |
| Elk | 11.03 | 16.30 | 9.46 | 229 | Elk | 13.84 | 17.79 | 11.75 | 229 |
| Gauley | 11.38 | 14.75 | 9.27 | 215 | Gauley | 14.40 | 17.96 | 11.69 | 215 |
| Greenbrier | 10.04 | 15.32 | 8.03 | 249 | Greenbrier | 11.97 | 16.51 | 10.54 | 249 |
| James | 9.39 | 10.21 | 8.59 | 12 | James | 12.03 | 12.73 | 11.43 | 12 |
| Little Kanawha | 10.24 | 12.85 | 9.20 | 345 | Little Kanawha | 12.54 | 16.20 | 11.84 | 345 |
| Lower Guyandotte | 9.85 | 10.37 | 9.24 | 113 | Lower Guyandotte | 12.29 | 13.52 | 11.28 | 113 |
| Lower Kanawha | 9.39 | 10.14 | 8.70 | 137 | Lower Kanawha | 11.53 | 12.77 | 10.50 | 137 |
| Lower New | 9.58 | 11.11 | 8.45 | 109 | Lower New | 12.73 | 15.16 | 10.77 | 109 |
| Lower Ohio | 9.33 | 9.57 | 8.98 | 35 | Lower Ohio | 11.37 | 11.76 | 11.15 | 35 |
| Middle Ohio North | 10.33 | 11.32 | 9.39 | 140 | Middle Ohio North | 12.73 | 13.49 | 11.94 | 140 |
| Middle Ohio South | 9.38 | 9.96 | 8.54 | 105 | Middle Ohio South | 11.68 | 11.96 | 10.76 | 105 |
| Monongahela | 10.14 | 10.91 | 9.07 | 66 | Monongahela | 12.94 | 14.19 | 11.99 | 66 |
| North Branch Potomac | 8.95 | 12.60 | 7.53 | 91 | North Branch Potomac | 11.54 | 15.37 | 10.11 | 91 |
| Potomac Direct Drains | 8.25 | 8.84 | 7.85 | 83 | Potomac Direct Drains | 10.71 | 11.11 | 10.21 | 83 |
| Shenandoah Hardy | 7.99 | 7.99 | 7.99 | 1 | Shenandoah Hardy | 10.98 | 10.98 | 10.98 | 1 |
| Shenandoah Jefferson | 8.22 | 8.36 | 8.10 | 17 | Shenandoah Jefferson | 10.72 | 10.94 | 10.33 | 17 |
| South Branch Potomac | 8.16 | 12.06 | ***6.46*** | 203 | South Branch Potomac | 10.80 | 15.56 | ***9.07*** | 203 |
| Tug Fork | 9.99 | 10.80 | 9.41 | 141 | Tug Fork | 12.57 | 13.33 | 11.76 | 141 |
| Twelvepole | 10.00 | 10.60 | 9.46 | 70 | Twelvepole | 12.44 | 13.38 | 11.65 | 70 |
| Tygart Valley | 11.35 | ***16.71*** | 9.58 | 206 | Tygart Valley | 14.34 | ***18.09*** | 12.45 | 206 |
| Upper Guyandotte | 10.51 | 12.22 | 9.78 | 144 | Upper Guyandotte | 13.46 | 15.09 | 12.65 | 144 |
| Upper Kanawha | 9.73 | 10.31 | 9.33 | 77 | Upper Kanawha | 12.90 | 13.54 | 11.85 | 77 |
| Upper New | 8.82 | 10.84 | 7.62 | 124 | Upper New | 11.03 | 13.55 | 10.17 | 124 |
| Upper Ohio North | 7.75 | 7.89 | 7.55 | 17 | Upper Ohio North | 11.52 | 11.76 | 10.98 | 17 |
| Upper Ohio South | 9.12 | 10.80 | 7.73 | 84 | Upper Ohio South | 12.16 | 13.24 | 11.07 | 84 |
| West Fork | 10.35 | 11.67 | 9.57 | 133 | West Fork | 13.13 | 14.16 | 12.07 | 133 |
| Youghiogheny | 11.71 | 12.22 | 11.27 | 10 | Youghiogheny | 14.41 | 14.82 | 14.02 | 10 |
| **Grand Total** | **10.02** | **16.71** | **6.46** | **3648** | **Grand Total** | **12.65** | **18.09** | **9.07** | **3648** |

**Table 3-2 Summer and fall HUC-8 watershed precipitation totals per grid point**

| SUMMER HUC8 | Avg (in) | Max (in) | Min (in) | No. in HUC8 | FALL HUC8 | Avg (in) | Max (in) | Min (in) | No. in HUC8 |
|---|---|---|---|---|---|---|---|---|---|
| Big Sandy | 10.79 | 10.87 | 10.73 | 10 | Big Sandy | 9.42 | 9.59 | 9.27 | 10 |
| Cacapon | 10.61 | 12.62 | 9.72 | 125 | Cacapon | 8.37 | 9.89 | 7.56 | 125 |
| Cheat | 13.44 | 16.10 | 10.98 | 203 | Cheat | 11.15 | 13.85 | 9.18 | 203 |
| Coal | 12.21 | 13.88 | 11.43 | 137 | Coal | 9.86 | 11.26 | 8.83 | 137 |
| Dunkard | 11.49 | 11.95 | 11.00 | 17 | Dunkard | 9.80 | 10.11 | 9.40 | 17 |
| Elk | 13.32 | 16.55 | 11.80 | 229 | Elk | 10.65 | 15.27 | 9.20 | 229 |
| Gauley | 13.98 | ***18.07*** | 11.21 | 215 | Gauley | 10.85 | 13.54 | 8.90 | 215 |
| Greenbrier | 11.30 | 15.95 | 9.78 | 249 | Greenbrier | 9.50 | 13.49 | 7.65 | 249 |
| James | 11.44 | 12.35 | 10.79 | 12 | James | 9.33 | 10.04 | 8.74 | 12 |
| Little Kanawha | 11.84 | 14.75 | 10.82 | 345 | Little Kanawha | 10.02 | 12.59 | 8.99 | 345 |
| Lower Guyandotte | 11.51 | 12.29 | 10.88 | 113 | Lower Guyandotte | 9.63 | 9.95 | 9.11 | 113 |
| Lower Kanawha | 11.44 | 12.24 | 10.65 | 137 | Lower Kanawha | 9.26 | 9.90 | 8.67 | 137 |
| Lower New | 11.98 | 14.15 | 10.32 | 109 | Lower New | 9.11 | 10.36 | 7.98 | 109 |
| Lower Ohio | 10.73 | 11.11 | 10.40 | 35 | Lower Ohio | 8.99 | 9.26 | 8.66 | 35 |
| Middle Ohio North | 11.64 | 12.37 | 10.93 | 140 | Middle Ohio North | 10.22 | 11.40 | 9.16 | 140 |
| Middle Ohio South | 11.03 | 11.70 | 10.34 | 105 | Middle Ohio South | 9.25 | 9.76 | 8.41 | 105 |
| Monongahela | 11.70 | 12.41 | 10.61 | 66 | Monongahela | 10.02 | 10.84 | 9.18 | 66 |
| North Branch Potomac | 10.46 | 13.86 | 9.08 | 91 | North Branch Potomac | 8.59 | 11.80 | 7.28 | 91 |
| Potomac Direct Drains | 9.94 | 10.24 | 9.65 | 83 | Potomac Direct Drains | 8.79 | 9.12 | 8.05 | 83 |
| Shenandoah Hardy | 11.36 | 11.36 | 11.36 | 1 | Shenandoah Hardy | 8.38 | 8.38 | 8.38 | 1 |
| Shenandoah Jefferson | 10.28 | 10.53 | 10.14 | 17 | Shenandoah Jefferson | 8.87 | 9.08 | 8.61 | 17 |
| South Branch Potomac | 10.63 | 14.01 | ***8.87*** | 203 | South Branch Potomac | 8.06 | 11.44 | **6.44** | 203 |
| Tug Fork | 11.26 | 11.84 | 10.77 | 141 | Tug Fork | 9.25 | 9.93 | 8.22 | 141 |
| Twelvepole | 11.34 | 12.00 | 10.81 | 70 | Twelvepole | 9.56 | 9.77 | 9.17 | 70 |
| Tygart Valley | 13.17 | 16.74 | 11.63 | 206 | Tygart Valley | 10.95 | **15.57** | 9.41 | 206 |
| Upper Guyandotte | 11.94 | 13.17 | 10.51 | 144 | Upper Guyandotte | 9.73 | 11.18 | 9.10 | 144 |
| Upper Kanawha | 12.15 | 12.70 | 11.52 | 77 | Upper Kanawha | 9.39 | 9.95 | 8.75 | 77 |
| Upper New | 10.18 | 12.34 | 9.35 | 124 | Upper New | 8.01 | 9.83 | 7.38 | 124 |
| Upper Ohio North | 10.58 | 10.82 | 10.40 | 17 | Upper Ohio North | 8.50 | 8.71 | 8.25 | 17 |
| Upper Ohio South | 10.86 | 12.21 | 10.23 | 84 | Upper Ohio South | 9.35 | 10.73 | 8.19 | 84 |
| West Fork | 12.02 | 13.44 | 11.40 | 133 | West Fork | 10.11 | 11.40 | 9.63 | 133 |
| Youghiogheny | 13.54 | 13.79 | 13.16 | 10 | Youghiogheny | 11.33 | 11.66 | 10.90 | 10 |
| **Grand Total** | **11.84** | **18.07** | **8.87** | **3648** | **Grand Total** | **9.70** | **15.57** | **6.44** | **3648** |

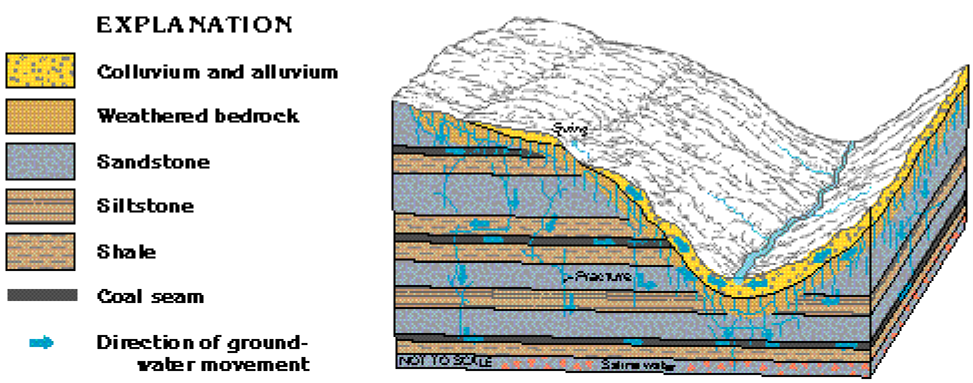
The initial water source for each watershed is precipitation (P). Nationally recognized average annual precipitation for West Virginia is 44 inches per year, which translates to 19.32 trillion gallons of water. Based on the previously mentioned precipitation data, average quantities of precipitation during each of the seasons were identified and converted to gallons. We have derived surface water consumptive use quantities from the Large Quantity User database and utilized GIS computer modeling to group them into HUC-8 watersheds, then queried the results to arrive at a seasonal consumptive use quantity per watershed.

A major drawback of the water budget method is that the available water is estimated as the residual term in an equation where the other budget terms are estimated with some degree of error. The amount of water that flows into a watershed, as well as the water that must be allowed to flow out of the watershed to guarantee water quality downstream, must also be estimated. This can result in large errors in the available water estimate. In an attempt to reduce error in this study, the stream discharge quantities (Q) that the water-budget calculation uses are based on actual stream flow measurements at stream flow-gaging stations from which the estimates of flow were derived over greater than a 10-year period of record (Wiley, Low-Flow Analysis and Selected Flow Statistics Representative of 1930-2002 for Stream Flow-Gaging Stations in or Near West Virginia, 2006). For this study we have set the minimum stream flow amount at seasonal base flow for unregulated streams, as determined by the report (Comparison of Base flows to Selected Stream flow Statistics Representative of 1930-2002 in West Virginia, USGS SIR 2012 5121), and used the minimum release from the dams on regulated streams. Due to flows on the Ohio River being regulated by the Army Corps of Engineers locks and dams, the water budgets for the bordering watersheds were calculated for only the in-state portion of those watersheds. There is ample water available for use from the Ohio year round.

The statewide average annual precipitation is 44 inches per year, which equates to 19.32 trillion gallons of water a year if evenly applied to the total land area of the state.

Change in storage (ΔS) is a term used to describe the quantity of water required to return the volume of water stored in the lakes to normal levels. If the lakes are at or above normal pool levels, the change in storage would be negative and result in more available water. If the lakes and groundwater are below normal, as would be typical following drought conditions, the change in storage would be positive, resulting in a reduction in the available water due to the quantity of water required to return the system to normal pool. As the amount of water lost and gained due to the changes in these systems is highly variable and inconsistent, it was not quantified for this preliminary water budget, therefore we will assume that change in storage is static.

Once precipitation falls in an aquifer's recharge area, a percentage is lost to evaporation, a portion percolates into the soil and the remainder runs off into streams. The portion of water that percolates into the soil is either used (transpired) by plants, infiltrates the soil and continues downward where it recharges groundwater reservoirs (aquifers) or is captured by mine pools. It is this portion that is commonly referred to as recharge (R). Recharge quantities were estimated based on mean ground water recharge rates at selected stream gages reported in the USGS Water Resources Investigations Report 01-4036 (Kozar & Mathes, 2001). It should be noted that once an aquifer reaches its full capacity, the excess water is typically returned to the surface stream as seepage. There is a general consensus among hydrologists that interconnectivity of the near surface aquifers and streams are common in the Appalachian Plateau's aquifers (GROUNDWATER ATLAS of the UNITED STATES Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia HA 730-L). The following Figure 3-1 depicts some common interconnectivity of groundwater flow within the Appalachian region.




Modified from Harlow, G.E., Jr., and LeCain, G.D., 1993, Hydraulic characteristics of, and ground-water flow in, coal-bearing rocks of southwestern Virginia: U.S. Geological Survey Water-Supply Paper 2388, 36 p.

**Figure 3-1 Interconnectivity of groundwater flow**

Evapotranspiration (ET) is a term used to describe the sum of evaporation and plant transpiration from the earth's land surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through its leaves. Evapotranspiration (ET) is an important part of the water cycle. In West Virginia ET is a prevalent reducer of water due to the heavily forested portion of the state. An exact quantity for ET is very difficult to determine. As a matter of fact, the Interstate Commission on the Potomac River Basin (ICPRB) combined the terms for recharge and ET as the residual term in the equation due to difficulty in obtaining these values. The New Jersey Raritan Basin Watershed Management Project used a value equal to 53% of the total precipitation in the area. Johnston and Baer (1987) used a value based on 55% of precipitation for a Maryland study and Auburn University used a value based on 60% of precipitation for Alabama. The U.S. Department of Interior and the USGS cooperatively determined an ET value equal to 63% of the total precipitation for the Jordan Creek Watershed, in Pennsylvania. However, when they compared the results to actual stream flow, they determined that the ET value was off as much as seven inches per year, which translates to an ET rate of 45% of the total precipitation in that area.

Based on the extreme variability of potential ET rates both across the state and seasonally, we have initially removed ET from the water budget calculation. Once the seasonal available water quantities were calculated, we applied a range of ET as a percent of precipitation to the results from 10% ET to 85% ET. The USGS Water Science Center of West Virginia has received funding for a four-year scientific investigation to formulate water budgets. The budgets will be based on seasonal ET rates for each watershed, along with results of the four-year study.

### 3.3 Calculation

The following is intended to provide a general description of the preliminary method to be used for determination of the individual watershed water budgets. However, this will not equate to the total amount of water in the aquifer available for pumping. A large percent must be protected to discourage a permanent drawdown of the ground and surface water systems. With the understanding that the quantities for ET and ΔS are likely to change with further evaluation, the water budget has been calculated as follows:

The water-budget method used in this study estimates available water as the residual term in:

$$A = ((P \times WS \times \%\ ET) + (Q_{in})) - (Q_{out} + LQ + R + \Delta S + Ag)$$

where:

***A*** is the amount of water available for use in millions of gallons per day

***R*** is recharge including infiltration to aquifers, mine pools and soil absorption

***P*** is seasonal precipitation

**$Q_{in}$** is water flowing into the watershed from an upstream watershed based on 7Q10 + 10% (least quantity of water in the stream for seven consecutive days over the past 10 years plus 10%)

***$Q_{out}$*** is stream discharge from the watershed based on Seasonal Base Flow (Wiley, 2012)

***LQ*** is total volume consumed by large quantity users (surface & groundwater)

***ET*** is evapotranspiration (as a percentage of precipitation remaining post ET)

**ΔS** is change in storage of surface water (could be positive or negative)

**Ag** is the water consumed for agriculture and livestock (negligible in West Virginia)

***WS*** area of the watershed

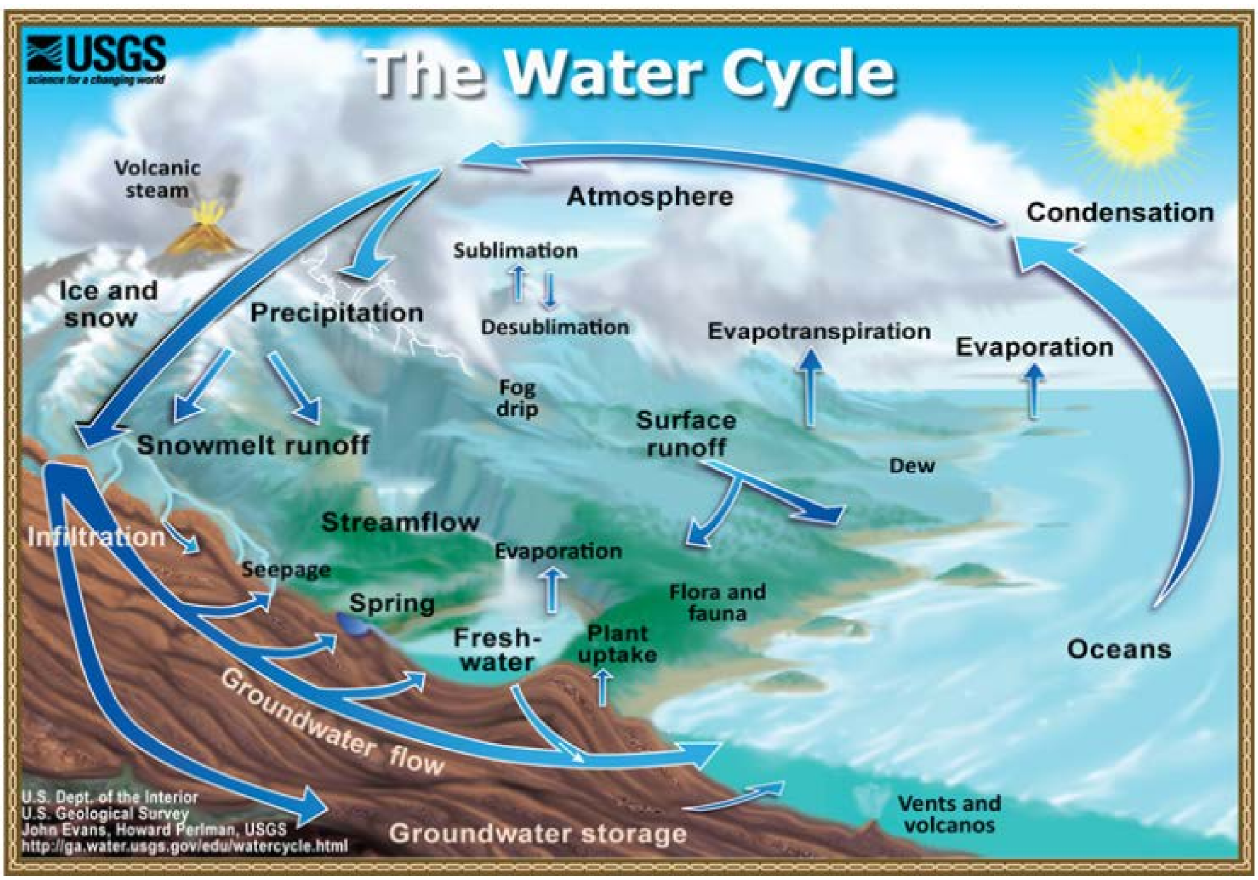
The equation has been simplified to:

$$A = ((P \times WS ) + Q_{in}) - (Q_{out} + LQ + R)$$

As discussed, the term *ΔS* is highly variable and the quantities have yet to be determined, therefore we will assume them to be static for this preliminary water budget and remove the term from the equation. Accurate agricultural use quantities could not be determined and are assumed to be a negligible quantity in West Virginia, therefore, this term was also removed from the equation. ET will be applied as a percentage of reduction to the final amount of available water.

## 3.4 Water Budget Results

Potential ET rates vary both across the state and seasonally, but will be more clearly defined by an ongoing USGS scientific investigation. ET rates are higher in the summer and spring and lower in the winter and fall. The ultimate goal of a water budget is to determine the amount of available water in the system. In order to derive the amount of available water, it is necessary to identify the quantities required to recharge the aquifers, include mine pool discharges, account for soil absorption and the change in storage of the lakes and streams, which are all based on a variable seasonal ET rate. One could pick any value of ET and multiply the volumes in Table 3-3 by the residual percentage once seasonal and site specific ET rates are known. It is widely accepted that ET consumes between 25% and 10% of the winter and spring precipitation and between 85% to 65% in the summer and fall, dependent on soil characteristics, ambient temperatures, wind velocity, land cover, altitude, impervious surfaces, and many other variables, as depicted by the USGS Water Cycle.



When exact values for these variables are derived, the water budget numbers will be recalculated. The total calculated available flow of water per HUC 8 watershed, excluding the waters in excess of 7Q10 plus 10% in the Ohio River and prior to reducing for ET, are shown in Table 3-3.

**Table 3-3 The average flow of available water calculated by the described method, prior to reducing for evapotranspiration, for each of the 32 HUC-8 watersheds. The numbers are in cubic feet per second (cfs) and do not include water available from the Ohio River in excess of 7Q10 + 10%**

| WATERSHED | Summer CFS no ET | Fall CFS no ET | Winter CFS no ET | Spring CFS no ET |
|---|---|---|---|---|
| Big Sandy | 167.4 | 259.0 | 400.8 | 620.2 |
| Cacapon | 1,504.0 | 2,327.2 | 3,601.0 | 5,571.9 |
| Cheat | 1,915.5 | 2,963.9 | 4,586.1 | 7,096.3 |
| Coal | 1,055.1 | 1,632.6 | 2,526.2 | 3,908.9 |
| Dunkard | 1,114.3 | 1,724.2 | 2,667.9 | 4,128.1 |
| Elk | 3,159.5 | 4,888.8 | 7,564.7 | 11,705.1 |
| Gauley | 3,162.6 | 4,893.5 | 7,571.9 | 11,716.3 |
| Greenbrier | 648.1 | 1,002.9 | 1,551.8 | 2,401.1 |
| James | 143.0 | 221.3 | 342.5 | 529.9 |
| Little Kanawha | 2,750.1 | 4,255.3 | 6,584.3 | 10,188.1 |
| Lower Guyandotte | 895.4 | 1,385.5 | 2,143.8 | 3,317.2 |
| Lower Kanawha | 1,200.0 | 1,856.9 | 2,873.2 | 4,445.8 |
| Lower New | 1,005.0 | 1,555.0 | 2,406.1 | 3,723.1 |
| Lower Ohio | 532.0 | 823.1 | 1,273.6 | 1,970.7 |
| Middle Ohio North | 2,344.7 | 3,628.1 | 5,613.9 | 8,686.5 |
| Middle Ohio South | 1,189.5 | 1,840.6 | 2,848.0 | 4,406.8 |
| Monongahela | 476.5 | 737.3 | 1,140.8 | 1,765.2 |
| North Branch Potomac | 1,156.1 | 1,788.8 | 2,767.9 | 4,282.9 |
| Potomac Direct Drains | 1,373.3 | 2,124.9 | 3,287.9 | 5,087.5 |
| Shenandoah Hardy | 17.4 | 27.0 | 41.7 | 64.6 |
| Shenandoah Jefferson | 210.5 | 325.7 | 504.0 | 779.8 |
| South Branch Potomac | 2,371.0 | 3,668.7 | 5,676.7 | 8,783.7 |
| Tug | 803.0 | 1,242.5 | 1,922.5 | 2,974.8 |
| Twelvepole | 938.3 | 1,451.9 | 2,246.5 | 3,489.1 |
| Tygart Valley | 2,083.2 | 3,223.4 | 4,987.7 | 7,717.6 |
| Upper Guyandotte | 1,292.9 | 2,000.5 | 3,095.5 | 4,789.7 |
| Upper Kanawha | 5,452.2 | 8,436.3 | 13,053.8 | 20,198.6 |
| Upper New | 1,789.7 | 2,769.3 | 4,285.1 | 6,630.4 |
| Upper Ohio North | 993.8 | 1,537.7 | 2,379.3 | 3,681.6 |
| Upper Ohio South | 885.6 | 1,370.3 | 2,120.3 | 3,280.7 |
| West Fork | 1,600.0 | 2,475.7 | 3,830.7 | 5,927.4 |
| Youghiogheny | 172.7 | 267.2 | 413.5 | 639.9 |
| **TOTAL** | **44,402.1** | **68,705.1** | **106,309.7** | **164,509.5** |

Keeping in mind the high percentage of potential error, the further upstream from the pour point one goes, the available water will be less, and that a range of ET as a percent of precipitation was applied to the results from 10% ET to 85% ET, one could assume an available quantity of water at the pour point of each watershed to be as shown in tables Table 3-4 and Table 3-5. Table 3-4 represents a constant flow of water in cubic feet per second (cfs) and Table 3-5 in millions of gallons per day (MGD). The average value from Table 3-5 estimates 41.8 billion gallons of additional water per day.

**Table 3-4 The average seasonal gallons of available water calculated by the described method, reducing total precipitation by the % evapotranspiration per season, for each of the 32 HUC-8 watersheds. The numbers are in cubic feet per second (cfs) and do not include water available from the Ohio River in excess of 7Q10 + 10%**

| WATERSHED | Summer 85% ET in cfs | Fall 65% ET in cfs | Winter 25% ET in cfs | Spring 10% ET in cfs |
|---|---|---|---|---|
| Big Sandy | 25.1 | 90.7 | 300.6 | 558.2 |
| Cacapon | 225.6 | 814.5 | 2,700.8 | 5,014.7 |
| Cheat | 287.3 | 1,037.4 | 3,439.6 | 6,386.7 |
| Coal | 158.3 | 571.4 | 1,894.7 | 3,518.0 |
| Dunkard | 167.1 | 603.5 | 2,000.9 | 3,715.3 |
| Elk | 473.9 | 1,711.1 | 5,673.5 | 10,534.6 |
| Gauley | 474.4 | 1,712.7 | 5,678.9 | 10,544.7 |
| Greenbrier | 97.2 | 351.0 | 1,163.9 | 2,161.0 |
| James | 21.5 | 77.5 | 256.9 | 476.9 |
| Little Kanawha | 412.5 | 1,489.4 | 4,938.2 | 9,169.3 |
| Lower Guyandotte | 134.3 | 484.9 | 1,607.9 | 2,985.5 |
| Lower Kanawha | 180.0 | 649.9 | 2,154.9 | 4,001.2 |
| Lower New | 150.7 | 544.3 | 1,804.6 | 3,350.8 |
| Lower Ohio | 79.8 | 288.1 | 955.2 | 1,773.6 |
| Middle Ohio North | 351.7 | 1,269.8 | 4,210.4 | 7,817.9 |
| Middle Ohio South | 178.4 | 644.2 | 2,136.0 | 3,966.1 |
| Monongahela | 71.5 | 258.1 | 855.6 | 1,588.7 |
| North Branch Potomac | 173.4 | 626.1 | 2,075.9 | 3,854.6 |
| Potomac Direct Drains | 206.0 | 743.7 | 2,465.9 | 4,578.8 |
| Shenandoah Hardy | 2.6 | 9.5 | 31.3 | 58.1 |
| Shenandoah Jefferson | 31.6 | 114.0 | 378.0 | 701.8 |
| South Branch Potomac | 355.6 | 1,284.0 | 4,257.5 | 7,905.3 |
| Tug | 120.4 | 434.9 | 1,441.9 | 2,677.3 |
| Twelvepole | 140.7 | 508.2 | 1,684.9 | 3,140.2 |
| Tygart Valley | 312.5 | 1,128.2 | 3,740.8 | 6,945.8 |
| Upper Guyandotte | 193.9 | 700.2 | 2,321.6 | 4,310.7 |
| Upper Kanawha | 817.8 | 2,952.7 | 9,790.4 | 18,178.7 |
| Upper New | 268.5 | 969.3 | 3,213.8 | 5,967.4 |
| Upper Ohio North | 149.1 | 538.2 | 1,784.5 | 3,313.4 |
| Upper Ohio South | 132.8 | 479.6 | 1,590.2 | 2,952.6 |
| West Fork | 240.0 | 866.5 | 2,873.0 | 5,334.7 |
| Youghiogheny | 25.9 | 93.5 | 310.1 | 575.9 |
| **TOTAL** | **6,660.3** | **24,046.8** | **79,732.3** | **148,058.6** |

Table 3-5 The average seasonal gallons of available water calculated by the described method, reducing total precipitation by a varying % for evapotranspiration per season, for each of the 32 HUC 8 watersheds. The numbers are in million gallons per day (MGD) and do not include water available from the Ohio River in excess of 7Q10 + 10%

| WATERSHED | Summer 85% ET in MGD | Fall 65% ET in MGD | Winter 25% ET in MGD | Spring 10% ET in MGD |
|---|---|---|---|---|
| Big Sandy | 16.23 | 58.58 | 194.27 | 360.74 |
| Cacapon | 145.80 | 526.40 | 1,745.42 | 3,240.87 |
| Cheat | 185.69 | 670.42 | 2,222.90 | 4,127.53 |
| Coal | 102.29 | 369.29 | 1,224.46 | 2,273.59 |
| Dunkard | 108.02 | 390.01 | 1,293.14 | 2,401.09 |
| Elk | 306.29 | 1,105.82 | 3,666.64 | 6,808.21 |
| Gauley | 306.58 | 1,106.89 | 3,670.13 | 6,814.72 |
| Greenbrier | 62.83 | 226.85 | 752.16 | 1,396.59 |
| James | 13.87 | 50.06 | 166.01 | 308.21 |
| Little Kanawha | 266.59 | 962.53 | 3,191.44 | 5,925.86 |
| Lower Guyandotte | 86.80 | 313.39 | 1,039.11 | 1,929.43 |
| Lower Kanawha | 116.33 | 420.02 | 1,392.65 | 2,585.88 |
| Lower New | 97.42 | 351.73 | 1,166.25 | 2,165.52 |
| Lower Ohio | 51.57 | 186.18 | 617.32 | 1,146.25 |
| Middle Ohio North | 227.30 | 820.66 | 2,721.08 | 5,052.46 |
| Middle Ohio South | 115.31 | 416.33 | 1,380.44 | 2,563.19 |
| Monongahela | 46.19 | 166.77 | 552.95 | 1,026.72 |
| North Branch Potomac | 112.07 | 404.62 | 1,341.61 | 2,491.13 |
| Potomac Direct Drains | 133.12 | 480.64 | 1,593.66 | 2,959.12 |
| Shenandoah Hardy | 1.69 | 6.11 | 20.21 | 37.57 |
| Shenandoah Jefferson | 20.41 | 73.67 | 244.29 | 453.57 |
| South Branch Potomac | 229.84 | 829.84 | 2,751.52 | 5,108.99 |
| Tug | 77.84 | 281.05 | 931.84 | 1,730.28 |
| Twelvepole | 90.96 | 328.41 | 1,088.89 | 2,029.42 |
| Tygart Valley | 201.95 | 729.12 | 2,417.56 | 4,488.90 |
| Upper Guyandotte | 125.33 | 452.50 | 1,500.40 | 2,785.90 |
| Upper Kanawha | 528.54 | 1,908.25 | 6,327.23 | 11,748.41 |
| Upper New | 173.50 | 626.40 | 2,077.01 | 3,856.54 |
| Upper Ohio North | 96.34 | 347.82 | 1,153.26 | 2,141.38 |
| Upper Ohio South | 85.85 | 309.96 | 1,027.72 | 1,908.20 |
| West Fork | 155.10 | 559.99 | 1,856.76 | 3,447.64 |
| Youghiogheny | 16.74 | 60.44 | 200.43 | 372.19 |
| **TOTAL** | **4,304.4** | **15,540.8** | **51,528.7** | **95,686.1** |

Based on the water budget results and the estimated consumptive needs of the state, there are no areas in danger of their water demands outgrowing their water availability.

## 3.5 Greenbrier Watershed Water Budget Model[1]

As an alternative to the water budgets calculated previously, the DEP partnered with Marshall University to develop another method of deriving a water budget estimate. The following is a description of this method for the Greenbrier River Watershed.

### 3.5.1 Introduction

The purpose of this Data and Model Summary is to provide information related to water availability within the Greenbrier Watershed. Understanding water availability can be aided by two complementary methods: (1) analysis of historical data that characterizes past water-related conditions within the watershed, and (2) preparation of models that can be used to predict future water availability based on influencing factors (e.g., precipitation, evapotranspiration, storage, etc.). By analyzing historical data, one can produce a statistical description of runoff, such as the probability that a certain flow rate would be encountered in a given month. These statistical summaries of past conditions can be utilized to characterize the range of events that are likely to occur in the future. Predictive models likewise enable an improved understanding of future watershed conditions, and are built by correlating independent variables that influence runoff (e.g., precipitation depth, temperatures, solar radiation, water consumption, etc.) to the dependent variable of runoff flow.

The analyses and models described herein have been prepared on a monthly basis, with the exception of the evapotranspiration model, which is operated on a daily basis and subsequently summarized by month. Certain analyses, indicated below, have also been performed or summarized on a seasonal basis, in keeping with the DEP's requests to have water availability characterized by quarter.

### 3.5.2 Watershed Characteristics

The location of the Greenbrier Watershed within West Virginia is shown in Figure 3-2, and a summary of watershed characteristics is provided in Table 3-6.

[1] Created by Isaac Wait, Ph.D., P.E., Associate Professor of the Division of Engineering at Marshall University and Mr. James A. Wolfe GIS Manager of the Center for Environmental, Geotechnical and Applied Sciences at Marshall University.

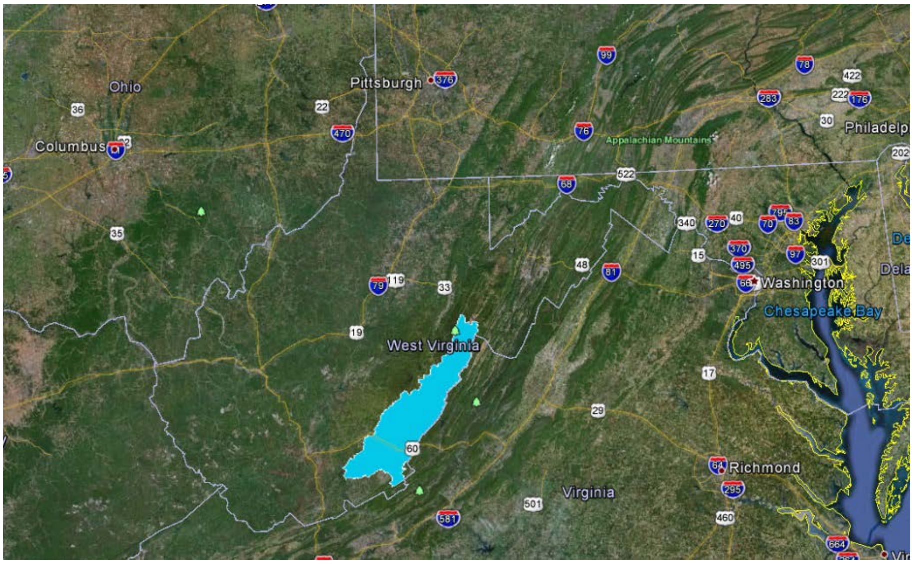



Figure 3-2  Greenbrier Watershed

Table 3-6  Summary of Greenbrier Watershed characteristics

| **Parameter** | **Value** |
|---|---|
| Location | Lat:38.1° N<br>Long:80.2° W |
| Basin Area (mi$^2$) | 1650 |
| Average basin elevation (ft) | 2666 |
| Average basin overland slope (%) | 18.8 |
| Maximum flow distance (mi) | 162.6 |
| Slope along maximum flow distance (%) | 0.29 |
| Shape factor (basin length / basin width) | 5.86 |
| Sinuosity factor of stream (max. stream length / basin length) | 1.56 |
| Runoff Curve Number | 63.9 |
| Is another HUC-8 watershed upstream? | No |
| Is flow from this watershed regulated by a dam? | No |
| Existing consumption from Large Quantity Water Users | Low |

The data summarized in Table 3-6 can be used for comparison purposes against other watersheds. For example, shape factor can be useful in understanding relative time of concentration durations, maximum flow distance can help define flow routing behavior, runoff curve number can be used to predict the ratio of precipitation to runoff, and so on.

### 3.5.3 Historical Runoff

USGS stream gage station 03184000 – Greenbrier River at Hilldale, WV – is the stream gage nearest the outlet point for the Greenbrier Watershed. It is located at Lat. 37°38'24", Long. 80°48'19", and has a drainage area of 1,619 square miles, representing 98% of the 1,650 square miles drainage area of the Greenbrier Watershed. An analysis of daily average flow data for a period of study January 1986 to April 2013 is summarized in Table 3-7 below.

**Table 3-7 Runoff depth by month for the Greenbrier Watershed. Note: Monthly runoff depth (in) for this watershed can be converted into gallons per month by multiplying by 2.867 x 1010**

| Month | Minimum (in) | Average (in) | Standard Deviation of Average (in) |
|---|---|---|---|
| Jan | 0.52 | 2.54 | 1.39 |
| Feb | 0.46 | 2.24 | 1.18 |
| Mar | 0.76 | 3.60 | 1.48 |
| Apr | 0.61 | 2.57 | 1.36 |
| May | 0.59 | 2.30 | 1.19 |
| Jun | 0.15 | 0.96 | 0.92 |
| Jul | 0.06 | 0.47 | 0.35 |
| Aug | 0.05 | 0.41 | 0.45 |
| Sep | 0.04 | 0.40 | 0.54 |
| Oct | 0.04 | 0.48 | 0.59 |
| Nov | 0.06 | 1.07 | 1.15 |
| Dec | 0.19 | 1.86 | 1.14 |

Historical data shows that the months July – October represent the months where water availability is the lowest and experience, on average, flows that are approximately 1/9th those encountered during the wettest month (i.e., March). A review of the minimum runoff flows observed during the period of study shows that the critical period of lowest runoff availability should be expanded to include June – November.

### 3.5.4 Large Quantity Users

Existing reported water use within the Greenbrier Watershed was investigated relative to data stored in the WVDEP / CEGAS database. Seven surface water intakes were identified: the Greenbrier Resort, City of Lewisburg Water Plant, Town of Marlinton, Alderson Water Treatment Plant, Big Bend PSD, Denmar Correctional Center and WVDNR Edray Hatchery. Continuous data was not available for the LQU's during all years of the study period, and so the maximum monthly water volume utilized was considered in order to assess whether existing LQU's have a meaningful impact on the total available water within the watershed. Table 3-8 contains a summary of LQU's and their respective monthly water use maximums.

**Table 3-8 Large Quantity User Water Utilization Summary**

| User | Year of Record | Maximum Monthly Water Volume Utilized ($ft^3$) |
|---|---|---|
| The Greenbrier | 2009 | 2,058,582 |
| City of Lewisburg Water Plant | 2011 | 8,072,935 |
| Town of Marlinton | 2005 | 1,024,888 |
| Alderson Water Treatment Plant | 2005 | 1,994,506 |
| Big Bend PSD | 2010 | 414,740 |
| Denmar Correctional Center | 2011 | 188,382 |
| WVDNR Edray Hatchery | 2005 | 2,887,488 |

If all of the LQU's identified in Table 3-8 were to use their maximum monthly water volume during the same month, this would represent a total monthly water volume of 16,226,784 cubic feet. Converting this to an equivalent water depth for the watershed area of 1650 square miles (for purposes of comparison to runoff depths provided in Table 3-7) yields an equivalent water depth of 0.0042 inches. This hypothetical simultaneous maximum use would represent 0.27% of the average runoff depth of the Greenbrier River (i.e., 1.59 in.), and thus the impact of existing LQU's is not further included in the predictive model that is described in the "Predicted Runoff" section of this report.

### 3.5.5 Baseflow and 7Q10

The computation of baseflow, defined by USGS as "the portion of streamflow contributed by groundwater discharge (USGS, 2012), was performed with the streamflow partitioning computer program (PART). An analysis of streamflow data from the Hilldale station on the Greenbrier River was conducted for the period 1937 – 2012, for which a complete data set of daily average daily flow records is available. Note that as per SIR 2012-5121, baseflow estimates are only applicable to unregulated streams. Similarly, caution is called for by SIR 2012-5121 when developing base flows for areas that experience dewatering due to underlying underground mines, or flow additions from flooded underground mines in a "downdip" configuration. Neither flow regulation nor significant mine influences are believed to meaningfully affect the baseflow estimates developed herein, but in other HUC-8 watersheds in West Virginia, both of these factors may limit the computation of reliable baseflow values. Table 3-9 provides the average seasonal baseflow values that were computed, both in terms of average basin depth in inches (the native output format for the PART program), and the corresponding flow rate (i.e., cfs).

**Table 3-9 Average Seasonal Baseflow for the Greenbrier Watershed**

| Season | Average Seasonal Baseflow | |
|---|---|---|
| | (in) | (cfs) |
| Jan – Mar | 4.05 | 1990 |
| Apr – June | 3.02 | 1470 |
| July – Sept | 0.66 | 320 |
| Oct – Dec | 1.56 | 750 |

Note: Conversion from baseflow depth (in) to baseflow rate (cfs) is by dividing the given depth by 12 to get depth in units of ft, multiplying by the watershed area of $4.6 \times 10^{10}$ $ft^2$, and then dividing by the number of seconds per season (86,400 sec/day, with 90.25, 91, 92, and 92 days in the winter, spring, summer, and fall, respectively).

Calculations were also performed to determine the Greenbrier Watershed's 7Q10, defined by USGS SIR 2008-5126 (Calculating Flow-Duration and Low-Flow Frequency Statistics at Streamflow-Gaging Stations) as the "annual 7-day minimum flow with a 10-year recurrence interval (non-exceedance probability of 10 percent)." Analysis was performed using the USEPA program DFLOW 3.1b, and determined that the 7Q10 for Greenbrier is 50.6 cfs. Manual calculations utilizing a seven day flow averaging period and exceedance probability estimation (i.e., n+1/rank) confirm the value reported by the DFLOW program.

### 3.5.6 Historical Precipitation and Evapotranspiration

Several precipitation gaging stations are in or near the Greenbrier Watershed, including: Bartow 1 S WV US (GHCND:USC00460509); Snowshoe WV US (GHCND:USC00468308); Frost 3 NE WV US (GHCND:USC00465672); Marlinton WV US (GHCND:USC00465672); Renick 3 WV US (GHCND:USC00467455); Lewisburg 3 N WV US (GHCND:USC00465224); and Alderson WV US (GHCND:USC00460102). Areal average precipitation depth for the watershed was computed using these stations, and is summarized in Table 3-10.

Also presented in Table 3-10 are computations of the water depth for "Evapotranspiration/Other" that is the result of subtracting runoff from precipitation (i.e., rearranging R = P – E). Since both runoff and precipitation can be measured directly, the difference between them can be readily determined. Most months, evapotranspiration is likely the largest contributing factor to runoff being less than precipitation, with change in storage being the second most important factor.

The amount of water stored within the watershed, both as groundwater and surface water, will vary in any given month. In dry months, water storage decreases, and in wet months water storage is replenished. For the Greenbrier Watershed, surface water storage is minimal (the surface area of impounded water is 0.5 $mi^2$ out of 1650 $mi^2$). Groundwater storage is difficult to measure, but can play an important role in water availability. In some (usually dry) months the amount of runoff can exceed the precipitation amount as water stored in the ground or on the surface flowed toward the outlet. In the long term, it is assumed that the net change in water storage will equal zero, as the water lost by groundwater storage to provide base flow during dry months is replenished during wet months.

Table 3-10 Precipitation and Evapotranspiration/Other depths by month for the Greenbrier Watershed

| Month | Precipitation | | Evapotranspiration/Other | |
|---|---|---|---|---|
| | Average (in) | Standard Deviation (in) | Average (in) | Standard Deviation (in) |
| Jan | 3.52 | 1.40 | 0.98 | 0.77 |
| Feb | 2.82 | 1.30 | 0.57 | 0.87 |
| Mar | 4.03 | 1.75 | 0.43 | 1.03 |
| Apr | 3.62 | 1.45 | 1.05 | 0.63 |
| May | 4.55 | 1.89 | 2.26 | 1.11 |
| Jun | 3.62 | 1.56 | 2.67 | 1.12 |
| Jul | 4.23 | 1.54 | 3.76 | 1.38 |
| Aug | 3.35 | 1.22 | 2.95 | 0.95 |
| Sep | 3.71 | 1.95 | 3.31 | 1.65 |
| Oct | 2.59 | 1.57 | 2.11 | 1.21 |
| Nov | 2.91 | 1.28 | 1.84 | 0.91 |
| Dec | 3.70 | 1.37 | 1.84 | 0.98 |

### 3.5.7 Evapotranspiration Model

A model of potential evapotranspiration (PET) was prepared using the Priestly-Taylor approach, as summarized in the equations provided below. Daily solar radiation data from January 1986 to present was obtained from the Bluefield State College solar radiation monitoring station, via the National Renewable Energy Laboratory (U.S. Department of Energy) website. Several model input parameters were not directly measured and typical values were instead utilized, and are summarized in Table 3-11.

$$PET = \alpha \cdot \left( \frac{\Delta}{\Delta + \gamma} \right) \cdot \frac{(R_n - G)}{\lambda \cdot \rho_w}$$

$$\Delta = \frac{2508.3}{(T + 237.3)^2} \cdot \exp\left( \frac{17.3 \cdot T}{T + 237.3} \right)$$

$$\gamma = \frac{c_p \cdot P}{0.622 \cdot \lambda}$$

$$\lambda = 2.501 - 0.002361 \cdot T_s$$

$$R_n = S_n - L_n$$

$$S_n = (1 - albedo) \cdot (TotGlobRad)$$

$$L_n = -\sigma \left( \frac{T^4{}_{\max,K} + T^4{}_{\min,K}}{2} \right) \varepsilon' f$$

$$G = 4.1 \frac{(T_{i+1} - T_{i-1})}{\Delta t}$$

Where:

$PET$ = Potential evapotranspiration (mm/day)
$\alpha$ = Priestly-Taylor calibration factor (unitless)
$\Delta$ = Slope of the saturation vapor pressure – temperature curve (kPa/K)
$\gamma$ = Psychrometric constant (kPa/K)
$\rho_w$ = density of water (kg/m3)
$T$ = Air temperature (K)
$T_s$ = Air temperature (°C)
$c_p$ = Specific heat of moist air, 0.001013 J/(kg·K)
$p$ = Atmospheric pressure (kPa)
$\lambda$ = Latent heat of vaporization (MJ/kg)
$R_n$ = Net radiation (MJ/m$^2$)
$S_n$ = Shortwave radiation (MJ/m$^2$)
$L_n$ = Longwave radiation (MJ/m$^2$)
$G$ = Heat flux density to the ground (MJ/m$^2$)
ε' = Net emissivity
$f$ = Cloudiness factor (unitless)
$albedo$ = Proportion of radiation that is reflected
$TotGlobRad$ = Total incoming solar radiation (MJ/m$^2$)

**Table 3-11 Unmeasured parameters incorporated into evapotranspiration model**

| Parameter | Value |
|---|---|
| Vapor pressure of water in the atmosphere, $e_a$ (kPa) | 2.0 |
| Net emissivity, ε' | 0.14 |
| Ratio of bright sunshine hours to daylight hours | 0.50 |
| $R_s$ / $S_0$ | 0.50 |
| $R_{s0}/S_0$ | 0.77 |
| Cloudiness factor, $f$ | 0.53 |

The spreadsheet utilized for evapotranspiration calculations has been provided to the DEP. Predicted evapotranspiration (ET) for a month is computed from PET using the monthly ET/PET factors that are presented in Table 3-12. These factors take into account that actual evapotranspiration will be less than potential evapotranspiration due to periods when the water available for evapotranspiration is less than the amount of water that could be evapotranspirated if an unlimited quantity were available. These factors also account for seasonal changes in vegetation, and other factors such as snow.

As an example of how to use the ET/PET factor, if the Priestly-Taylor model yields a PET of 4.58 inches for the month of April, then the ET for that month would be 1.20 inches (i.e., 0.263 x 4.58 inches).

**Table 3-12 Ratio of predicted evapotranspiration (ET) to potential evapotranspiration (PET)**

| Month | ET / PET Factor |
|---|---|
| Jan | 0.604 |
| Feb | 0.319 |
| Mar | 0.148 |
| Apr | 0.263 |
| May | 0.463 |
| Jun | 0.588 |
| Jul | 1.000 |
| Aug | 0.975 |
| Sep | 1.000 |
| Oct | 1.000 |
| Nov | 0.993 |
| Dec | 1.000 |

In developing the ET/PET factors listed in Table 3-12 through best-fit analysis between the historically-derived evapotranspiration depth and the model-predicted evapotranspiration, the ratio ET/PET was limited to a maximum of 1.000. This limit was selected to ensure that the predicted evapotranspiration never exceeds potential evapotranspiration. When incorporating the evapotranspiration model into the runoff model (described below), the maximum ET for any given month was limited to a maximum of the precipitation depth for that month.

### 3.5.8 Predicted Runoff

The generalized model for predicting runoff from a watershed is:

$$Q_{out} = Q_{in} + PR - ET - GR - \Delta S - LQ - AG$$

Where:

$Q_{out}$ = Stream discharge from watershed
$Q_{in}$ = Water into the watershed from upstream
$PR$ = Precipitation
$ET$ = Evapotranspiration
$GR$ = Groundwater recharge (+/-)
$\Delta S$ = Surface water storage recharge (+/-)
$LQ$ = Large Quantity user water consumption
$AG$ = Agricultural user water consumption

For the Greenbrier Watershed, since there is not another watershed upstream, $Q_{out}$ is neglected. Since data for large quantity user water consumption indicates that it is less than 1% of the average monthly flows, it is neglected. The fraction of the watershed utilized for farming suggests that agricultural user water consumption is likewise negligible, and so the term AG is omitted from the model. In any given month the change in surface water storage and the groundwater recharge will not be zero, but in the long term, and over the period of study (i.e., 1986 – 2013) they were taken to be zero. Thus, over a long-term period, the generalized watershed model can be simplified to:

$$Q_{out} = (PR - ET) \cdot FACTOR$$

Where $FACTOR$ = 0.878

To predict runoff from the watershed in a given month, one can simply subtract predicted evapotranspiration from the precipitation depth under consideration, and then multiply by 0.878, which is an empirical calibration factor required to correct for instances where ET/PET factors have been limited to 1.000, and to ensure that the model, over time, neither over- nor under-predicts runoff. In cases where the predicted runoff depth would be equal to a value of zero, runoff depth was instead assigned a value of 0.044 inches, which was the minimum depth observed during the study period. Continuing the example from above, if a precipitation depth of 4.00 inches was anticipated for an April month where the predicted evapotranspiration was 1.20 inches, then the predicted runoff depth would be 2.46 inches (i.e., (4.00 – 1.20) x 0.878).

As shown in Figure 3-3, when comparing predicted runoff depth to actual runoff depth during the study period, an $R^2$ value of 0.74 is obtained. Variance between predicted and actual flow can be attributed to a variety of factors, including changes in storage not addressed by the lumped Evapotranspiration/Other model term. Other factors contributing to variance include spatial variations in rainfall, temperature, radiation and other parameters over the watershed area, the utilization of typical, rather than measured, values in some parts of the evapotranspiration model, the effect of slowly melting snow and large storm events occurring on the last day of the month.

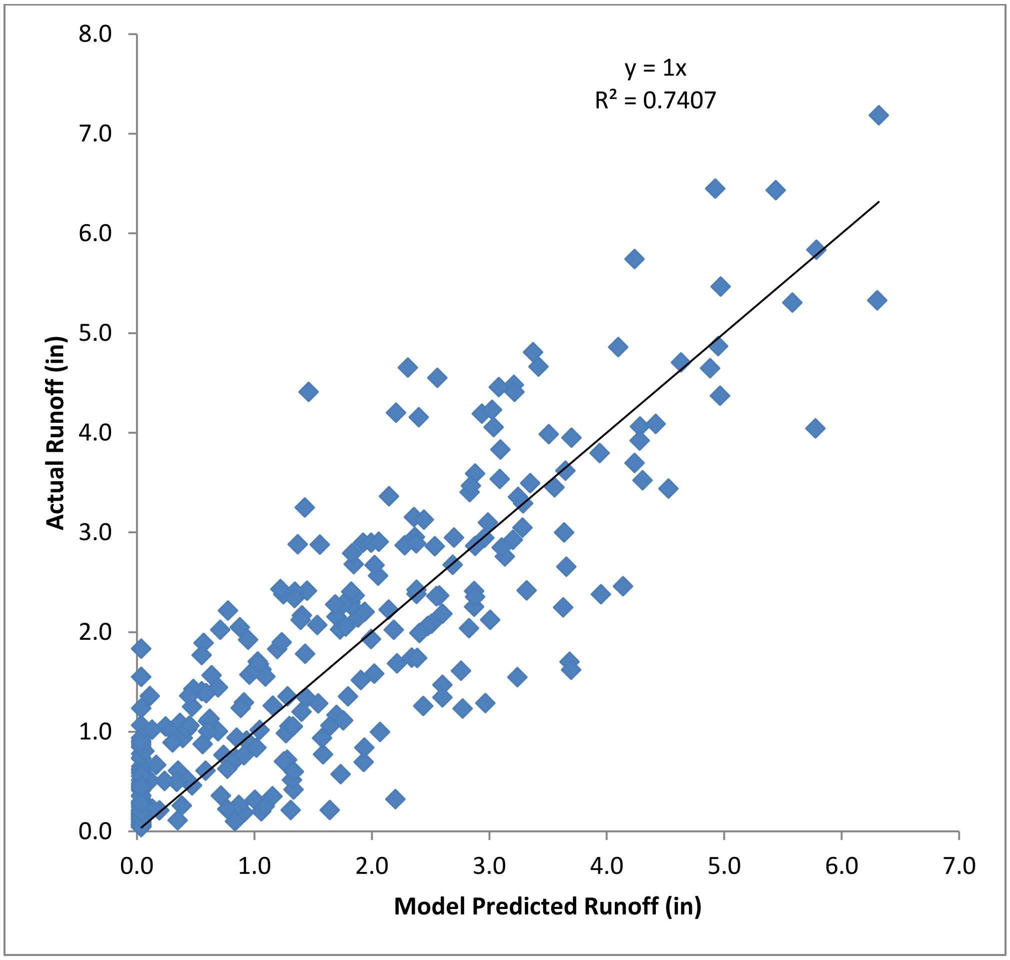



Figure 3-3  Comparison of Model Predicted Runoff and Actual Runoff during the study period (January 1986 – April 2013)

Where either historical data or the predictive model are utilized to predict future conditions, it is important to recognize the limitations affecting both approaches related to the length of the study period. A longer study period, where more years are included in the summary of past precipitation and runoff flows, will better enable the identification of low-probability event extremes. For example, with the 27-year study period utilized for these analyses (i.e., 1986 - 2013), the minimum August runoff flow depth of 0.04 inches per month corresponds to a low-flow event probability of approximately 4% in any given year. Even lower flows have almost certainly occurred in the past, prior to the period of study, and correspond to a smaller probability of occurrence in a given year.

### 3.5.9 Water Availability

An expression of the water availability at the outlet of the Greenbrier Watershed is provided in Table 3-13. This characterization is based on average seasonal stream gage flow data from the period 1936 – 2013, and the seasonal baseflow and 7Q10 values described above.

**Table 3-13 Ratio of predicted evapotranspiration (ET) to potential evapotranspiration (PET)**

| 1) Season | Mean Daily Discharge (cfs) | | 4) Average of Mean Daily Discharge minus 7Q10+10% (cfs) | 5) Average of Mean Daily Discharge minus Seasonal Baseflow |
|---|---|---|---|---|
| | 2) Average | 3) St. Dev. | | |
| Jan – Mar | 4171 | 4877 | 4115 | 2181 |
| Apr – June | 2701 | 3375 | 2645 | 1231 |
| July – Sept | 656 | 1344 | 600 | 336 |
| Oct – Dec | 1642 | 3031 | 1586 | 892 |

Columns 4 and 5 of Table 3-13 can be thought of as different expressions of how much water can, on average, be used at the outlet of the Greenbrier Watershed if a certain streamflow must be preserved. Column 4 identifies the average seasonal flow rate that could be utilized if the flow rate of 7Q10+10% were to be preserved. Since the 7Q10 flow rate is quite low, corresponding to a flow rate that only has a 10% chance of occurring during a continuous seven day period in any given year, Column 4 values are greater than Column 5 values. Column 5 values identify the average seasonal flow rate that could be utilized while preserving a flow rate equal to the seasonal baseflow (which is greater than the 7Q10 flow rate).

In the context of understanding how much water is truly “available” for use within the Greenbrier Watershed, it is important to note that the flow amounts indicated in Columns 4 and 5 of Table 3-13 are based on the average of mean daily discharge (i.e., Column 2 of Table 3-13). The implication of this is that, on average, 50% of the time the seasonal average of mean daily discharge will be greater than the amount indicated in Column 2, and 50% of the time it will be less than this amount. In fact, as demonstrated by the relatively large standard deviation values included in Column 3, flow rates are highly variable from year to year. This demonstrates the caution that should be taken when attempting to define how much water “will” be available for continuous use, and the importance of considering a water user’s relative appetite for risk that water will not be available during certain periods.

To illustrate this, consider the hypothetical scenario of a water user who is permitted to withdraw 336 cfs from the Greenbrier Watershed outlet, under the logic that this flow rate would, on average, preserve not only the summer baseflow (which happens to be the lowest seasonal baseflow), but all of the other seasonal baseflows as well. The key weakness of this logic is the phrase, “on average,” since there will be as many situations where this is not the case as where it is.

By subtracting the flow rate of 336 cfs from the actual recorded flow rates from 1936 – 2013, it is shown that this withdrawal would, in fact, not preserve the seasonal baseflow on 59% of the days during the period. The effect of very large storm events, which yields very large flow rates, is that the median flow rate and mean flow rate differ by an amount that accounts for the seasonal baseflow not being preserved half the time.

As an illustration of another means of considering water availability, Figure 3-5 demonstrates the relationship between withdrawal flow rate and the percentage of days where the 7Q10+10% flow rate would not be preserved in the stream. Withdrawing 92 cfs, for example, would correspond to the situation where stream flow would be less than the 7Q10+10% flow rate of 56 cfs on 10% of the days in the period 1936-2013.

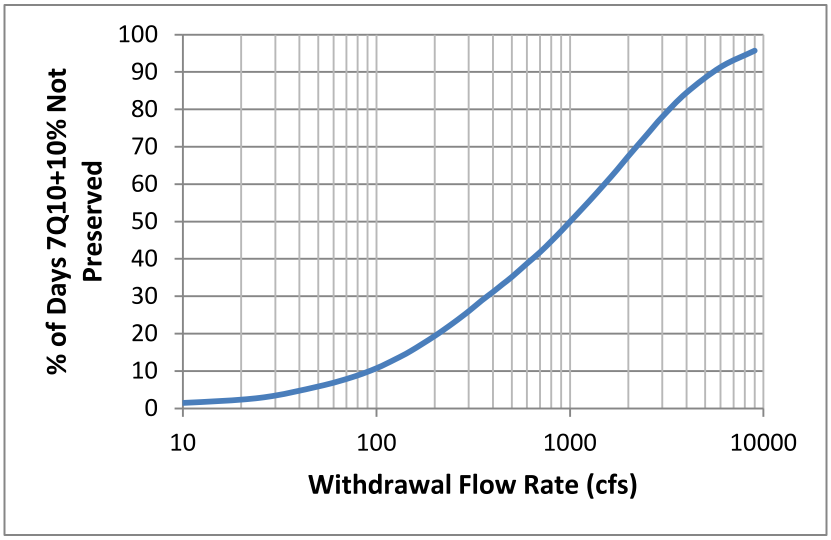



**Figure 3-4 Withdrawal flow rate vs. percent of days where the 7Q10+10% flow rate would not be preserved in the stream**

### 3.5.10 Primary Data Sources Utilized

Watershed boundary – USDA NRCS Data Gateway: http://datagateway.nrcs.usda.gov/GDGOrder.aspx

Runoff flow data – USGS Water Data:

http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=03184000

Precipitation – PRISM Climate Group: http://prism.oregonstate.edu/

Precipitation, Temperature, and other Weather Data – NOAA National Climatic Data Center:

http://gis.ncdc.noaa.gov/map/viewer/#app=cdo

Solar Radiation – Bluefield State College site, NREL: http://www.nrel.gov/midc/bsc/

### 3.5.11 Comparison of Marshall University and DEP Water Budgets

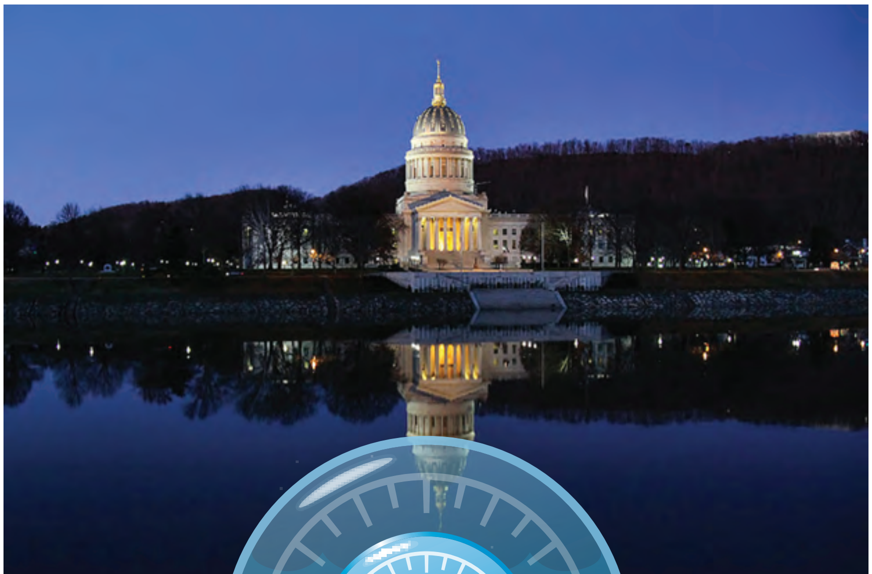
The ultimate goal of a water budget is to determine the amount of available water in the system. As stated previously in this chapter, potential ET rates vary both across the state and seasonally, and will be clearly defined by an ongoing USGS scientific investigation. Typically, ET rates are higher in the summer and fall and lower in the winter and spring. The final ET rate is dependent on soil characteristics, ambient temperatures, wind velocity, land cover, altitude, impervious surfaces and many other variables. One could pick any value of ET and multiply the volumes in table 3.3.1 by the residual percentage once seasonal and site specific ET rates are known. In order to derive the amount of available water, it is necessary to identify the quantities required to recharge the aquifers, quantify mine pool discharges and springs, account for soil absorption and the change in storage of the lakes and streams, and then apply the appropriate ET rate.

All of these variables result in a high potential for differing results when comparing two different water budget methods. Therefore, it is no surprise when comparing the DEP water budget results to the Marshall University water budget results for the Greenbrier Watershed that the numbers are quite different. As shown in the following table, Marshall University (MU) calculated the quantity of available water at the pour point of the Greenbrier Watershed for the summer, fall and winter to be much greater than the DEP method. However, the DEP method resulted in a much higher amount of water available in the spring than the MU method.

**Table 3-14 Comparison of water budget results**

| **Greenbrier Watershed** | **DEP Water Budget cfs** | **MU Water Budget cfs** | **Difference** |
|---|---:|---:|---|
| Summer | 97 | 336 | MU 239 cfs > DEP |
| Fall | 351 | 892 | MU 541 cfs > DEP |
| Winter | 1,164 | 2,181 | MU 1,017 cfs > DEP |
| Spring | 2,161 | 1,231 | DEP 930 cfs > MU |
| **TOTAL** | 3,773 | 4,640 | MU 867 cfs > DEP |

In conclusion, although a water budget can give you a tangible number to do some preliminary desktop water management planning, prior to any final project decisions, an onsite evaluation of the water availability should be performed and the variables in these water budget methods replaced by field verified numbers.



# CHAPTER FOUR
# FUTURE WATER OUTLOOK

**WATER USE SECTION** west virginia department of environmental protection

## Chapter - 4 Future Water Outlook

### 4.1 Future consumptive demand

There are two basic ways to estimate consumptive use. The first is to calculate the difference between how much water is withdrawn by a specific user and how much that user returns to the environment after use. For instance, the portion consumptively used by a public water provider is the total amount withdrawn from a source minus the amount that is discharged by the corresponding wastewater treatment plant. While seemingly straightforward, this method is complicated because discharge information related to each withdrawal can be misleading. Portions of the water go unaccounted for because of infiltration and losses. Additionally, water may be added as a result of inflow from stormwater before the discharge is measured.

> Consumptive use is "a function of climate, economics and culture" and is thus difficult to forecast with much certainty

The second way to calculate consumptive use is to multiply withdrawals by a coefficient that estimates how much water is removed from the system based on the type of water use. Again using public water supply as an example, estimates can be made for how much water is lost due to leaky infrastructure and through uses, such as outdoor watering, that typically lead to a loss. These estimates are made given what is known about water supply systems and the end uses. Regardless of the method used, consumptive use is "a function of climate, economics, and culture" (Shaffer & Runkle, 2007) and is thus difficult to forecast with much certainty. The coefficient method is most commonly used in large-scale studies since the level of detailed information required for the other method is rarely available.

Given the available water use data for West Virginia, the DEP selected the consumptive use coefficient method for this study. Using this method, estimates of past consumptive use and projections for 2020, 2030 and 2040 were made. High and low scenarios of consumptive use were developed for both past and projected withdrawals. These scenarios were completed to put boundaries around the possibilities and account for the inherent uncertainties in long-term forecasting. In order to make the future consumptive use estimates, withdrawal projections also had to be developed. Projections of both consumptive use and withdrawals were done for the state by the U.S. Geological Survey (USGS) on eight-digit hydrologic unit codes (HUC-8) (Figure 4-1) and by county. The methods used to develop the watershed and county projections do not allow the results to be compared because the assessments are of different geographic areas. This chapter focuses on the watershed-level results. The methods and results by county are available in Appendices P-T.

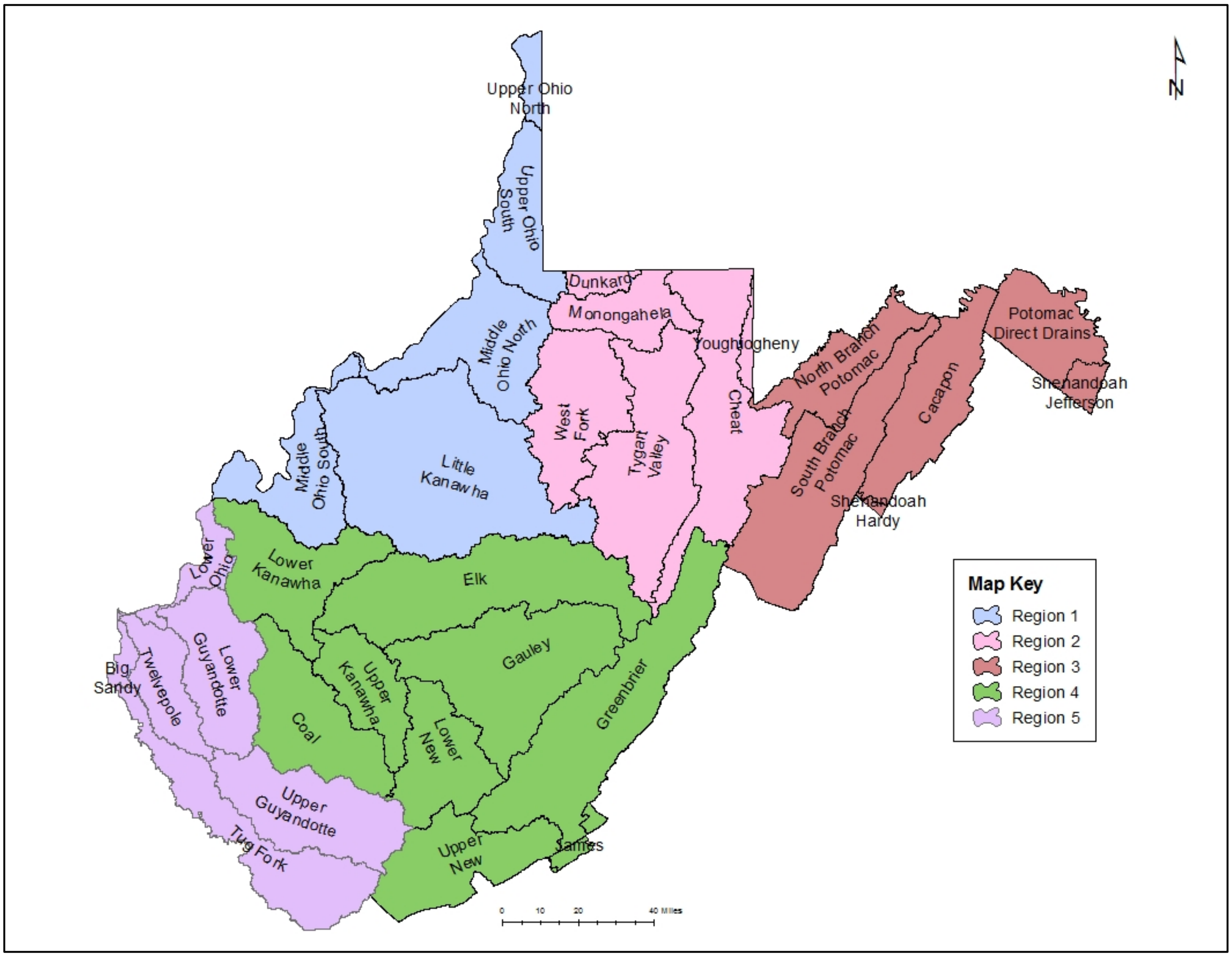



Figure 4-1 West Virginia has 32 HUC-8 watersheds and are shown divided into five regions.

## 4.2 Review of West Virginia Water Use Survey 2006 Final Report of Consumptive Use

Consumptive water use is defined by (Solley, Merk, & Pierce, 1988) as the part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the water body, surface water or groundwater source. Other sources of consumptive use information largely agree with this definition.

One way the DEP has sought to improve previous evaluation of consumptive use, to facilitate resource planning and management, is to consider Industry-specific consumptive uses

The *West Virginia Water Resources Protection Act Water Use Survey Final Report* includes consumptive use estimations calculated as withdrawals minus discharges (DEP 2006, Chapter 2, tables of results by county are in Appendices E and F). The report indicates that in some cases both withdrawal and discharge data were provided by users and, therefore, withdrawal minus return flow calculations could be made. In many instances; however, reliable data was not available to perform the calculation because the discharges were not metered, were metered but mixed with stormwater discharges, or the returned water was discharged to multiple points. One way the DEP has sought to improve previous evaluation of consumptive use, to facilitate resource planning and management, is to consider Industry-specific consumptive uses as presented in Section 4.3.

Chapter 7 (Section 7.3) of the 2006 report contains estimates of future water use by the industrial sector. These were calculated by the Marshall University Center for Business and Economic Research using industry-specific water use coefficients (referred to as “net use”) (Table 4-1). The coefficients are based on water use per-employee and are reported in gallons per-employee per-day (GED) (DEP, 2006). Appendix L (DEP, 2006), lists the 2005-2010 annual estimates by North American Industry Classification System (NAICS) code for counties and industries. Seven industry sectors were considered; namely, thermoelectric power; manufacturing; residential; a combined sector including arts, entertainment, and recreation; a combined sector including forestry, fishing, hunting, and agriculture; a mining sector that includes coal mining, stone quarries, and oil production; and a sector including eight other separately identified industries.

Marshall University used several methods to estimate net use including the Large Quantity User survey data; fixed industry-specific estimated net use rate; and net use rates from other sources such as USGS. An explanation of the estimation method used for each of these industries is provided in Chapter 7 (DEP, 2006). Residential net use was estimated at the county level using a total of sales to metered residential customers and the number of residential customers, to calculate a household average. Adjustments were made for counties where residential use data was unavailable.

**Table 4-1 Estimates of consumptive use coefficients used in DEP 2006 Chapter 7, a residential coefficient was not reported.**

| Use type | Consumptive use coefficient (%) |
|---|---|
| Thermoelectric | 1 |
| Manufacturing | 21 |
| Residential | -- |
| Art, entertainment, and recreation | 15 |
| Livestock | 80 |
| Crops | 90 |
| Logging | 2 |
| Mining | 20 |

A general limitation of using a per-employee rate is that it does not account for operational efficiencies achieved by many facilities that have been able to maintain output with reduction in employment or have increased their water use efficiency (DEP, 2006). There are general uncertainties inherent in each of the methods of estimating consumptive use coefficients, most related to the lack of data on withdrawals, discharges and/or the number of employees. The other area of uncertainty relates to applying average rates of withdrawal and use to facilities in different areas of the state. Understanding how much water is consumed in a watershed is essential to water resources planning to ensure the availability of sufficient amounts of water. Quantifying consumptive use can be challenging, however, because necessary empirical measurements are often not available or are fraught with uncertainties. Estimating consumptive use as was done in the 2006 report can be problematic due to the potential for over-generalization.

### 4.3 Choosing a Consumptive Use Estimation Method

Most studies of consumptive water use are concerned with estimating consumptive losses from the human use of water supply. However, a common source of uncertainty in the estimations of consumptive use is the evapotranspiration losses. Evapotranspiration is not typically included in the coefficient calculation methods. Another source of uncertainty in the methods evaluated here is measurement uncertainties. The accuracy of any measurement and recording of flow data is entirely dependent upon the equipment and practices at each reporting facility. There is typically no reporting or assessment of these inaccuracies and discrepancies. Another possible source of uncertainty relates to the reporting parameters. In a study using a county-based reporting scale, for instance, a withdrawal made in one county with an associated discharge or transfer to another county results in 100 percent consumptive use in the withdrawal county regardless of the actual consumptive use. A final source of uncertainty in consumptive use estimates is unreported withdrawals and discharges. With a reporting requirement threshold of 750,000 gallons withdrawn in any month, there are many users in West Virginia that are not required to report their withdrawals or associated discharges.

With a reporting requirement threshold of 750,000 gallons withdrawn in any month, there are many users in West Virginia that are not required to report their withdrawals or associated discharges.

The Shaffer and Runkle (2007) report was used in this study for two reasons. First, it compiled consumptive use coefficients from approximately 100 sources, analyzing the methods and uncertainties of each. Second, the study provided statistical analyses to show the distribution of the coefficients by water use category, thereby providing insight into the underlying uncertainties. The methods used to develop the coefficients for each use category were also described.

## 4.4 LQU Withdrawals

The projections made by the DEP are based on water withdrawal data from the Large Quantity User (LQU) database. A detailed explanation of the management of the database and methodology used to deal with reporting deficiencies can be found in Chapter - 2. For this study, annual withdrawal amounts were used. No estimates were made for users who did not meet the LQU threshold or who are exempt from reporting, such as self-supplied water for domestic use or agricultural use. Additionally, while not in the LQU database (except for the water supply brokers represented in the Frac Water use category), information on water used in the hydraulic fracturing process from Marcellus Shale is collected separately and maintained in the Frac Water Reporting database. A detailed explanation of the projection methodology for the Marcellus data is in Section 4.8. Because the data was collected over a different period of time, water use for this industry is considered separately.

Withdrawals and consumptive use were not projected for two of the LQU database water use categories. Both hydroelectric and aquaculture uses are considered to be non-consumptive. The Agriculture/aquaculture use category contained nearly all aquaculture withdrawals with only one nursery reporting enough withdrawals for irrigation to be considered a LQU. For both hydroelectric and aquaculture uses, water tends to run through a system instead of being used for a process or incorporated into a product. The Marcellus Shale projection was done using data from the Frac Water Reporting database, not included in the LQU database.

In order to make past consumptive use estimates, as well as withdrawal and consumptive use projections for this project, water use categories had to be combined. The reasons for this are explained in Section 4.3. The categories used for consumptive use are:

- Mining and Petroleum (LQU database categories - Mining and Petroleum)
- Manufacturing (LQU database categories - Industrial, Chemical and Timber)
- Public Water Supply
- Recreation
- Thermoelectric
- Marcellus Shale/Hydraulic Fracturing

The results from creating the Mining and Petroleum and Manufacturing categories are shown in Appendices P and Q, respectively. The withdrawals by reorganized use types are displayed in Figure 4-2 and Figure 4-3. Marcellus Shale withdrawals are not shown here because data was not collected over the same time period. Refer to Section 4.8 for the Marcellus Shale data.

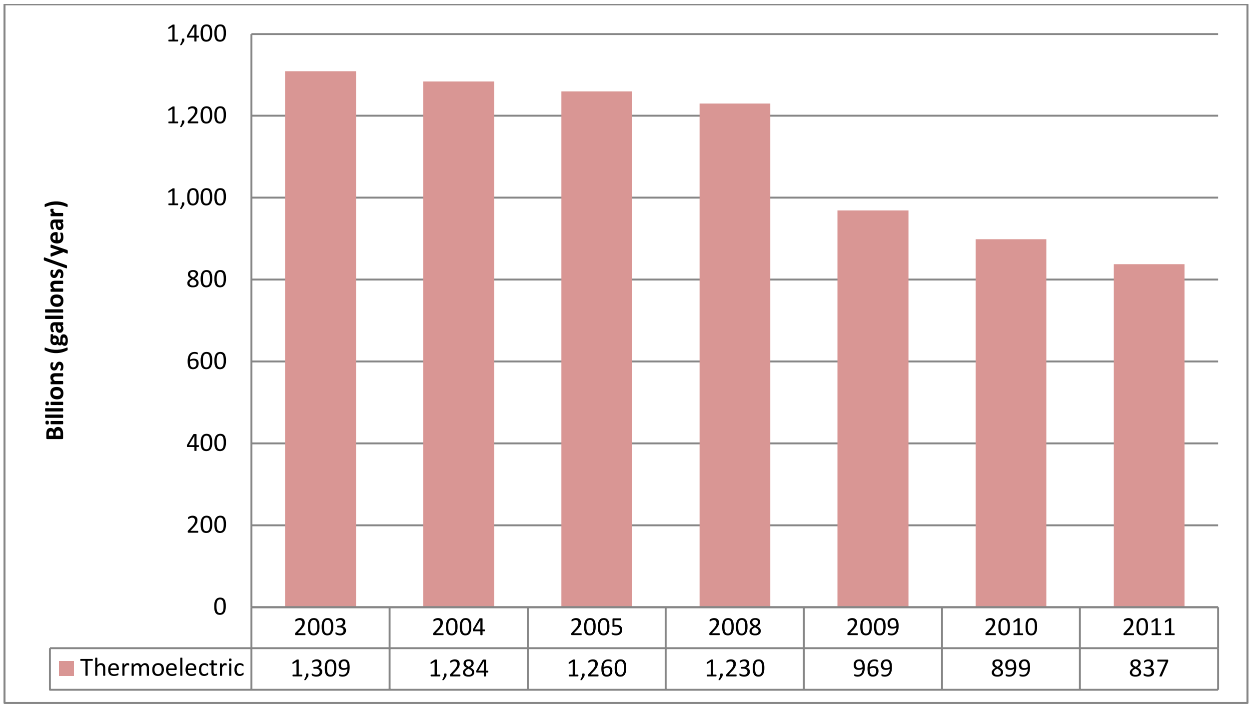
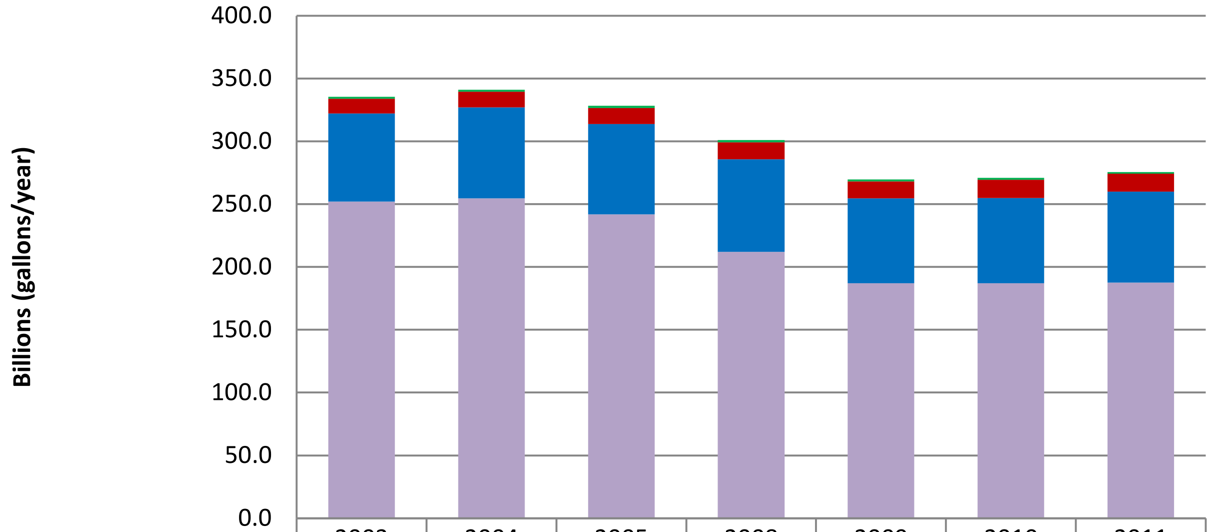



**Figure 4-2 Annual withdrawals from the LQU database for the (amended) Thermoelectric* group in billions of gallons. *Shown separately due to scale.**




| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|
| Recreation | 1.6 | 1.6 | 1.8 | 1.8 | 1.6 | 1.7 | 1.4 |
| Mining and Petroleum | 11.7 | 12.3 | 12.6 | 13.4 | 13.5 | 14.5 | 14.2 |
| Public Water Supply | 70.2 | 72.4 | 72.0 | 73.6 | 67.5 | 67.9 | 72.5 |
| Manufacturing | 252.0 | 254.7 | 241.8 | 212.1 | 187.1 | 186.9 | 187.5 |

**Figure 4-3 Annual withdrawals from the LQU database for (amended) groups in billions of gallons.**

Figure 4-2 shows withdrawals by the Thermoelectric category, which is the largest withdrawer of water. The Manufacturing category follows behind the Thermoelectric category, and is depicted in Figure 4-3 along with the other categories. According to the three-year average, the majority of withdrawals occur in four watersheds – North Branch Potomac, Middle Ohio North, Upper Ohio South and Upper Kanawha. The large withdrawals in each of these watersheds are driven by withdrawals for thermoelectric use. The three-year average calculation explained in Chapter - 2 was used to generate the map of the distribution of withdrawals among watersheds seen in Figure 4-4. The changes in withdrawals over time for each watershed are presented in the West Virginia Watershed Descriptions companion report and Appendices P-T.

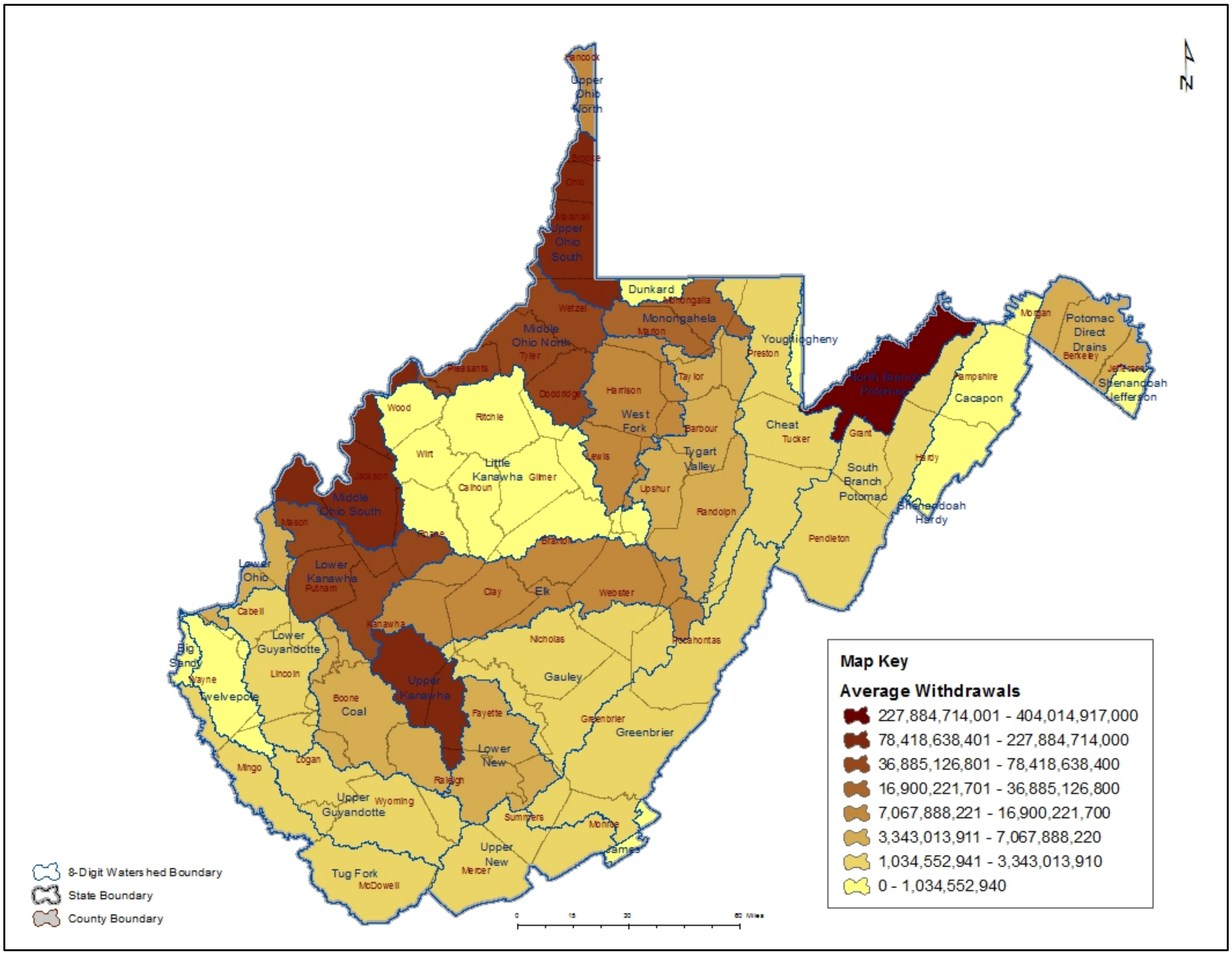



Figure 4-4 Average annual withdrawals occurring due to the activity of the recombined SIC groups, measured in gallons.

## 4.5 Consumptive Use Scenarios

As mentioned previously, this section uses the consumptive use coefficients from Shaffer and Runkle (2007). Their study, *Consumptive Water-Use Coefficients for the Great Lakes Basin and Climatically Similar Areas*, compiled consumptive use coefficients from nearly 100 sources around the world, focusing on those that could inform the selection of consumptive use rates in the Great Lakes region and climatically similar areas. The study indicates that West Virginia has a climate similar to the Great Lakes region and, therefore, it is reasonable to apply rates from "climatically similar areas" to the state in this study. These areas were determined by temperature and precipitation patterns, water resource region, and by comparable water use and consumptive loss rates. Other climatically similar areas indicated by the study are Iowa, Missouri, Tennessee, Kentucky, Virginia, Maryland, Delaware, New Jersey, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire and Maine.

Table 4-2 is a modified version of the results table that appears in Shaffer and Runkle (2007). The table shows statistical values for consumptive use coefficients in the Great Lakes Basin, climatically similar areas and the world. The median and 75$^{th}$ percentile values for Domestic and Public Supply, Industrial, Thermoelectric Power, and Mining from the climatically similar areas were used to estimate consumptive use for this study's Public Water Supply, Manufacturing, Thermoelectric, and Mining and Petroleum water use categories, respectively (see bold values in Table 4-2). The median values were used to generate a low scenario of consumptive use and the 75$^{th}$ percentile values were used for a high scenario. For the Recreation category, an average of the industrial and irrigation consumptive use coefficients from Shaffer and Runkle was used (56.5 for the high scenario and 55 for the low scenario). These were selected because the LQU database definition of Recreation withdrawals includes both golf courses and businesses, like hotels and casinos. The consumptive use estimate for each year (2003-2005, 2008-2011) was determined by multiplying each facility's estimated or recorded withdrawal by the corresponding consumptive use coefficient.

**Table 4-2 Consumptive use factors for the Great Lakes Basin, climatically similar areas, and the world from Shaffer and Runkle 2007.**

| Water Use Category | Statistics | | | | | |
|---|---|---|---|---|---|---|
| | Minimum Value | 25$^{th}$ Percentile | Median Value | 75$^{th}$ Percentile | Maximum Value | Number of References |
| **Climatically similar areas** | | | | | | |
| Domestic and Public Supply | 6 | 10 | **15** | **20** | 70 | 68 |
| Industrial | 0 | 4 | **10** | **13** | 34 | 97 |
| Thermoelectric Power | 0 | 0 | **2** | **4** | 75 | 75 |
| Irrigation | 37 | 90 | 100 | 100 | 100 | 75 |
| Livestock | 10 | 86 | 100 | 100 | 100 | 73 |
| Commercial | 3 | 8 | 10 | 13 | 33 | 61 |
| Mining | 0 | 10 | **14** | **20** | 86 | 83 |

Appendices P-T summarizes estimates of past consumptive use in West Virginia using the coefficients discussed in this section (except for Marcellus Shale which is described below). Figure 4-5 indicates that the Thermoelectric and Manufacturing sectors consumptively use the most water. Total consumptive use is driven by large withdrawals in the Thermoelectric sector despite low consumptive use coefficients (Figure 4-5). Although the Shaffer and Runkle consumptive use numbers used for thermoelectric range between 2-4%, power plants with SOx scrubbers and hyperboloid cooling towers are known to have a much larger consumptive use, approaching 70% (Allegheny Energy Supply prepared by URS Corporation, 2003). This difference is significant and could greatly impact thermoelectric consumptive use numbers in West Virginia. Going forward, site specific analysis will be pursued to improve estimates of consumptive use in West Virginia. The Manufacturing sector has a high consumptive use rate that leads to high consumptive use totals even with the lower withdrawal totals. The total consumptive use of the three-year average is displayed for the high scenario on map in Figure 4-6. For the Marcellus Shale use category, Section 4.8

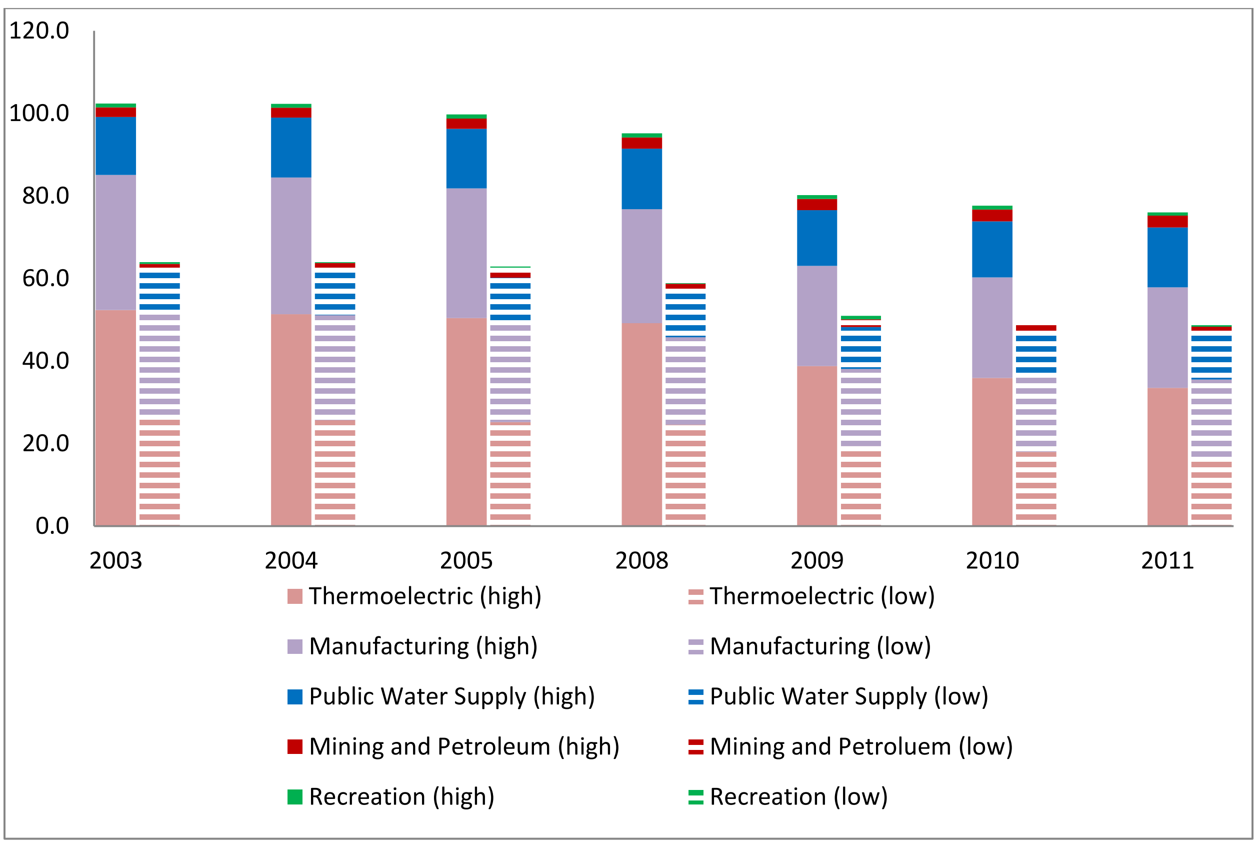



**Figure 4-5 Annual high and low consumptive use scenario calculations (based on Shaffer and Runkle consumptive use coefficients) in billions of gallons.**

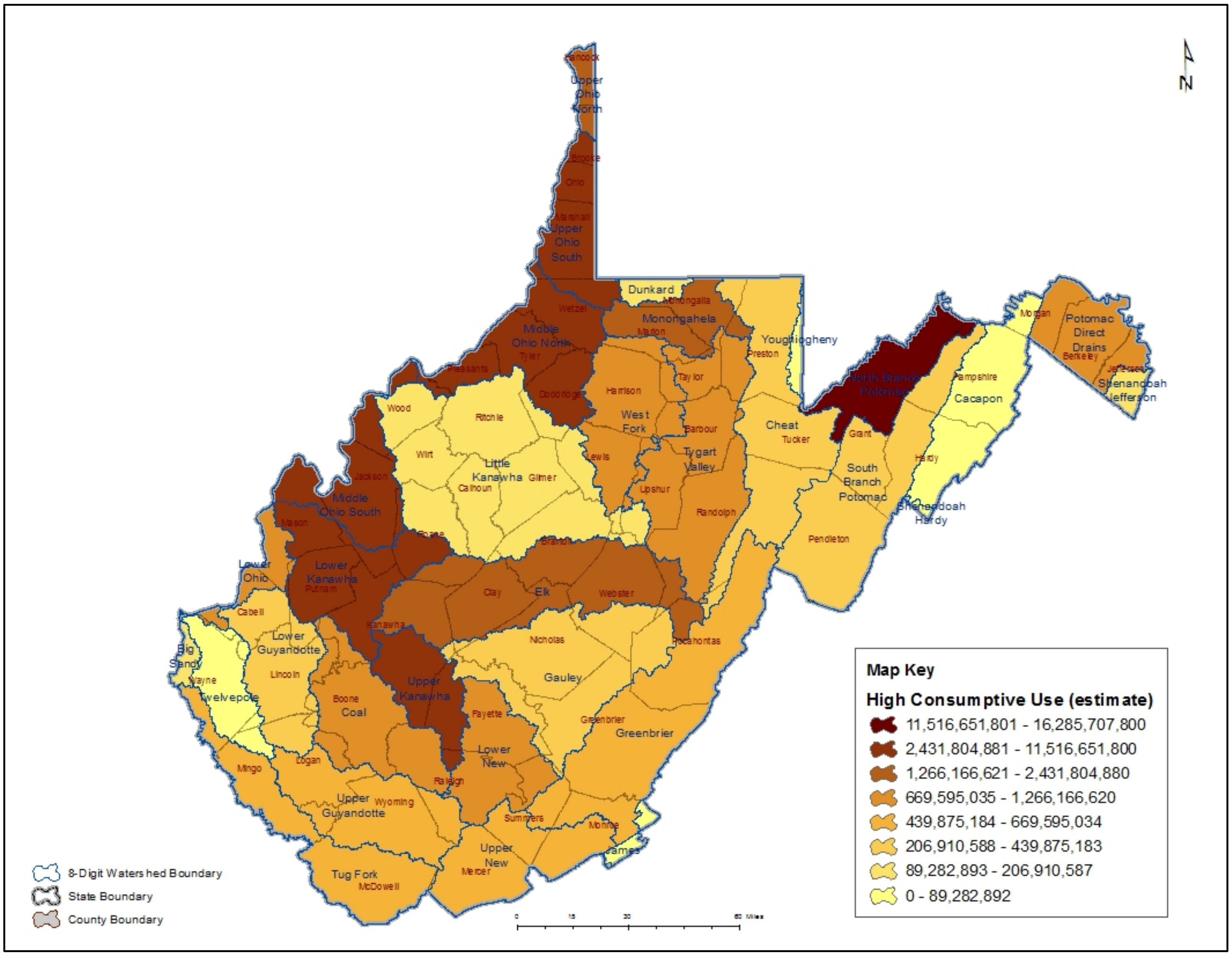



**Figure 4-6 Estimate of average annual consumptive use (based on a high consumptive use scenario) occurring due to the activity of the recombined SIC groups, measured in gallons.**

## 4.6 Future Withdrawal Projections

To project consumptive use, water withdrawal projections were completed first. This section explains the methods used and assumptions made to project withdrawals in 2020, 2030 and 2040. The consumptive use coefficients discussed in Section 4.5 were then applied to these projected withdrawals to estimate consumptive use by watershed and county as explained in Section 4.6.1.

### 4.6.1 Withdrawal Projection Methods

As with any forecast of water use, many assumptions were made about conditions in the future. The required assumptions include how many people will be using water and for what purposes; how economic markets may change and how that will affect water use and what technologies will be in place that could affect use rates. The scope of this project limited the amount of research that could be done regarding future conditions and technologies in the water use categories. Therefore, projections were based on existing data that could be applied statewide.

**General Withdrawal Projection Steps:**

1. Add withdrawals by watershed (or county) for the years of data in the LQU database.
2. Add the number of employees or people by watershed (or county) for the years of data in the LQU database.
3. Divide withdrawals by employees/people in each watershed (or county) to get a per employee/person water use rate for the years of data in the LQU database.
4. Average the per employee/person use rates across the years of data to get one use rate.
5. Multiply the average use rate by the future number of employees/people in each watershed (or county) to get a total withdrawal estimate.

Figure 4-7 Withdrawal projection procedure

Withdrawals were projected at the watershed and county levels – not for individual withdrawal points (Figure 4-7). While similar methods were used for the two sets of projections, the geographic differences between them do not allow the results to be compared. The basis for the projections was how much water was withdrawn by a given sector between 2003 and 2011 and how much growth or contraction the sector is expected to see in the future. This allowed historic water uses to be averaged over the total number of people or employees estimated to live (population) or work (employees) in a given geographic area. Variation in past use was retained by using these per-person and per-employee water use rates at the watershed and county scale. Per-individual use rates were calculated for each watershed and county by water use type.

These per-individual calculations were done for the Mining and Petroleum, Recreation, Manufacturing and Public Water Supply use categories. For these sectors, the total reported water withdrawals in

2003, 2004, 2005, 2008, 2009, 2010 and 2011 were divided by the number of individuals using the water in each watershed and county for the respective year. To estimate future water use, the number of individuals were projected and then multiplied by the average water use rate for the corresponding geographic area. Projections were done for 2020, 2030 and 2040.

West Virginia employment data was available by county through (WorkForce West Virginia, 2012). This data was available by NAICS code for years corresponding to withdrawal data in the LQU database. There were some instances where a withdrawal existed in the LQU database, but no employment data was reported for that county. These cases were handled on an individual basis and the methods used are explained in the following sections.

Employment projections used change factors that were specific to West Virginia, or represented expected national rates of change. The West Virginia-specific rates came from the *2013 West Virginia Economic Outlook*. This is the most recent annual report from the West Virginia University Bureau of Business and Economic Research (BBER). Among other items, these reports provide an overview of the current and future economic situation and forecast jobs by industry for the state. The report relies on researchers at BBER and industry experts throughout the state. Their local knowledge is combined in the report with data from such sources as WorkForce West Virginia, IHS Global Insight, U.S. Bureau of Economic Analysis, U.S. Bureau of Labor Statistics and the U.S. Energy Information Administration. The national-level change rates came from the U.S. Bureau of Labor Statistics' 2012 *Industry employment and output projections to 2020* (Bureau of Labor Statistics, 2012). This is a biennial report that projects employment from data collected by their Employment Projections Program. Rates of change in employment by industry reflect national economic trends.

The following sections detail how the water withdrawal projections were completed for each water use category. Each use category has a corresponding appendix that provides a detailed description of the methods and the results.

#### 4.6.1.1 Mining and Petroleum

In order to implement the withdrawal projection method described above, the relevant employment data was collected[2]. To make the best use of the available employment data, the LQU water use categories of Mining and Petroleum were combined into one category and organized by watershed and county (Tables P-1 and P-6, respectively, in Appendix P). These uses are defined as:

- Mining – Coal mining, coal processing plants, quarries, any other type of mining activity where rocks or minerals are removed from the earth.
- Petroleum – Waterfloods. Does not include water used when hydrofracturing a well.

A few NAICS codes were considered for use under the natural resources and mining sector. The mining, quarrying, and oil and gas extraction sector (code 21) includes:

> "establishments that extract naturally occurring mineral solids, such as coal and ores; liquid minerals, such as crude petroleum; and gases, such as natural gas. The term mining is used in the broad sense to include quarrying, well operations, beneficiating (e.g., crushing, screening, washing, and flotation), and other preparation customarily performed at the mine site, or as a part of mining activity (BLS 2013)."

A subsector of this category is the "mining (except oil and gas)" category (code 212) which is comprised of industries that:

> "primarily engage in mining, mine site development, and beneficiating (i.e., preparing) metallic minerals and nonmetallic minerals, including coal. The term 'mining' is used in the broad sense to include ore extraction, quarrying, and beneficiating (e.g., crushing, screening, washing, sizing, concentrating, and flotation), customarily done at the mine site."

[2] Refer to Appendix P for a step-by-step explanation of the methods used and all tables related to Mining and Petroleum calculations.

The Petroleum water use category was not considered independently because most of the relevant county employment data was not separated from gas employment. To come up with employment figures that would allow for per-employee water use calculations, a series of assumptions were made. In the counties where there were no reported withdrawals for the hydraulic fracturing of Marcellus Shale, code 21 was used to capture all mining and petroleum employment. This assumes that jobs in addition to mining were all petroleum-related, not gas.

In counties with reported Mining, Petroleum, and Marcellus Shale withdrawals in any year, code 212 was used to avoid considering increases in employment likely due to the development of natural gas extraction. This assumption – that water used in the Mining and Petroleum category should be matched with the employment only in the mining sector – is reasonable because most job growth in the oil and gas sector in recent years can be attributed to Marcellus Shale development (West Virginia University, College of Business and Economics, 2012). The same employment NAICS code for each county was used over the period of record in the

**Steps for apportioning county employment data to watersheds:**

1. Determine which watersheds cover each county.
   <u>Example:</u> Portions of Webster County are in the Elk, Gauley, and Little Kanawha watersheds
2. Determine the portion of the county withdrawal that occurs in each overlapping watershed.
   <u>Example:</u> In 2004 there were five withdrawals in
   Webster County:
   Total Webster County withdrawal: 353,884,000 gallons Elk: 247,515,000 gallons (70% of county withdrawal)
   Gauley: 106,369,000 gallons (30% of county withdrawal)
   Little Kanawha: 0 gallons (0% of county withdrawal)
   *Repeat this step for each county.
3. Apply withdrawal proportions to county employment totals (round results to a whole number).
   <u>Example:</u> 2004 Webster County mining employment:
   375
   Elk employment: 375 employees * 70% = 263
   Gauley employment: 375 employees * 30% = 113
   Little Kanawha employment: 375 employees * 0% = 0
   *Repeat this step for each county.
4. Add the employees in each watershed.

**Figure 4-8 Procedure for apportioning county employment data to watersheds**

LQU database to get consistent employee use rates regardless of when development of the Marcellus Shale began in a certain area.

Table P-8 shows the employment numbers used for each county. These employment numbers were used to develop per employee use rates by county (Table P-9).

To estimate employment numbers by watershed, county employment was apportioned to the watershed-level using the method explained in Figure 4-8. The employment numbers for each watershed are shown in Table P-3. High and low employment projections were based on 2011 employment data. The high scenario increased employment annually by 0.4 percent (Equation 1). This annual rate came from the (Bureau of Labor Statistics, 2012), which predicts that jobs in the mining sector will increase at this rate through 2020. This rate was also applied for the 2030 and 2040 projections to represent a steadily increasing number of employees. The low scenario used an annual decreasing rate of 1.7 percent predicted by the *2013 West Virginia Economic Outlook* (West Virginia University, College of Business and Economics, 2012) through 2017. This rate was applied for the 2020, 2030 and 2040 scenarios.

**Equation 1**

$$E_{t2} = E_{t1} \times (1 \pm r)_{(t2-t1)}$$

Where, $E$ is the employees at time $t$, $t$ is the year and $r$ is the annual rate of change applied to employment.

Using the employment projections and the average per employee water use rate calculated from the historic data, withdrawal projections for the Mining and Petroleum sector were calculated using Equation 2. The average per employee water use rates for the Mining and Petroleum sector by watershed and county are in Table P-4 and Table P-9, respectively.

**Equation 2**

$$W_2 = E_{t2} \times U_{\alpha}$$

Where, $W_2$ is the forecasted withdrawal and $U_{\alpha}$ is the average use rate.

Not all of the counties had employment data available from WorkForce West Virginia. For these counties – Brooke, Hancock, and Pendleton – the annual rates were applied directly to the 2011 water withdrawal.

The Mining and Petroleum watershed-level withdrawal and consumptive use projections are in Table P-5 and the county-level projections are in Table P-10.

#### 4.6.1.2 Manufacturing

In order to project the Industrial, Chemical, and Timber use categories using employment and industry data, the withdrawals were combined into a single Manufacturing category by watershed and county (Tables Q-1 and Q-6, respectively, in Appendix Q)[3]. The description of each category explains that the water in all categories is used for manufacturing:

- Timber – Including facilities that manufacture wood products – pulp mills, charcoal manufacturers, dimensional lumber, etc.
- Industrial – General manufacturing other than chemical.
- Chemical – Manufacture of chemicals, chemical compounds, etc., regardless of feedstock source.

Combining the water uses into one Manufacturing category allowed employment data from (WorkForce West Virginia, 2012) to be used to calculate per employee use rates by watershed and county. To do this, employment numbers for NAICS code 31-33 were pulled for the counties where a Manufacturing withdrawal was reported in the LQU database (Table Q-8). NAICS code 31-33 covers:

> "establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products. Establishments in the Manufacturing sector are often described as plants, factories, or mills and characteristically use power-driven machines and materials-handling equipment. However, establishments that transform materials or substances into new products by hand or in the worker's home and those engaged in selling to the general public products made on the same premises from which they are sold, such as bakeries, candy stores, and custom tailors, may also be included in this sector. Manufacturing establishments may process materials or may contract with other establishments to process their materials for them. Both types of establishments are included in manufacturing" (Bureau of Labor Statistics, 2013).

[3] Refer to Appendix Q for a step-by-step explanation of the methods used and all tables related to Manufacturing calculations.

Using the same method described in Figure 4-8 in the previous section, the county-level employment data was transformed to the watershed level (Table Q-3). Per-employee water use rates for the Manufacturing sector were calculated for each watershed and county (Table Q-4 and Table Q-9, respectively).

In order to project withdrawals into the future, employment figures were projected for 2020, 2030 and 2040. A high and a low scenario were created using two rates of change for employment in the Manufacturing sector (Equation 1). For the high scenario, employment in each county was increased by 1.5 percent annually. This is the rate that the *2013 West Virginia Economic Outlook* predicts employment will grow by between 2012 and 2017, the forecast period for the report (West Virginia University, College of Business and Economics, 2012). While the report predicts this rate of growth only through 2017, it was used for the three projection years to represent a high water withdrawal scenario. For the low scenario, a decreasing rate of employment, 0.1 percent annually, was used per a Bureau of Labor Statistics projection out to 2020 (Bureau of Labor Statistics, 2012). To represent a low water withdrawal scenario, this rate was used for the 2030 and 2040 projections as well. The projected number of employees and the average water use rates were used to estimate total withdrawals by watershed and county using Equation 2. Table Q-5 and Table Q-10 show the results of the high and low scenario projections by watershed and county, respectively.

#### 4.6.1.3 Recreation

The Recreation water use projection used the same method as the Mining and Petroleum and Manufacturing sectors[4]. For employment data, the Leisure and Hospitality NAICS category was used. Leisure and Hospitality contains two subcategories: Arts, entertainment, and recreation (code 71) and accommodation and food services (code 72) (Bureau of Labor Statistics, 2013). These categories cover the water uses in the Recreation category, among others such as restaurants, bars, theaters, and museums. To use the employment data to project Recreation water use, employment under code 71 was used in combination with select categories under code 72 that related to the Recreation water uses. Table R-8 in Appendix R provides the estimate of employees in each county with a Recreation water use withdrawal. Employment at the watershed level was derived using the steps detailed in Figure 4-8 (Table R-3).

[4] Refer to Appendix R for a step-by-step explanation of the methods used and all tables related to Recreation calculations.

Employment projections were based on rates from the *2013 West Virginia Economic Outlook* (2012) and the Bureau of Labor Statistics (2012). The Bureau of Labor Statistics assumes that Leisure and Hospitality employment will increase annually by 1.0 percent through 2020. This rate was used to develop the high scenario through 2040. Alternatively, the low scenario used a zero percent change in employment for 2020, 2030 and 2040 (West Virginia University, College of Business and Economics, 2012). The projected numbers of employees by watershed and county are in Table R-3 and Table R-8 (Equation 1). Dividing the water withdrawals in each watershed or county by the number of employees yielded the per employee use rates (Table R-4 and Table R-9, respectively). The projected withdrawals were estimated by multiplying the average per-employee water use rate for the years of data in the LQU database by the projected number of employees by watershed (Table R-5) and by county (Table R-10) (Equation 2).

#### 4.6.1.4 Public Water Supply

Projections for the Public Water Supply sector used a slightly different method from that used for the sectors described above[5]. Only one withdrawal scenario was created for this use category as there is more confidence in the future population projections.

The projections for this category relied on past and forecasted population data. County population data for 2000 and 2010 was obtained from the U.S. Census. The population data was at the Census block level making it possible to assign each block to a watershed. The process was completed for the 2010 data. For the blocks that crossed more than one watershed, satellite imagery was used to determine the number of households, and therefore population, which should be assigned to each watershed. This level of detail was not available for the 2000 block data. The process used to assign the population in each block to a watershed was: if a block crossed more than one watershed, the population in that block was proportionally distributed to the watersheds based on the overlapping land areas of the watershed and blocks. Once this was done, the 2000 population was aggregated by watershed.

To estimate population for 2003, 2004, 2005, 2008 and 2009 figures were interpolated from the known years of data, and 2011 was extrapolated by watershed and county (Table S-3 and Table S-8, respectively, in Appendix S). Using these annual population estimates, a per capita use rate was calculated for each county and watershed by dividing the withdrawal in a given year by the estimated number of people in the watershed and county that year (Table S-4 and Table S-9, respectively).

[5] Refer to Appendix S for a step-by-step explanation of the methods used and all tables related to Public Water Supply calculations.

To project withdrawals in 2020, 2030 and 2040, the average per capita withdrawal was multiplied by the future number of people in each watershed (Table S-5). This process used county population projections for 2020 and 2030 from *Population Projection for West Virginia Counties* (Cristiadi, 2011) and accounts for potential growth and contraction areas. Population in 2040 was extrapolated from these estimates. The rate of change expected in each county was applied to the corresponding 2011 block populations which allowed for a projection at the watershed level. County projections were also completed using withdrawal and census data by county (Table S-10).

#### 4.6.1.5 Thermoelectric

The Thermoelectric withdrawal projections used industry growth forecasts for both the high and low scenarios and did not consider employment as a factor due to limited specific employment data[6]. The *2013 West Virginia Economic Outlook* predicts an annual decrease of 2.3 percent in coal-fired power capacity through 2017 (West Virginia University, College of Business and Economics, 2012). This rate was applied to the 2020 projection in both the high and low scenario. The U.S. Energy Information Administration's 2013 *Annual Energy Outlook* predicts that nationally the "total coal-fired generating capacity falls from 318 gigawatts in 2011 to 278 gigawatts in 2040" (U.S. Energy Information Administration, 2012). This is an annual decrease of 0.46 percent. This rate was used for the high and low scenario's 2030 and 2040 projections. It is possible that there will be a decrease in thermoelectric power production in the near term given U.S. Environmental Protection Agency emission regulations and low natural gas prices. The decrease in thermoelectric power production may cause plant closures in the 2015 timeframe. Thus, the 2.3 percent decrease for 2020, and a slower rate – 0.46 percent – in 2030 and 2040, could reasonably be expected.

The low scenario projection removes those thermoelectric plants that are already slated to close prior to 2020. The industry rates described above were then applied to represent a lower withdrawal scenario. The power stations removed and the respective watersheds affected were:

- First Energy: Albright, Willow Island and Rivesville (First Energy Corp. 2012)
    - Cheat Watershed
    - Middle Ohio North Watershed
    - Monongahlea Watershed

[6] Refer to Appendix T for a step-by-step explanation of the methods used and all tables related to Thermoelectric calculations.

- AEP: Kammer, Kanawha River and Phillip Sporn (AEP 2013)
    - Upper Ohio South Watershed
    - Upper Kanawha Watershed
    - Middle Ohio South Watershed

The high and low withdrawal projections are shown by watershed and county respectively in Table T-3 and Table T-6 in Appendix T.

### 4.6.2 Withdrawal Projection Results

The projected withdrawals for the high and low scenarios in 2020, 2030 and 2040 are shown by watershed in Table 4-3 and by water use category in

Table 4-4. The Thermoelectric sector continues to withdraw the greatest amount of water in the state. The watersheds with the greatest withdrawals – North Branch Potomac, Middle Ohio South, Upper Ohio South and Upper Kanawha – all have large thermoelectric withdrawals. Both of the scenarios show a decrease in the total amount of water withdrawn over time. Though, some sectors show an increase in withdrawals in the high scenario and decrease in the low scenario; this is indicative of the uncertainty faced in long-term predictions.

The Thermoelectric sector continues to withdraw the greatest amount of water in the state. The watersheds with the greatest withdrawals – North Branch Potomac, Middle Ohio South, Upper Ohio South and Upper Kanawha – all have large thermoelectric withdrawals.

**Table 4-3 Current average annual withdrawals and future high and low scenario estimates by watershed, in billions of gallons per year.**

| HUC 8 | Current 3 Year Average (Bgal/yr) | High Scenario Withdrawals (Bgal/yr) | | | Low Scenario Withdrawals (Bgal/yr) | | |
|---|---|---|---|---|---|---|---|
| | | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Big Sandy | 0.95 | 0.94 | 0.89 | 0.83 | 0.94 | 0.89 | 0.82 |
| Cacapon | 0.72 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Cheat | 2.05 | 2.02 | 2.04 | 2.05 | 1.33 | 1.35 | 1.35 |
| Coal | 5.16 | 5.44 | 5.43 | 5.42 | 5.34 | 5.23 | 5.12 |
| Dunkard | 0.60 | 0.96 | 0.97 | 0.97 | 0.94 | 0.93 | 0.91 |
| Elk | 12.14 | 11.68 | 11.18 | 10.53 | 11.68 | 11.18 | 10.52 |
| Gauley | 1.66 | 1.98 | 1.95 | 1.90 | 1.96 | 1.92 | 1.85 |
| Greenbrier | 1.84 | 1.84 | 1.82 | 1.75 | 1.83 | 1.81 | 1.73 |
| James* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Little Kanawha | 1.03 | 1.16 | 1.13 | 1.06 | 1.16 | 1.13 | 1.06 |
| Lower Guyandotte | 1.51 | 1.52 | 1.50 | 1.46 | 1.51 | 1.48 | 1.44 |
| Lower Kanawha | 78.42 | 67.78 | 68.50 | 69.21 | 66.95 | 66.82 | 66.67 |
| Lower New | 4.72 | 4.92 | 4.81 | 4.60 | 4.91 | 4.80 | 4.57 |
| Lower Ohio | 5.24 | 5.20 | 5.16 | 5.10 | 5.19 | 5.15 | 5.08 |
| Middle Ohio North | 68.86 | 68.27 | 68.72 | 69.14 | 45.50 | 45.34 | 45.14 |
| Middle Ohio South | 227.88 | 131.72 | 131.41 | 130.98 | 24.40 | 24.34 | 24.17 |
| Monongahela | 36.89 | 38.39 | 38.84 | 39.39 | 37.78 | 38.21 | 38.73 |
| North Branch Potomac | 404.01 | 394.68 | 392.87 | 391.04 | 394.68 | 392.86 | 391.04 |
| Potomac Direct Drains | 7.07 | 8.88 | 9.96 | 11.06 | 8.83 | 9.85 | 10.90 |
| Shenandoah Hardy* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Shenandoah Jefferson | 0.80 | 0.92 | 1.04 | 1.14 | 0.92 | 1.04 | 1.13 |
| South Branch Potomac | 1.98 | 2.10 | 2.11 | 2.03 | 2.10 | 2.11 | 2.03 |
| Tug Fork | 3.34 | 3.76 | 3.56 | 3.32 | 3.73 | 3.50 | 3.23 |
| Twelvepole | 0.45 | 0.62 | 0.61 | 0.60 | 0.61 | 0.59 | 0.57 |
| Tygart Valley | 6.33 | 6.53 | 6.55 | 6.37 | 6.53 | 6.54 | 6.35 |
| Upper Guyandotte | 2.68 | 2.93 | 2.84 | 2.72 | 2.90 | 2.77 | 2.62 |
| Upper Kanawha | 130.69 | 131.46 | 131.54 | 131.61 | 38.21 | 38.11 | 37.99 |
| Upper New | 2.63 | 2.55 | 2.47 | 2.35 | 2.55 | 2.47 | 2.35 |
| Upper Ohio North | 16.69 | 26.75 | 26.98 | 27.19 | 26.36 | 26.19 | 25.99 |
| Upper Ohio South | 146.98 | 143.39 | 142.53 | 141.63 | 14.00 | 13.70 | 13.35 |
| West Fork | 16.90 | 16.79 | 16.72 | 16.59 | 16.78 | 16.71 | 16.57 |
| Youghiogheny | 0.95 | 0.11 | 0.11 | 0.10 | 0.11 | 0.11 | 0.10 |
| TOTALS | 1,191.17 | 1,085.37 | 1,084.30 | 1,082.21 | 729.81 | 727.18 | 723.50 |

*No Large Quantity User withdrawals are registered in the James or the Shenandoah Hardy as of 2011.

**Table 4-4 Current average annual withdrawals and future high and low scenario estimates by water use category, in billions of gallons per year.**

| Water Use Category | Current 3 Year Average (Bgal/yr) | High Withdrawals (Bgal/yr) | | | Low Withdrawals (Bgal/yr) | | |
|---|---|---|---|---|---|---|---|
| | | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Mining and Petroleum | 13.95 | 16.07 | 16.13 | 16.20 | 15.74 | 15.47 | 15.22 |
| Manufacturing | 189.65 | 177.28 | 179.94 | 182.64 | 174.48 | 174.31 | 174.13 |
| Public Water Supply | 69.28 | 72.34 | 72.29 | 71.17 | 72.34 | 72.29 | 71.17 |
| Recreation | 1.54 | 1.53 | 1.55 | 1.56 | 1.52 | 1.52 | 1.52 |
| Thermoelectric | 915.26 | 818.16 | 814.39 | 810.65 | 465.73 | 463.59 | 461.46 |
| TOTALS | 1,189.69 | 1,085.37 | 1,084.30 | 1,082.21 | 729.81 | 727.18 | 723.50 |

## 4.7 Consumptive Use Projections

Projecting consumptive use by watershed for 2020, 2030 and 2040 was done using the high and low withdrawal scenarios described in the previous section and the consumptive use rates detailed in Section 4.5 (Table 4-2). The high consumptive use rates were applied to the high withdrawal results and the low consumptive use rates were applied to the low withdrawal results.

**Table 4-5 High and low scenario consumptive use rates for each water use category.**

| **Water Use Category** | **Consumptive Use Rate (percent)** | |
|---|---|---|
| | **HIGH** | **LOW** |
| Mining and Petroleum | 20 | 14 |
| Manufacturing | 13 | 10 |
| Public Water Supply | 20 | 15 |
| Recreation | 56.5 | 55 |
| Thermoelectric | 4 | 2 |
| Marcellus Shale | 100 | - |

Results are shown by watershed in Table 4-6 and by water use category in Table 4-7. The North Branch Potomac Watershed has by far the highest consumptive use estimates. This is driven by the large Thermoelectric withdrawal even though the consumptive use rate for the sector is the lowest of all sectors in this study (2 to 4 percent). Other watersheds with comparatively high consumptive use totals are the Upper Kanawha, Middle Ohio South, Middle Ohio North, Upper Ohio South and Lower Kanawha watersheds. These watersheds all have large withdrawals in both the Manufacturing and Thermoelectric sectors. The Upper Ohio North Watershed has a large consumptive use total related to Manufacturing withdrawal.

**Table 4-6 Current annual consumptive use estimates for 2011 and future high and low scenario consumptive use estimates by watershed, in billions of gallons per year.**

| HUC 8 | High Scenario Consumptive Use (Bgal/yr) | | | | Low Scenario Consumptive Use (Bgal/yr) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2011 | 2020 | 2030 | 2040 | 2011 | 2020 | 2030 | 2040 |
| Big Sandy | 0.18 | 0.18 | 0.17 | 0.16 | 0.14 | 0.14 | 0.13 | 0.12 |
| Cacapon | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 |
| Cheat | 0.39 | 0.47 | 0.48 | 0.48 | 0.34 | 0.39 | 0.40 | 0.40 |
| Coal | 0.95 | 1.09 | 1.09 | 1.08 | 0.67 | 0.75 | 0.74 | 0.72 |
| Dunkard | 0.12 | 0.19 | 0.19 | 0.19 | 0.08 | 0.13 | 0.13 | 0.13 |
| Elk | 2.43 | 2.34 | 2.24 | 2.11 | 1.82 | 1.75 | 1.68 | 1.58 |
| Gauley | 0.33 | 0.40 | 0.39 | 0.38 | 0.24 | 0.29 | 0.28 | 0.27 |
| Greenbrier | 0.62 | 0.61 | 0.60 | 0.59 | 0.55 | 0.53 | 0.53 | 0.52 |
| James* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Little Kanawha | 0.24 | 0.23 | 0.23 | 0.21 | 0.18 | 0.17 | 0.17 | 0.16 |
| Lower Guyandotte | 0.28 | 0.29 | 0.28 | 0.27 | 0.21 | 0.21 | 0.21 | 0.20 |
| Lower Kanawha | 8.71 | 7.61 | 7.71 | 7.81 | 6.54 | 5.62 | 5.61 | 5.60 |
| Lower New | 1.02 | 1.05 | 1.03 | 0.99 | 0.78 | 0.80 | 0.78 | 0.75 |
| Lower Ohio | 1.03 | 1.02 | 1.01 | 0.99 | 0.77 | 0.76 | 0.76 | 0.74 |
| Middle Ohio North | 7.67 | 6.96 | 7.02 | 7.08 | 5.65 | 4.60 | 4.58 | 4.55 |
| Middle Ohio South | 8.56 | 7.25 | 7.26 | 7.24 | 5.31 | 2.18 | 2.18 | 2.16 |
| Monongahela | 2.20 | 2.77 | 2.88 | 3.01 | 1.34 | 1.76 | 1.84 | 1.94 |
| North Branch Potomac | 16.28 | 15.90 | 15.83 | 15.75 | 8.18 | 7.99 | 7.95 | 7.91 |
| Potomac Direct Drains | 1.17 | 1.59 | 1.80 | 2.02 | 0.89 | 1.19 | 1.35 | 1.50 |
| Shenandoah Hardy* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Shenandoah Jefferson | 0.17 | 0.19 | 0.21 | 0.23 | 0.13 | 0.14 | 0.16 | 0.17 |
| South Branch Potomac | 0.40 | 0.42 | 0.42 | 0.41 | 0.30 | 0.32 | 0.32 | 0.31 |
| Tug Fork | 0.68 | 0.75 | 0.71 | 0.67 | 0.50 | 0.55 | 0.51 | 0.47 |
| Twelvepole | 0.09 | 0.12 | 0.12 | 0.12 | 0.06 | 0.09 | 0.09 | 0.08 |
| Tygart Valley | 1.30 | 1.31 | 1.31 | 1.27 | 0.97 | 0.98 | 0.98 | 0.95 |
| Upper Guyandotte | 0.55 | 0.59 | 0.57 | 0.54 | 0.40 | 0.42 | 0.40 | 0.38 |
| Upper Kanawha | 9.82 | 8.97 | 9.01 | 9.06 | 6.49 | 3.95 | 3.94 | 3.92 |
| Upper New | 0.51 | 0.51 | 0.49 | 0.47 | 0.38 | 0.38 | 0.37 | 0.35 |
| Upper Ohio North | 2.36 | 3.65 | 3.67 | 3.68 | 1.81 | 2.76 | 2.74 | 2.71 |
| Upper Ohio South | 6.71 | 6.60 | 6.53 | 6.45 | 3.61 | 0.96 | 0.92 | 0.88 |
| West Fork | 1.22 | 1.23 | 1.23 | 1.21 | 0.78 | 0.79 | 0.79 | 0.78 |
| Youghiogheny | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 |
| TOTALS | 52.78 | 74.32 | 74.53 | 74.52 | 34.15 | 40.65 | 40.55 | 40.28 |

*No Large Quantity User withdrawals are registered in the James or the Shenandoah Hardy as of 2011.

**Table 4-7 Current annual consumptive use estimates for 2011 and future high and low scenario consumptive use estimates by water use category, in billions of gallons per year.**

| Water Use Category | High Consumptive Use (Bgal/yr) | | | | Low Consumptive Use (Bgal/yr) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2011 | 2020 | 2030 | 2040 | 2011 | 2020 | 2030 | 2040 |
| Mining and Petroleum | 2.83 | 3.21 | 3.23 | 3.24 | 1.98 | 2.20 | 2.17 | 2.13 |
| Manufacturing | 24.38 | 23.05 | 23.39 | 23.74 | 18.75 | 17.45 | 17.43 | 17.41 |
| Public Water Supply | 14.51 | 14.47 | 14.46 | 14.23 | 10.88 | 10.85 | 10.84 | 10.68 |
| Recreation | 0.82 | 0.86 | 0.87 | 0.88 | 0.79 | 0.83 | 0.83 | 0.83 |
| Thermoelectric | 33.50 | 32.73 | 32.58 | 32.43 | 16.75 | 9.31 | 9.27 | 9.23 |
| TOTALS | 76.03 | 74.32 | 74.53 | 74.52 | 49.16 | 40.65 | 40.55 | 40.28 |

## 4.8 Marcellus

To forecast the future withdrawals for hydraulic fracturing, an estimation of the future number of wells was needed. A 2010 paper prepared for the American Petroleum Institute projected a low, medium and high development scenario for West Virginia, Pennsylvania and New York (Considine, 2010). For West Virginia, the predicted number of wells in the low scenario was 273 and 752 in the high scenario. Using the number of predicted wells in the low and high development scenarios and 5.15 million gallons as the average water withdrawal per well, a total water need was estimated for the state (Table 4-8).

**Table 4-8 High and low scenario Marcellus Shale withdrawals for 2020 in billions gallons per year**

| Development Scenario | Number of Projected Wells | Projected Withdrawal (Bgal) |
|---|---|---|
| High | 752 | 3.85 |
| Low | 273 | 1.41 |

To apportion the statewide withdrawal to the watershed scale it was assumed that the future water withdrawals would occur in the same watersheds at the same proportion as they had in the past (Table 4-9). This assumes that drillers are using streams with readily available water supplies which are easy to access and that these will continue to be the preferred sources in the future. No assumptions were made about the changes in technologies that might affect future water use in the industry. All water withdrawals used in association with horizontal drilling and hydraulic fracturing activities are considered consumptive at this time.

Table 4-9 Estimated water withdrawals and consumptive use projections for Marcellus Shale industry

| Watershed | 2011 Water Withdrawals (Mgal/yr) | Percent of Total Withdrawal | Estimated 2020 Withdrawals/ Consumptive Use Projections (Mgal/yr) | |
|---|---|---|---|---|
| | | | HIGH Scenario | LOW Scenario |
| Tygart Valley | 102.6 | 11.1 | 427.4 | 156.5 |
| West Fork | 150.95 | 16.4 | 631.4 | 231.2 |
| Monongahela | 60.41 | 6.5 | 250.3 | 91.7 |
| Cheat | 10.16 | 1.1 | 42.4 | 15.5 |
| Dunkard | 3.04 | 0.3 | 11.6 | 4.2 |
| Upper Ohio North | 28.42 | 3.1 | 119.4 | 43.7 |
| Upper Ohio South | 176.9 | 19.2 | 739.2 | 270.0 |
| Middle Ohio North | 263.55 | 28.6 | 1101.0 | 403.3 |
| Little Kanawha | 121.3 | 13.1 | 504.4 | 184.7 |
| Elk | 3.78 | 0.4 | 15.4 | 5.6 |
| TOTAL | 922.78 | 100.0 | 3850.0 | 1410.0 |

## 4.9 Non-consumptive water needs

Projected consumptive water use, by itself, is not an adequate measure of the demands on the state's water supply. For example, West Virginia's whitewater rafting tourism industry depends upon water, none of which is considered consumptive use. To better understand the extent of such non-consumptive uses throughout the state, the Act requires the projection of existing and future non-consumptive needs in areas with important or unique natural, scenic, environmental or recreational, local or statewide significance. There are numerous non-consumptive uses of West Virginia waters, several of which will be reviewed here. These uses include wildlife and associated habitats, as well as public lands including wild and scenic rivers. These non-consumptive uses are discussed below; however, quantified demands for these non-consumptive uses are not available at this time. Actual projections of water needs for non-consumptive needs will require future analysis.

### 4.9.1 Wildlife and Associated Habitats

West Virginia is rich in biological diversity. Significant work has been done to understand the species' ranges, habitats, and relationships to water resources. Studies such as the West Virginia Gap Analysis have attempted to document the range of many species across the state utilizing available land cover data (USGS, 2002). Organizations including the West Virginia Division of Natural Resources (DNR) and the United States Fish and Wildlife Service (USFWS) track species across the state.

As defined in the Endangered Species Act, endangered species are "any species which is in danger of extinction throughout all or a significant portion of its range other than species of the *Class Insecta* as determined by the Secretary to constitute a pest whose protection under the provisions of the Act would present an overwhelming and overriding risk to man." Threatened species are "any species which is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range." Rare species in West Virginia have few individuals across their entire range, are decreasing regionally, and/or require unique habitats. There are 15 federally endangered species in West Virginia (not including those considered to be extirpated or accidental) including 11 animal and four plant species. The diamond darter is has been recently named an endangered species and is not included in these numbers. There are five federally threatened species in West Virginia. Two species, the peregrine falcon and the bald eagle, were removed from the federal list in 1999 and 2007, respectively (DNR, 2012). These and many other rare species are given state ranks by the Natural Heritage Program and global ranks by NatureServe and are subsequently tracked by DNR for management purposes. Availability of water resources is essential to protecting the rare, threatened, and endangered species. The nature of the relationship to the water resources for a particular species depends on a number of factors. For example, if the water resources in an area become insufficient, is the organism able to move to another water source? Does the organism depend on the waterways for an occasional drink or does it live in the water for its entire life cycle? Appendix U documents the importance of water resources for each of the federally listed species in West Virginia.

The count of these rare, threatened, and endangered individuals by HUC-8 is provided in Table 4-10. The Elk Watershed, followed by the Middle Ohio South Watershed, has the largest count of rare, threatened, and endangered individuals. The Shenandoah Hardy Watershed has the fewest individuals with only two element occurrences. Figure 4-9 and Figure 4-10 show the areas with the largest number of individuals by HUC-12 for terrestrial and aquatic species, respectively.

Table 4-10  Total count of rare, threatened, and endangered individuals by HUC8 watershed.  Data source: DNR

| HUC8 | Watershed Name | Element Occurrences* |
|---|---|---|
| 05050007 | Elk | 3938 |
| 05030202 | Middle Ohio South | 2977 |
| 05020004 | Cheat | 2846 |
| 05030201 | Middle Ohio North | 2388 |
| 05030203 | Little Kanawha | 2182 |
| 05050003 | Greenbrier | 2133 |
| 05050006 | Upper Kanawha | 1711 |
| 02070001 | South Branch Potomac | 1535 |
| 05090101 | Lower Ohio | 1048 |
| 05050005 | Gauley | 1033 |
| 02070004 | Potomac Direct Drains | 798 |
| 02070003 | Cacapon | 761 |
| 05050002 | Upper New | 632 |
| 05050008 | Lower Kanawha | 625 |
| 05050004 | Lower New | 624 |
| 05020001 | Tygart Valley | 567 |
| 02070002 | North Branch Potomac | 514 |
| 05020002 | West Fork | 484 |
| 05020005 | Dunkard | 426 |
| 05030106 | Upper Ohio South | 388 |
| 05090102 | Twelvepole | 314 |
| 05070201 | Tug Fork | 276 |
| 05050009 | Coal | 230 |
| 02070007 | Shenandoah Jefferson | 220 |
| 05070102 | Lower Guyandotte | 215 |
| 05020006 | Youghiogheny | 136 |
| 05020003 | Monongahela | 135 |
| 05070101 | Upper Guyandotte | 130 |
| 05030101 | Upper Ohio North | 113 |
| 02080201 | James | 111 |
| 05070204 | Big Sandy | 34 |
| 02070006 | Shenandoah Hardy | 2 |

*The element occurrences field is a count of rare, threatened, and endangered individuals.

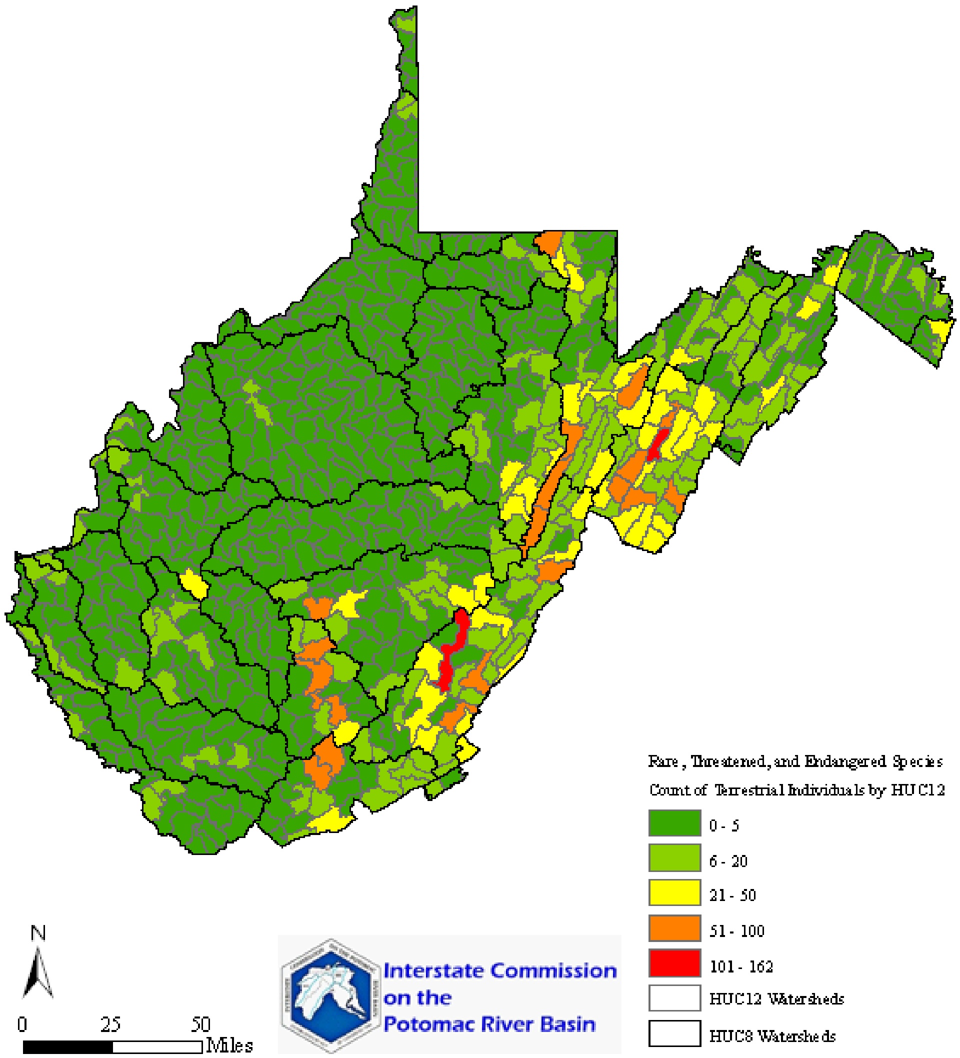



Figure 4-9 Count of rare, threatened, and endangered terrestrial individuals by HUC12. Data source: DNR

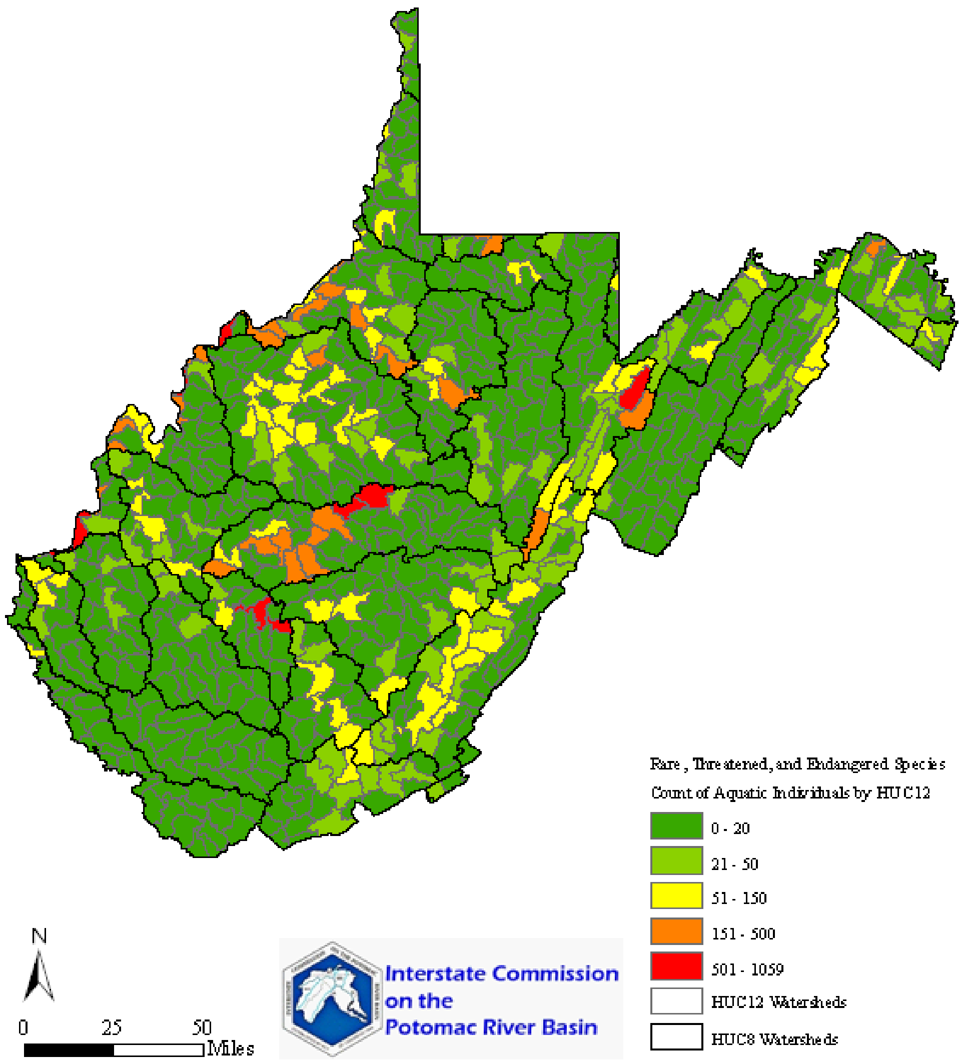



**Figure 4-10 Count of rare, threatened, and endangered aquatic individuals by HUC12. Data source: DNR**

### 4.9.2 Public Lands

Public lands are important for a number of ecological, environmental, and social reasons (Loomis, 2002). These areas are important for maintaining wildlife because the sole habitats of many species occur on public lands. For example, the majority of the federally threatened flat-spired three-toothed snail's range occurs within Cooper's Rock State Forest (USFWS, 1983). Further, the pervious spaces on public lands provide opportunity for infiltration, groundwater recharge and water quality protection. Recreation often occurs on public lands. In West Virginia, approximately 71,000 hunters, 156,000 birdwatchers, hikers and nature photographers, and more than 300,000 anglers recreate on public lands and waters each year, amounting to an economic impact of approximately $350 million per year (Brown, 2003).

There are approximately 2,500 square miles (sq. mi.) of public lands in West Virginia including national forests, national historic parks, national recreation areas, national rivers, national scenic rivers, national wildlife refuges, state forests, state parks, state recreation areas and wildlife management areas (Figure 4-11). The Cheat Watershed has the largest amount of public lands, with 491.1 sq. mi., followed by the Greenbrier, Gauley and the South Branch Potomac watersheds (Table 4-11). Public lands in West Virginia are primarily owned by the federal government followed by the state government (Table 4-12). As management of these lands is in the public sphere, activities that are harmful to water quality and quantity can be appropriately minimized and beneficial activities can be promoted.

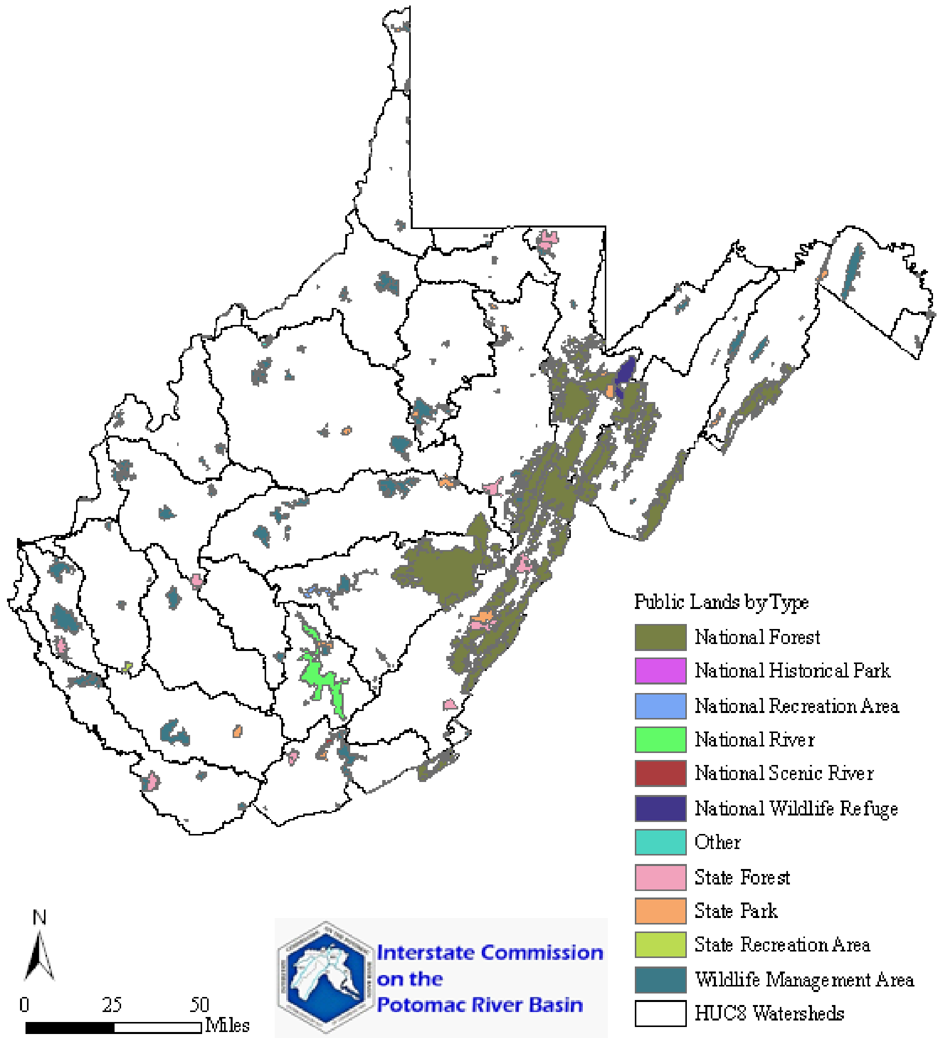



Figure 4-11 Location of public lands in West Virginia by type

**Table 4-11 Area of public lands by type for each HUC-8 (sq. mi.).**

| | Federal | | | | | | State | | Federal and/or State | Federal, State, or Local | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Wildlife Refuge | Scenic River | Rec. Area | River | Historical Park | Forest | Rec. Area | Park | Wildlife Management Area | Other | **Sum** |
| Cheat | 39.2 | | | | | 432.7 | | 12.7 | 6.5 | | **491.1** |
| Greenbrier | | | | | | 461.9 | | 18 | 1.1 | | **481** |
| Gauley | | | 17.4 | | | 281.2 | | 0.4 | 21 | | **320** |
| South Branch Potomac | | | | | | 238.8 | | | 16.3 | | **255.1** |
| Elk | | | | | | 52.6 | | 11 | 64.9 | | **128.5** |
| Lower New | | | | 113.1 | | | | 7.2 | 5 | | **125.3** |
| Cacapon | | | | | | 82.6 | | 9.4 | 17.3 | | **109.3** |
| Tygart Valley | | | | | | 44.6 | | 10.2 | 12 | 2.5 | **69.3** |
| Twelvepole | | | | | | | | | 59.2 | | **59.2** |
| Little Kanawha | | | | | | | | 7.2 | 44.6 | 3.3 | **55.1** |
| Upper New | | 6.8 | | | | 3.9 | | 8.3 | 29.4 | | **48.4** |
| Potomac Direct Drains | | | | | 0.3 | | | 6.8 | 36 | 0.8 | **43.9** |
| West Fork | | | | | | | | 3.7 | 35.2 | | **38.9** |
| Upper Guyandotte | | | | | | | | 5.9 | 31.1 | | **37** |
| Tug Fork | | | | | | | | | 33.2 | | **33.2** |
| Middle Ohio North | 2.6 | | | | | | | | 25.5 | 1.3 | **29.4** |
| James | | | | | | 27.1 | | | 1.7 | | **28.8** |
| Lower Kanawha | | | | | | | | | 24.1 | | **24.1** |
| Middle Ohio South | 3.1 | | | | | | | 0.8 | 11.9 | | **15.8** |
| Coal | | | | | | | | | 13.7 | | **13.7** |
| Lower Guyandotte | | | | | | | 4.8 | | 4.8 | 0.2 | **9.8** |
| Upper Ohio North | 0.7 | | | | | | | 2.1 | 6.6 | | **9.4** |
| Lower Ohio | 0.2 | | | | | | | | 9.1 | | **9.3** |
| North Branch Potomac | 0.1 | | | | | 0.1 | | | 8.7 | | **8.9** |
| Upper Ohio South | 1.6 | | | | | | | | 5.1 | | **6.7** |
| Upper Kanawha | | | | | | | | | 4.9 | | **4.9** |
| Shenandoah Jefferson | | | | | 1.4 | | | | 2.3 | | **3.7** |
| Shenandoah Hardy | | | | | | 3.5 | | | | | **3.5** |
| Monongahela | | | | | | | | | 1.8 | | **1.8** |
| Dunkard | | | | | | | | | 1.2 | | **1.2** |
| Youghiogheny | | | | | | | | 0.2 | | | **0.2** |
| **Total** | **47.5** | **6.8** | **17.4** | **113.1** | **1.7** | **1629** | **4.8** | **103.9** | **534.2** | **8.1** | **2466.5** |

Table 4-12 Public lands by owner type for the state of West Virginia.

| Type | Percent of Public Lands |
|---|---|
| Federal | 77.4 |
| State | 20.1 |
| Private | 1.3 |
| State & Private | 0.8 |
| State & Federal | 0.2 |
| County | 0.2 |

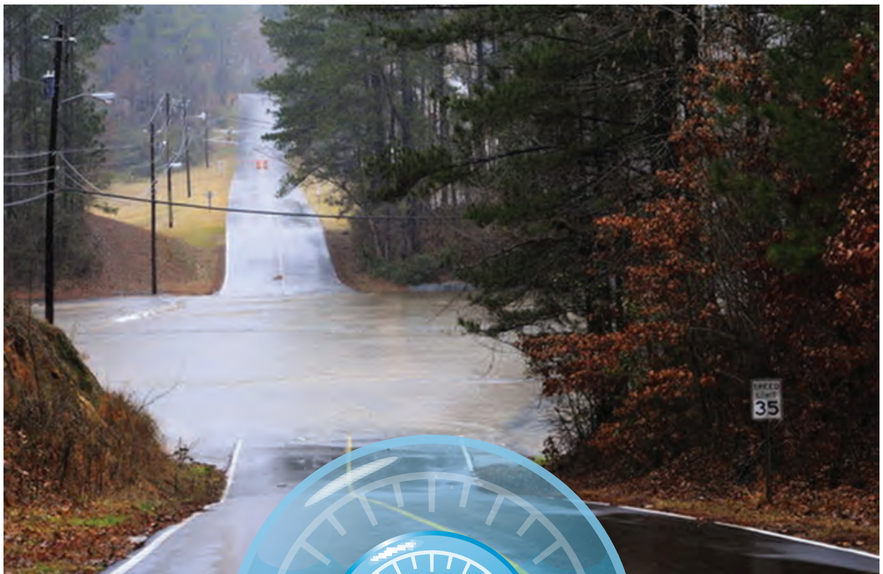
### 4.9.3 Wild and Scenic Rivers

The Wild and Scenic Rivers Act was signed by President Lyndon Johnson in 1968, creating the National Wild and Scenic Rivers System. The purpose of the act is to preserve rivers with “outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations.” The distinguishing characteristics of wild and scenic rivers are defined as follows. Wild rivers are free of impoundments, generally inaccessible except by trail, essentially primitive in terms of watersheds or shorelines and free of water pollution. Scenic rivers are free of impoundments, largely primitive in terms of shorelines or watersheds, shorelines largely undeveloped, but accessible in places by roads.

The Bluestone River is the only National Wild and Scenic River in West Virginia, originally designated in 1988. The Bluestone River is located in the Upper New Watershed. The designated segment is 12.7 miles in length. Starting its journey on the East River Mountain in Virginia, the Bluestone River flows 77 miles before joining the New River at Bluestone Lake. The designated portion of the river is in the Bluestone Gorge between Pipestem and Bluestone state parks. The gorge offers a myriad of outdoor activities including warmwater fishing, whitewater boating, hiking and hunting. The river is home to diverse aquatic and terrestrial species including fish (e.g. smallmouth bass, bluegill and catfish), birds (e.g. kingfishers and great blue herons), and mammals (e.g. beaver, fox, bobcat and deer). The region is forested and includes maple, oaks, hickories, birch and sycamores.

Two other West Virginia river segments worth noting are the New River Gorge National River and the Gauley River National Recreation Area. According to the National Park Service, the New River Gorge was declared a National River in 1978 and includes over 50 miles of the New River from Bluestone Dam to Hawk’s Nest Lake. The Gauley River National Recreation Area is comprised of 25 miles of the Gauley River and six miles of the Meadow River.

Country road flooded




# CHAPTER FIVE
# OTHER CONDITIONS AFFECTING WATER AVAILABILITY

**WATER USE SECTION** west virginia department of environmental protection

Drought effect on small lake

# Chapter - 5 Other Conditions Affecting Water Availability

## 5.1 Natural Conditions Affecting Water Availability

The Act requires "A discussion of any area of concern regarding historical or current conditions that indicate a low-flow condition or where a drought or flood has occurred or is likely to occur that threatens the beneficial use of the surface water or groundwater in the area." The DEP partnered with the Interstate Commission on the Potomac River Basin (ICPRB) to study and assess the impacts of flood and drought conditions on water availability. The results of the study, presented herein, highlight significant floods and droughts of the past century and describe the impact of these events on the state's water infrastructure.

### 5.1.1 Flooding

The general public perception is that nature is something that can be controlled and natural disasters can be prevented. The opposite is the case in that flooding is a natural disaster that cannot be prevented. In some ways, human activity increases the potential for flooding by filling stream channels and floodways, increasing the amount of impervious surface area and constructing poorly designed stream crossings. However, if enough rain falls in the same area for an extended period of time, the inevitable result is flooding.

In order to understand the levels of severity of a flood, it is necessary to classify or rank the flood events. Engineers and hydrologists refer to the flood recurrence interval to define the amount of water involved and/or the size of the flood. The most commonly referenced recurrence intervals are the 2, 5, 10, 25, 50, 100 and 500 year flood events. The 25-year flood refers to a flood with a probability of occurring once during a 25-year period. In other words, it is a flood that has a probability of 1 in 25 of occurring in any given year, or a 4% chance of occurring in any given year. The probability and percent chance for flood recurrences are shown in the following table (Table 5-1).

Table 5-1 Flood recurrence probability

| Flood Recurrence Interval In Years | Probability Of Occurring In Any Given Year | Percent Chance Of Occurring In Any Given Year |
|---|---|---|
| 100 | 1 in 100 | 1 |
| 50 | 1 in 50 | 2 |
| 25 | 1 in 25 | 4 |
| 10 | 1 in 10 | 10 |
| 5 | 1 in 5 | 20 |
| 2 | 1 in 2 | 50 |

The intensity of rainfall required to produce a particular flood varies across the state due to the different regions' topography and land cover types. The regions are identified in the following figure from the West Virginia Department of Highways (WVDOH) Drainage Manual.

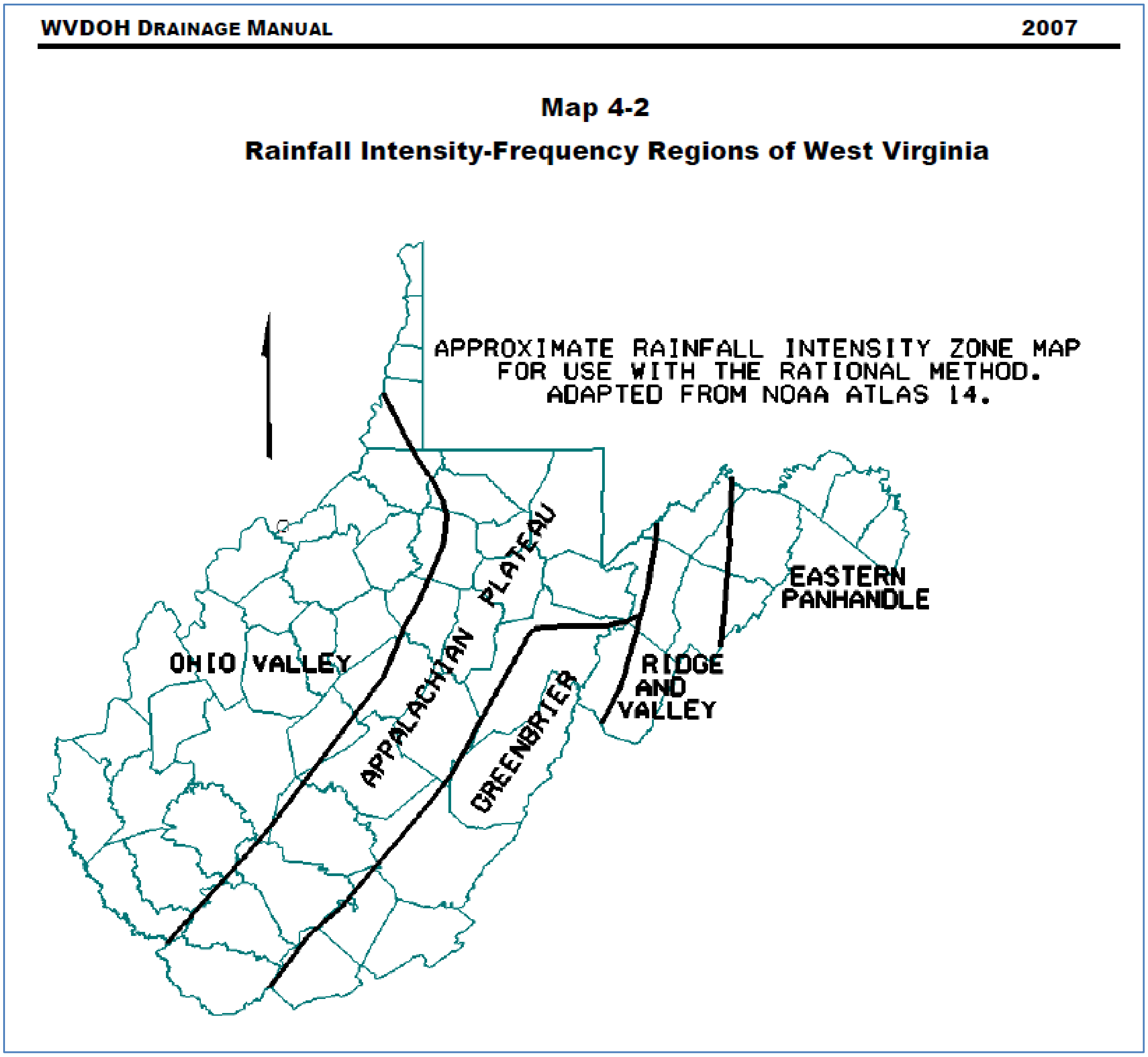



Figure 5-1 WVDOH Drainage Manual

The WVDOH has published a manual to assist in calculation of stormwater runoff for sizing of bridges and drainage culverts. The WVDOH Drainage Manual contains values for the 1, 2, 5, 10, 25, and 100 year flood events in inches per hour for each of the regions and can be found at the following web site:

http://www.transportation.wv.gov/highways/engineering/pages/publications.aspx

Recurrence interval peak discharges in cubic feet per second have been calculated for gaging stations in West Virginia and surrounding states by the United States Geological Survey (USGS) and have been published in their Water Resources Investigation Report 00-4080 and can be downloaded from the following site: http://pubs.usgs.gov/wri/wri004080/pdf/wri00-4080.pdf.

Floods affect water availability by damaging critical infrastructure and introducing pollutants from stormwater runoff and combined sewer overflows. The intermingling of these contaminants with surface and groundwater exacerbates local supply issues. Floods are caused by three storm types in West Virginia: thunderstorms during late afternoon and evening in summer, frontal systems in winter or early spring and tropical cyclones, including hurricanes and tropical storms, in late summer or early fall (Doll, Meyer, & Archer, 1963). In addition, rainfall combined with snowmelt may cause floods in early spring. Extreme flooding can be expected on small streams during the summer and on larger streams during late fall or winter. Intense thunderstorms can be the most dangerous because they produce flash floods with little or no warning. Because the terrain in West Virginia consists of many small basins, much of the state is subject to this type of flood.

The most devastating floods are caused by precipitation effects from hurricanes or tropical storms. These storms are most intense on the eastern slopes of the Potomac River Basin and the upper parts of the New River Basin. While prediction of extreme weather is difficult at best, a review of notable events of the past may help to better identify potential areas of concern. The record precipitation event in West Virginia is 19.5 inches of rain in two hours and 10 minutes at Rockport in July of 1889. The number used in dam design for the probable maximum precipitation event is 27.5 inches of rainfall in six hours.

The record precipitation event in West Virginia is 19.5 inches of rain in two hours and 10 minutes at Rockport in July of 1889

West Virginia's annual frequency of severe thunderstorms and tornadoes is less than other states in the region. The complicated mountain terrain disrupts the circulation systems necessary for the formation of such storms, although there have been 125 documented tornadoes ranging from F-0 to F-3 (under 205 mph winds), resulting in a total of 15 fatalities over the past 60 years (TornadoHistoryProject.com). Notable F-3 tornadoes formed at Meadow Bridge on April 3, 1974, in Monongalia and Preston counties on June 3, 1980, and in Wayne and Lincoln counties on March 2, 2012.

On April 4th and 5th, 1977, there was a flood in the southern part of West Virginia that was the result of widespread rainfall and intense convective thunderstorms. At the time, it was the most destructive flood in the state's history, since the 100-year flood was exceeded at 29 streamflow measurement sites (Runner & Chin, 1980). Rainfall estimates for the two-day storm exceeded 15 inches along the West Virginia-Virginia border. In 1985, another two-day flood occurred on November 4th and 5th, surpassing the 1977 flood as the most devastating in the state. Forty-seven lives were lost, thousands were left homeless and approximately 500 bridges were destroyed. Rainfall estimates for the two-day storm were as much as 20 inches along the Eastern Divide, between eastern West Virginia and western Virginia in the Ohio River and Potomac River drainage basins.

Major floods in West Virginia have occurred as a result of winter-spring storms and storms resulting from the remnants of hurricanes. During March 9-22, 1936, four separate storms passed over the northeastern United States resulting in record maximum peak discharges in the Potomac and lower Monongahela River basins. At some USGS gaging stations in the Eastern Panhandle, such as the Cacapon River near Great Cacapon, the 1936 flood crests are still the highest recorded. However, at other gaging stations, such as the South Branch Potomac River near Springfield, the flood crests of 1936 have since been exceeded by the record 1985 flood.

During March 4-19, 1963, three frontal systems moved through the Appalachian Mountains from Alabama to West Virginia. Warm rain from the Gulf of Mexico initially fell on a thick snowpack and caused minor flooding in southern West Virginia. Additional storms from March 10-12 then fully saturated the ground, which set the stage for another large storm (March 16-19) to produce record flooding on streams in southern West Virginia. The resulting flood in the Guyandotte and Big Sandy River watersheds was the most severe for those watersheds since 1915. Near-record flooding occurred in the Little Kanawha, Cheat and Greenbrier River watersheds, where 22 counties were declared disaster areas. The estimated property damage was approximately $10 million (Barnes, Jr., 1964).

In early March 1967, a three-day rainfall of 4-5 inches in south-central and northern West Virginia caused widespread flooding on many streams. Runoff combined with snowmelt to cause the worst flooding since 1888 in northern West Virginia along the West Fork River, which rose eight feet above flood stage. The storm also produced record runoff volume along streams in southern West Virginia. In the Coal River Watershed, streams rose 30 feet and overbank flooding of 15 feet inundated many areas. Twenty-nine counties were declared disaster areas. The estimated damage was $16 million.

Rainfall was widespread and intense over southern West Virginia during April 2-5, 1977. Rainfall quantities ranged from about four inches at a few locations to 15.5 inches in areas of McDowell County within 30 hours. Flood peaks along the Tug Fork and Guyandotte Rivers exceeded all known discharges. Communities along the Tug Fork, from Welch to Fort Gay, were inundated by 20-25 feet of water. The small communities of Matewan, Thacker and Lobata were completely flooded. On the Tug Fork near Litwar, the peak stage exceeded the previous highest stage by about six feet, and the discharge was 54,500 cubic feet per second (cfs). At Williamson and Kermit, the peak discharges of 94,000 and 104,000 cfs, respectively, were the largest since at least 1926. A floodwall that protects Williamson to a stage of about 44 feet was overtopped by more than eight feet. The flood had a unit runoff of more than 100 cfs per square mile on drainage areas of about 1,000 square miles and had a recurrence interval of greater than 100 years. This flood became a benchmark flood in southern West Virginia, with damage of $60 million (Runner & Chin, 1980).

The flood of November 4-5, 1985 in northern and eastern West Virginia was extremely destructive. When combined with the remnants of Hurricane Juan carrying large quantities of moisture from the Gulf of Mexico, the result was additive flooding that devastated sections of West Virginia. Mountainous areas along the Eastern Divide received the most rainfall. Measured quantities of rainfall ranged from 12-20 inches. Flood peaks in the Cheat, Elk, Greenbrier, Tygart Valley, Little Kanawha and South Branch Potomac River watersheds were the greatest recorded. The Little Kanawha River at Glenville crested at 36.5 feet, two feet higher than any peak since 1915. The flood left about 9,000 homes either destroyed or severely damaged and 47 deaths were reported. Property damage was estimated at $500 million across the 29 counties declared disaster areas. More than 500 bridges were damaged or washed away and sections of major highways were eroded. Agricultural losses in the South Branch Potomac River Watershed were extensive. Thousands of farm animals were lost. Prime farmland along the flood plain was eroded or left as acres of cobbles that could not be farmed without extensive repairs (Teets & Young, 1985).

The West Virginia Conservation Agency (WVCA) and the U.S. Army Corps of Engineers (USACE) have developed a partnership with numerous federal and state agencies to formulate a comprehensive, strategic plan for reducing flood damages in the state. The WVCA published the Statewide Flood Protection Plan in 2005. Categories of recommendations within the plan include: flood plain management and mapping, flood warning systems, flood damage assessment, building codes permitting and enforcement, dredging and stormwater management education. The document has many recommendations, some have been fulfilled, others not. One of the future pursuits of the Water Use Section will be to host an annual water resources symposium, having a different focus each year. Purposes of this symposium include facilitation of interagency collaborations and staying mindful of important issues such as flood and drought planning. The contact lists for the responsible agencies would be updated as a result of the proceedings.

In order to effectively manage floods and reduce the devastating effects, updating flood inundation maps and continuing to improve the flood warning system is imperative. The existing flood mapping tools are cooperatively maintained by the West Virginia Division of Homeland Security and Emergency Management (WVDHSEM), the Federal Emergency Management Agency (FEMA) and the West Virginia GIS Technical Center and are available at the following location: http://www.mapwv.gov/flood/. One way to better protect the citizens of West Virginia from flooding is through technology called Light Detection and Ranging (LIDAR). LIDAR can be used to create a digital elevation model that is far superior to those currently available. Statewide LIDAR coverage would greatly improve the accuracy of flood plain mapping as well as improve many other existing modeling tools. It would also assist in addressing the challenges of stream slope measurements; well head elevations; location of valley fills, mine portals and sunken streams; wetland delineation; and many others. Roughly 30% of the state has been flown utilizing LIDAR technology. Based on estimates from WVU's NRAC and the DEP's TAGIS group, it would cost approximately $1.2 million to obtain LIDAR coverage of the remaining 70% of the state. While the costs and benefits of LIDAR have been discussed at interim Commission meetings, the issue of funding was never addressed. The Commission should consider an interim study to further explore the benefits of statewide LIDAR coverage; a funding source(s) for the same; and the appropriate recipient(s) of that funding.

### 5.1.2 Drought

A drought can be described as an extended period of dry weather due to unusual northward expansion of the thermodynamically stable, subtropical high-pressure systems that are in the mid-atmosphere (Davies, Bailey, & Kelly, 1972). The presence of these high-pressure systems greatly decreases afternoon thunderstorms. These flow patterns tend to keep frontal systems and the attendant precipitation to the north and west of the state. Periods of less than average precipitation or streamflow can vary in duration from weeks to years and affect localized or statewide areas. Droughts impact water availability by decreasing surface water quantities, which results in depletion of storage reserves such as reservoirs and groundwater aquifers. Additionally, low-flows in streams lead to water quality issues by concentrating pollutants.  Severe droughts are less of a problem than floods in West Virginia; however, even short-term droughts can be detrimental to local agricultural communities and can limit surface water supply.

There are four different types of droughts, each of which have their own criteria and definition.  A meteorological drought is a measure of the departure of precipitation from normal, due to climatic differences over very large areas.  A meteorological drought in one location of the state may not be considered a drought in another location of the state.  An agricultural drought, which is commonly referred to as the onset of a drought, refers to a situation in which the amount of moisture in the soil no longer meets the needs of crops, or reaches the wilting point of a particular crop.  A hydrological drought occurs when surface and subsurface water supplies are below normal, which takes place as much as 50% of the time.  A socioeconomic drought refers to the situation that occurs when physical water shortages in reservoirs, streams and groundwater aquifers begin to affect people's ability to carry on their normal daily water use activities.

A drought can be defined as a period of abnormally dry weather sufficiently prolonged by the lack of precipitation which leads the affected area to experience serious hydrologic imbalance.  Another way to define the word drought is a period of unusually persistent dry weather that lasts long enough to cause serious damage to agriculture and/or causes public and/or private water supply shortages. The severity of the drought depends upon the overall amount of water loss, the period of time without precipitation and the size of the affected area.

Extended, severe droughts occur in West Virginia about every 25 years on average (Barksdale, O'Bryan, & Schneider, 1966).  However, unlike flooding, no exact recurrence intervals have been identified for drought due to the many ways to define a drought. A review of notable events of the past may help to better forecast potential areas of concern.

During the years of 1929-32, the most severe drought in West Virginia's recorded history was experienced.  Some streams that have drainage areas greater than 900 square miles had periods of zero flow during the summer and fall of 1930.  At some precipitation stations, annual precipitation was approximately 50% below normal.  In many instances, municipal water supplies were critically short. For example, during the 1930's drought, the flow in the Elk River was not sufficient enough to fill its banks at its mouth and confluence with the Kanawha.  This resulted in the then heavily polluted waters of the Kanawha to backflow up the Elk River channel past the city of Charleston's main drinking water intake. The filtration plant was not equipped to deal with the pollutants in the Kanawha at that time, and therefore the plant was forced to shut down until normal flows returned to the Elk.

In northern West Virginia, small water-supply reservoirs were depleted and public consumption was decreased from 3 to 1.5 million gallons per day. Tygart Valley River at Elkins became dry; as a result, a pipeline was laid through a railway tunnel to transport water from Shavers Fork.

The drought of 1940-42, although statewide in extent, was not as devastating as the drought of 1929-32. In many areas of the state, however, the duration of localized moisture deficiency exceeded that in 1929-32, as well as the 25-year drought recurrence interval.

During the period 1952-54, drought conditions were most severe in the western and northern portions of West Virginia. With respect to streamflow deficits at gaging stations in these areas, the drought had a recurrence interval that exceeded 25 years. In the mountainous southern and eastern regions of the state, streamflow was only slightly less than normal and the drought recurrence interval was about 10 years.

The entire northeastern United States was affected by the drought of 1963-70 which began in some states in early 1960. When the drought finally ended, it had been the longest in the history of the region. In West Virginia, the duration of the drought exceeded seven years, which was the longest moisture-deficient period on record at most sites. The drought affected the entire state and had a recurrence interval that exceeded 25 years. Streamflow was less than normal at many gaging stations, and by the mid-1960's had reached record minimums. By the end of 1965, groundwater levels had registered new record lows in the Eastern Panhandle. In 1966, streamflows reached record lows at several sites on the Cacapon River and the South Fork South Branch Potomac River.

All of West Virginia felt the effects of the drought of 1987-88. As a result of record-breaking heat and the least rainfall in decades, many agricultural and forestry crops withered and died. The entire $300-million agriculture industry in West Virginia was adversely affected. The short duration drought was broken by record rainfall during the spring and summer of 1989.

The West Virginia Department of Agriculture (WVDA) and WVDHSEM are the lead agencies for drought management. WVDHSEM has published a statewide Drought Response Plan, Annex U of the West Virginia Emergency Operations Plan in 2008. WVDHSEM uses a combination of three indices to assess drought stage: Palmer Drought Severity Index (PDSI), Crop Moisture Index (CMI), and Standard Precipitation Index (SPI).

The Palmer Drought Severity Index (PDSI) attempts to measure the duration and intensity of the long-term drought-inducing circulation patterns. Long-term drought is cumulative, so the intensity of drought during the current month is dependent on the current weather patterns plus the cumulative patterns of previous months. Since weather patterns can change almost literally overnight from a long-term drought pattern to a long-term wet pattern, the PDSI can respond fairly rapidly.

The Crop Moisture Index (CMI) uses a meteorological approach to monitor week-to-week crop conditions. It was developed by Palmer (1968) from procedures within the calculation of the PDSI. Whereas the PDSI monitors long-term meteorological wet and dry spells, the CMI was designed to evaluate short-term moisture conditions across major crop-producing regions. It is based on the mean temperature and total precipitation for each week within a climate division, as well as the CMI value from the previous week. The CMI responds rapidly to changing conditions, and it is weighted by location and time so that maps, which commonly display the weekly CMI across the United States, can be used to compare moisture conditions at different locations.

The Standard Precipitation Index (SPI) was designed to enhance the detection of onset and monitoring of drought (McKee et al, 1993). The SPI is a simpler measure of drought than the PDSI and is based solely on the probability of precipitation for a given time period. A key feature of the SPI is the flexibility to measure drought at different time scales. Because droughts vary greatly in duration, it is important to detect and monitor them at a variety of time scales.

### 5.1.3 Drought Response

The following stages of drought response are excerpted directly from Annex U of the West Virginia Emergency Operations Plan:

A) A drought monitoring and assessment system is required to provide sufficient time for state and local decision-makers to take appropriate action. The drought stages are intended to guide implementation of the state's response to a drought depending upon seasonality and meteorological events. Each stage is determined by weighing all of the criteria used with the aid of the National Climatic Data Center of the National Oceanic and Atmospheric Administration (NOAA) to determine the severity of the drought which includes: precipitation, ground water, stream flow, reservoir levels, PDSI, CMI, SPI, Fire Weather Forecast and the Fire Danger. These nine drought criteria are reassessed each month; therefore, the stages are adjusted only once per month. This facilitates progression through the stages on a monthly basis and if the drought worsens, the spacing of re-assessments every 30 days also provides for conservation measures to be effective.

B) Assessments will employ four stages of concern:

1) Normal

a) Refers to conditions that do not negatively impact water supplies, vegetation or water quality in the state. No action needed.

2) Alert

| PDSI | CMI | SPI |
|---|---|---|
| -2.00 to -2.99<br><br>(yellow) | -1.0 to -1.9<br><br>(yellow) | -1.00 to -1.49<br><br>(tan) |

a) When the PDSI reads -2.00 to -2.99 and streamflow, reservoir levels and ground water levels are below normal over a several-month period and/or the Director of WVDHSEM, in coordination with appropriate state officials, determines Stage II activities are required, the governor is to be requested to make a Drought Alert Declaration.

b) The alert can be rescinded once rainfall, streamflows, reservoir levels and ground water levels return to normal or near normal levels for that time of year. The PDSI would be above -1.0 for normal or near normal levels.

3) Conservation

| PDSI | CMI | SPI |
|---|---|---|
| -3.00 to -3.99<br>(tan)<br>Severe Drought | -2.0 to -2.9<br>(tan)<br>Excessively Dry | -1.50 to -1.99<br>(brown)<br>Severely Dry |

a) Activated when the PDSI is between -3.00 to -3.99 and/or when the director of WVDHSEM, in coordination with appropriate state officials, determines that Stage III activities are required. Streamflow, reservoir levels and ground water levels continue to decline and forecasts indicate an extended period of below normal precipitation.

b) A return to alert level happens when precipitation increases; streamflows, reservoir levels and ground water levels stop their decline; and the PDSI begins to rise to -2.99 or higher or when the director of WVDHSEM, in coordination with appropriate state officials, determines that Stage II activities are required. Extended forecasts should indicate a return to normal conditions.

4) Emergency

| PDSI | CMI | SPI |
|---|---|---|
| -4.00 and below<br>(brown)<br>Extreme Drought | -3.0 or less<br>(brown) Severely Dry | -2.00 and less<br>(red)<br>Extremely Dry |

a) Activated when the PDSI is lower than -4.00 and/or the director of WVDHSEM, in coordination with appropriate state officials, determines that Stage IV activities are required. The governor may issue a Drought Emergency Declaration when water supplies are inadequate to meet projected demands and extreme measures must be taken. Forecasts are to indicate that precipitation levels, streamflows, reservoir levels, and ground water levels will continue to decline.

b) The Governor's declaration empowers state agencies to review allocation of supplies in communities not adequately responding to their water shortage and to implement emergency programs and actions as provided in the West Virginia Code.

Additionally, the USDA maintains the National Drought Monitor may be found at http://droughtmonitor.unl.edu/.

### 5.1.4 Effect of Weather Conditions on Consumptive Use

Forecasting withdrawals and consumptive use under normal or average conditions is difficult. To the extent that drought and climate change cause warmer and drier conditions, consumptive use will rise. Warmer and drier conditions cause a higher rate of evaporation and transpiration by plants. People use more water on outdoor landscaping and there is a greater demand on electricity supplies to run cooling systems. Even under non-drought conditions, withdrawals typically rise during the summer months. Simply stated, under warmer and drier conditions both water withdrawals and consumptive use are likely to increase.

Consumptive use in some sectors is more likely to be affected by droughts and potentially warmer and drier conditions. Public water supply and recreation totals would most likely increase, as more outdoor watering is required for landscaping and golf courses. Withdrawals, and thus consumptive use totals, would likely increase in the thermoelectric sector as there is a greater demand for electricity. Though not in the LQU database, even small-scale agricultural withdrawals and other irrigation uses would see an increase in withdrawals and consumptive use. Sectors less likely to experience an increase would be mining, manufacturing, and Marcellus Shale. These sectors consume water based on requirements for specific processes that are not related to weather conditions.

A forthcoming study from the Interstate Commission on the Potomac River Basin (Ahmed et al. forthcoming) illustrates how without restrictions on use, withdrawals would increase and stress the water supply system for the metropolitan Washington, D.C. area during moderate drought conditions. It also shows that if voluntary and mandatory restrictions on use are implemented, total withdrawals decrease in the same scenario. Therefore, the study demonstrates that the impacts of both droughts and climate change could possibly be mitigated by management measures. Lessons from the Potomac River Basin indicate that management measures and cooperative solutions require a high level of engagement from all the stakeholders. These solutions also require planning far in advance to build necessary water infrastructure to meet demands and to build the relationships necessary to make cooperative, voluntary management options succeed.

## 5.2 Impact of Anthropogenic Activities on Low Flow in West Virginia

The Act requires the DEP to identify potential in-stream or off-stream uses that could affect natural streamflow, especially low-flow conditions, to the detriment of water resources. Many human activities utilize water resources, from domestic use to the production of materials and energy needed by modern society. A number of anthropogenic activities have the potential to negatively impact low-flow conditions in streams, including land uses, dams, water withdrawals and discharges.

### 5.2.1 Changes in Land Use

Human populations and their use of the land have direct impacts on the hydrologic cycle. For example, increasing impervious cover in urban areas causes the streams to become more "flashy." In these urban systems, precipitation does not have the opportunity to infiltrate the soil due to roads, rooftops, parking lots and other impervious surfaces. Instead, the water quickly runs off over the land surface to nearby waterways. As a result, less precipitation is able to recharge the groundwater aquifer, the source of streamflow during low-flow periods. To this end, the current and future West Virginia land use characteristics may influence low-flow conditions in the state by temporarily increasing local flow.

> Results indicated that the largest change from 1992 to 2006 took place within the planted/cultivated land cover class

In order to gain a better understanding of what changes have taken place in the state, the DEP partnered with the Center for Environmental, Geotechnical and Applied Sciences (CEGAS) to identify areas of change, as well as areas with an increase in impervious surfaces. Change Detection is the process of determining and evaluating differences in a variety of surface phenomena over time. Change detection is useful in applications such as land cover change (Masry, Crawley, & Hilborn, 1975), change analysis (Macleod & Congalton, 1998), assessment of deforestation, analysis of change in vegetation phenology associated with change, damage assessment and other environmental changes (Singh, 1989).

CEGAS acquired three image datasets from the National Land Cover Database (NLCD) to study land cover changes: 1992, 2001, and 2006 and two image datasets to examine impervious surfaces changes 2001 and 2006. Results indicated that the largest change from 1992 to 2006 took place within the planted/cultivated land cover class. From 1992 to 2006 this planted/cultivated land experienced a loss of 981 square miles (Figure 5-2). Likewise, forested area saw a decrease of 670 square miles, (Figure 5-3). Showing a significant increase was that of developed land (Figure 5-4). Over this 14-year period, developed land increased by 1,386 square miles. In order to understand the changes from 1992 to 2006, Table 5-2 has a class by class breakdown as well as the total net area that was lost of gained for each class.

From 1992 to 2006, it was determined by CEGAS that 14.91% of the state's area has experienced some sort of change. In order to get a better understanding of the changes that have taken place over that time period, please refer to Table 5-2. For example, what we see is that of the 14.91% of the total change within the state, 39.15% of that was in developed land, accounting for an increase of 1,386 square miles. Table 5-2 also shows a class to class change. For example, of the 39.15% change in developed land, 25.48% of the change took place "from" forest in 1992 "to" developed in 2006.

**Table 5-2 Changing land cover results as calculated by CEGAS from 1992 to 2006 covering the state of West Virginia**

| | | 2006 "to" class | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) | Net gain/lost square miles |
| 1992 "from" class | Unchanged (85.09%) | | | | | | | | | | |
| | | 0.71 | 1.18 | 0.14 | 76.05 | 0.00 | 0.00 | 6.97 | 0.05 | 85.09 | |
| | Changed (14.91%) | | | | | | | | | | |
| | Water | | 0.39 | 0.06 | 0.68 | 0.00 | 0.08 | 0.16 | 0.02 | 1.40 | 9 |
| | Developed | 0.06 | | 0.06 | 0.74 | 0.00 | 0.06 | 0.22 | 0.00 | 1.14 | 1,386 |
| | Barren | 0.07 | 0.89 | | 3.46 | 0.04 | 1.18 | 1.20 | 0.05 | 6.89 | -120 |
| | Forest | 1.25 | 25.48 | 2.78 | | 0.48 | 7.73 | 11.26 | 0.31 | 49.29 | -670 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 22 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 381 |
| | Planted/Cultivated | 0.17 | 12.27 | 0.66 | 25.10 | 0.10 | 1.38 | | 0.23 | 39.92 | -981 |
| | Wetlands | 0.08 | 0.12 | 0.03 | 0.93 | 0.00 | 0.02 | 0.18 | | 1.36 | 27 |
| | **Column totals** | **1.64** | **39.15** | **3.59** | **30.91** | **0.62** | **10.45** | **13.02** | **0.61** | **100.00** | |

Change results matrix for West Virginia. Unchanged values are a percentage of the entire state, while changed values are a percentage of only what changed.

In addition to land use, CEGAS also examined the increase of impervious surfaces (Figure 5-5). The change in impervious area for each watershed was calculated as a percent of the total area of the watershed within the state's boundary using data acquired from the NLCD, which collected data from 2001 and 2006. The total increase in impervious area was 34 square miles. For a more detailed HUC-8 comparison of land cover comparison and impervious changes, see Appendices V and W, respectively. Table 5-3 shows a breakdown of percent change, from 1992 to 2006 (land cover) and 2001 to 2006 (impervious surfaces) for each watershed. This breakdown of the study shows that every watershed in the state had a loss of planted/cultivated crops, a loss of 4.1% of the total area. Conversely, development indicated an increase in every watershed, an increase of 5.7% of the total area.

The total increase in impervious surface area from 2001 to 2006 in West Virginia was 34 square miles

The Middle Potomac River Watershed Assessment (MPRWA) illustrates how the state's land use changes may impact low-flows. A major finding of the MPRWA was the strong relationships between impervious surface, flow alteration and significant ecological impacts (U.S. Army Corps of Engineers et al. 2012). Impervious cover also has the potential to reduce groundwater recharge by reducing infiltration during low-flow conditions. Streamflow flashiness and the number and magnitude of high flow events start to increase when total impervious surface area in a watershed exceeds 0.5 - 2.0% (U.S. Army Corps of Engineers et al. 2012). See the West Virginia Watershed Description companion report for total impervious surface data for each watershed.

Table 5-3 Percent change from 1992 to 2006 of forest, developed and planted/cultivated land cover as well as the change from 2001 to 2006 of impervious cover by 8-digit Hydrologic Unit Code (HUC-8) watershed within the state boundary. The final row of the table is the percent change for all watersheds.

| Watershed | HUC8 Area (sq. mi.) | Percent Change of Forest | Percent Change of Developed | Percent Change of Planted/Cultivated Crops | Percent Change of Impervious Surfaces |
|---|---|---|---|---|---|
| | | 1992 to 2006 | | | 2001 to 2006 |
| South Branch Potomac | 1372 | -0.77 | 3.62 | -2.41 | 0.05 |
| North Branch Potomac | 585 | -2.94 | 4.77 | -0.34 | 0.05 |
| Cacapon | 840 | -1.55 | 3.68 | -1.70 | 0.05 |
| Potomac Direct Drains | 586 | -6.19 | 9.16 | -3.00 | 0.76 |
| Shenandoah Hardy | 17 | 2.35 | 5.88 | -4.12 | 0.00 |
| Shenandoah Jefferson | 103 | -6.99 | 14.27 | -7.57 | 0.99 |
| James | 74 | -4.46 | 4.59 | -4.19 | 0.00 |
| Tygart Valley | 1375 | -0.69 | 6.02 | -4.98 | 0.09 |
| West Fork | 880 | 0.06 | 7.66 | -7.13 | 0.14 |
| Monongahela | 456 | -2.98 | 9.30 | -6.49 | 0.44 |
| Cheat | 1324 | -0.94 | 4.58 | -2.73 | 0.05 |
| Dunkard | 109 | 4.31 | 5.87 | -10.55 | 0.10 |
| Youghiogheny | 72 | 2.22 | 8.75 | -8.89 | 0.08 |
| Upper Ohio North | 126 | -6.83 | 13.41 | -8.10 | 1.40 |
| Upper Ohio South | 561 | 0.36 | 8.31 | -10.04 | 0.40 |
| Middle Ohio North | 953 | 0.41 | 5.51 | -6.15 | 0.06 |
| Middle Ohio South | 705 | -0.38 | 8.00 | -8.14 | 0.19 |
| Little Kanawha | 2308 | -0.19 | 5.12 | -5.04 | 0.06 |
| Upper New | 800 | -4.54 | 8.09 | -6.38 | 0.20 |
| Greenbrier | 1644 | 2.22 | 4.39 | -6.23 | 0.03 |
| Lower New | 691 | -7.83 | 7.77 | -0.38 | 0.22 |
| Gauley | 1420 | -1.61 | 3.94 | -2.56 | 0.04 |
| Upper Kanawha | 519 | -5.43 | 4.20 | -1.06 | 0.17 |
| Elk | 1532 | -2.87 | 4.32 | -1.91 | 0.06 |
| Lower Kanawha | 924 | -1.40 | 7.37 | -3.46 | 0.27 |
| Coal | 892 | -10.06 | 3.52 | -0.54 | 0.12 |
| Upper Guyandotte | 939 | -10.27 | 5.19 | -0.60 | 0.11 |
| Lower Guyandotte | 740 | -6.76 | 6.96 | -4.81 | 0.20 |
| Tug Fork | 935 | -10.21 | 6.03 | -0.70 | 0.15 |
| Big Sandy | 74 | -7.16 | 11.76 | -10.27 | 0.53 |
| Lower Ohio | 221 | -3.57 | 9.46 | -8.60 | 0.17 |
| Twelvepole | 442 | -8.46 | 6.22 | -4.68 | 0.16 |

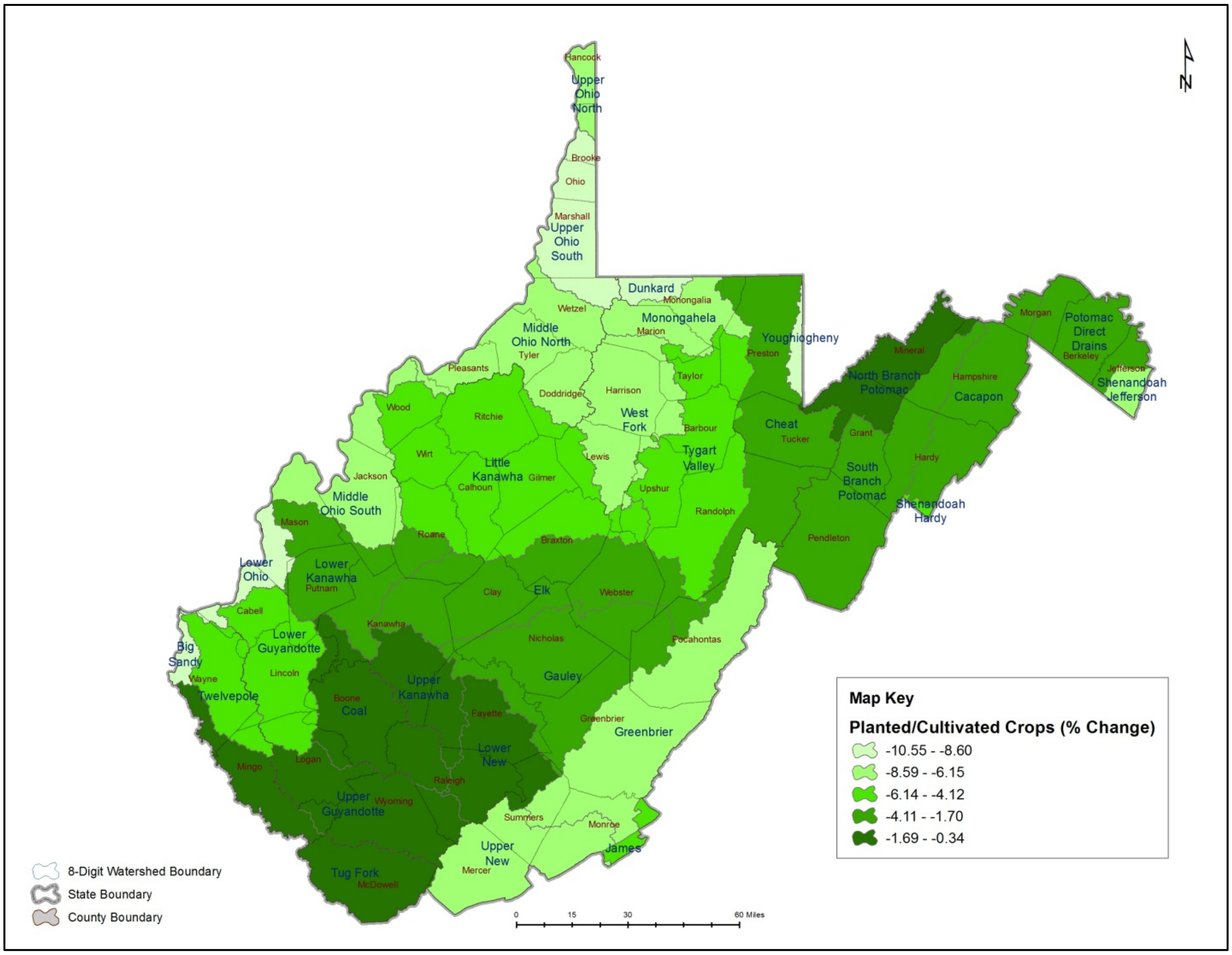



Figure 5-2 Percent change in Planted/Cultivated Crops (NLCD land cover database 1992 – 2006) by HUC-8 watershed.

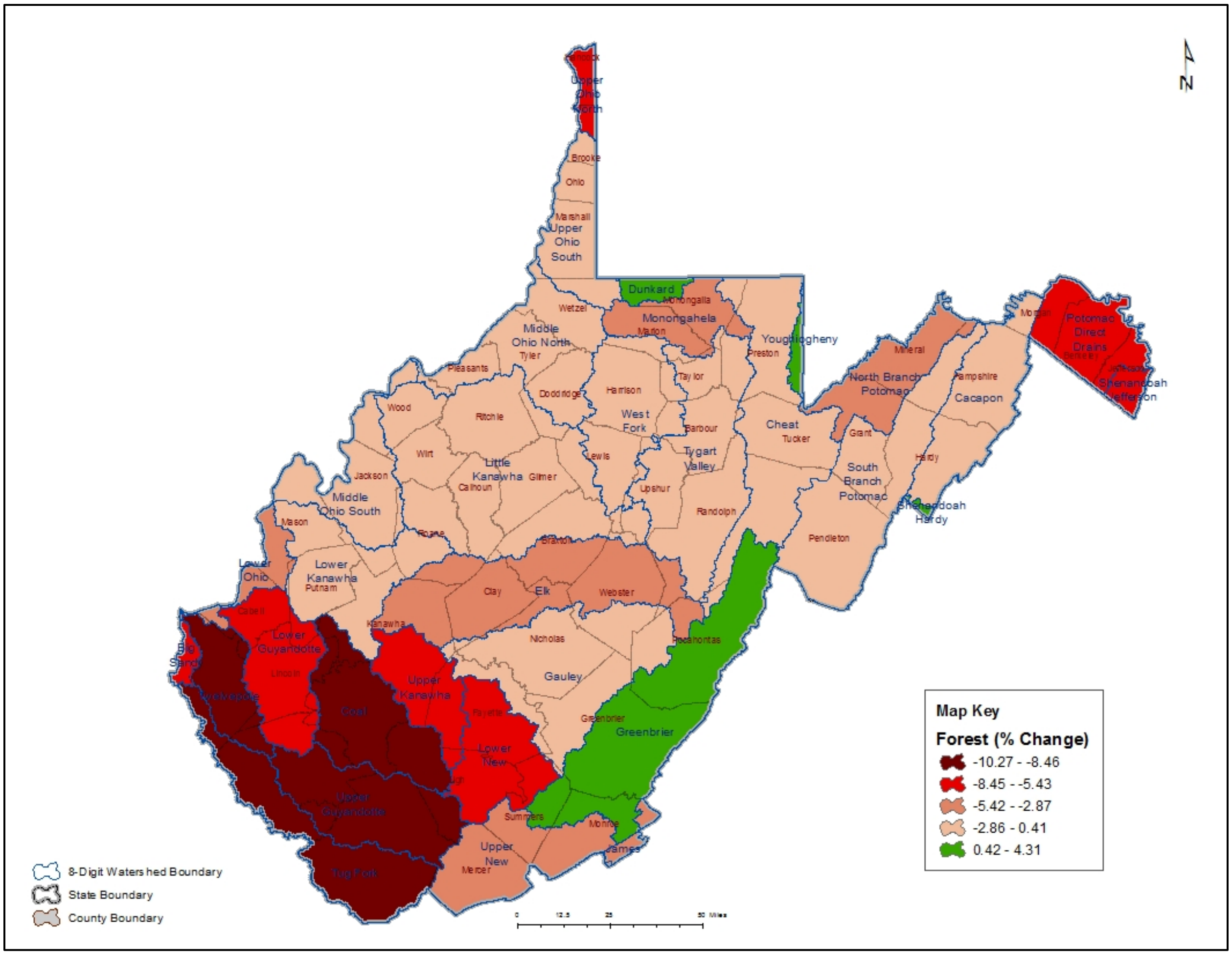



Figure 5-3 Percent Change in Forest NLCD land cover database 1992 – 2006 by HUC-8 watershed.

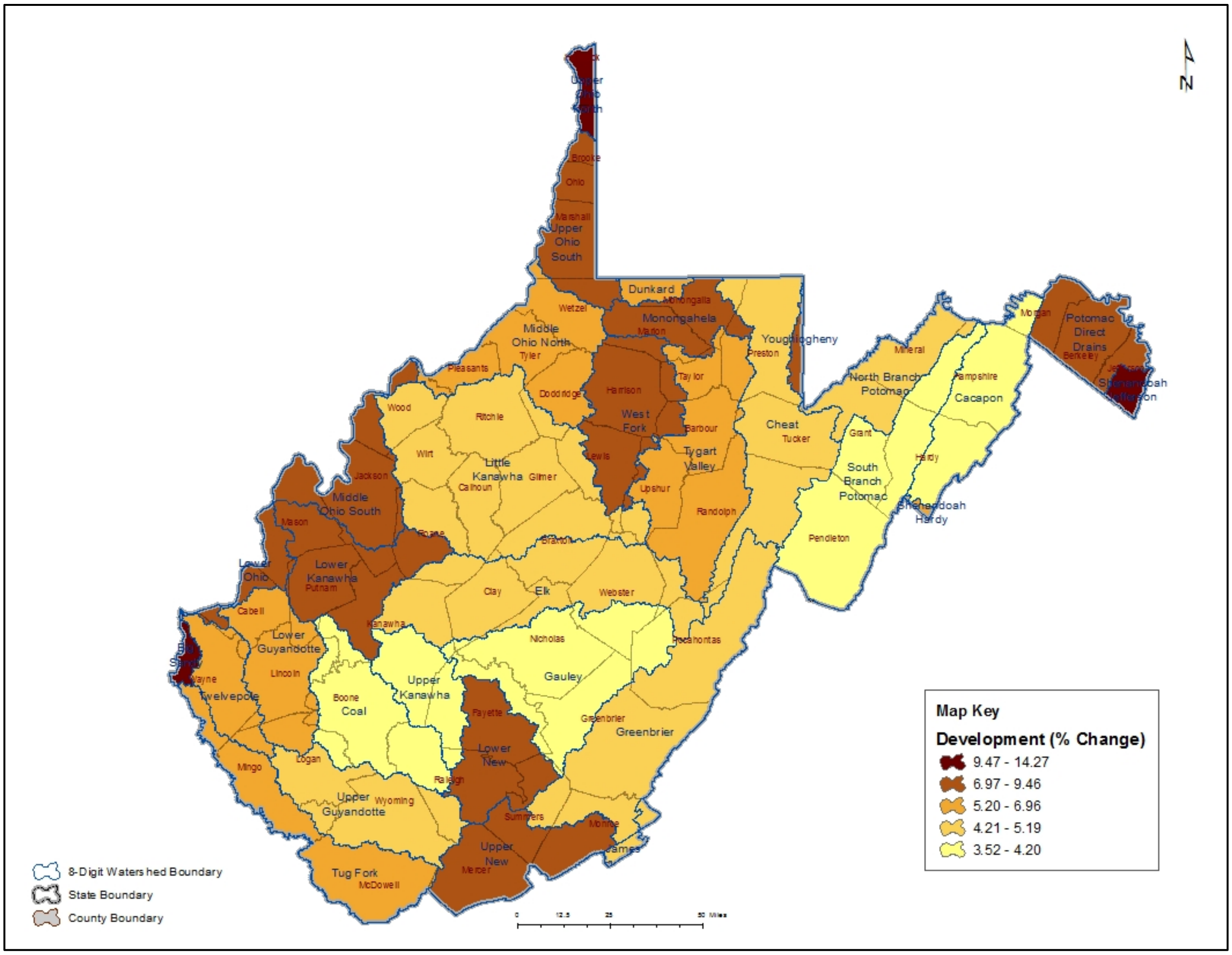



Figure 5-4 Percent Change in Development NLCD land cover database 1992 – 2006 by HUC-8 watershed.

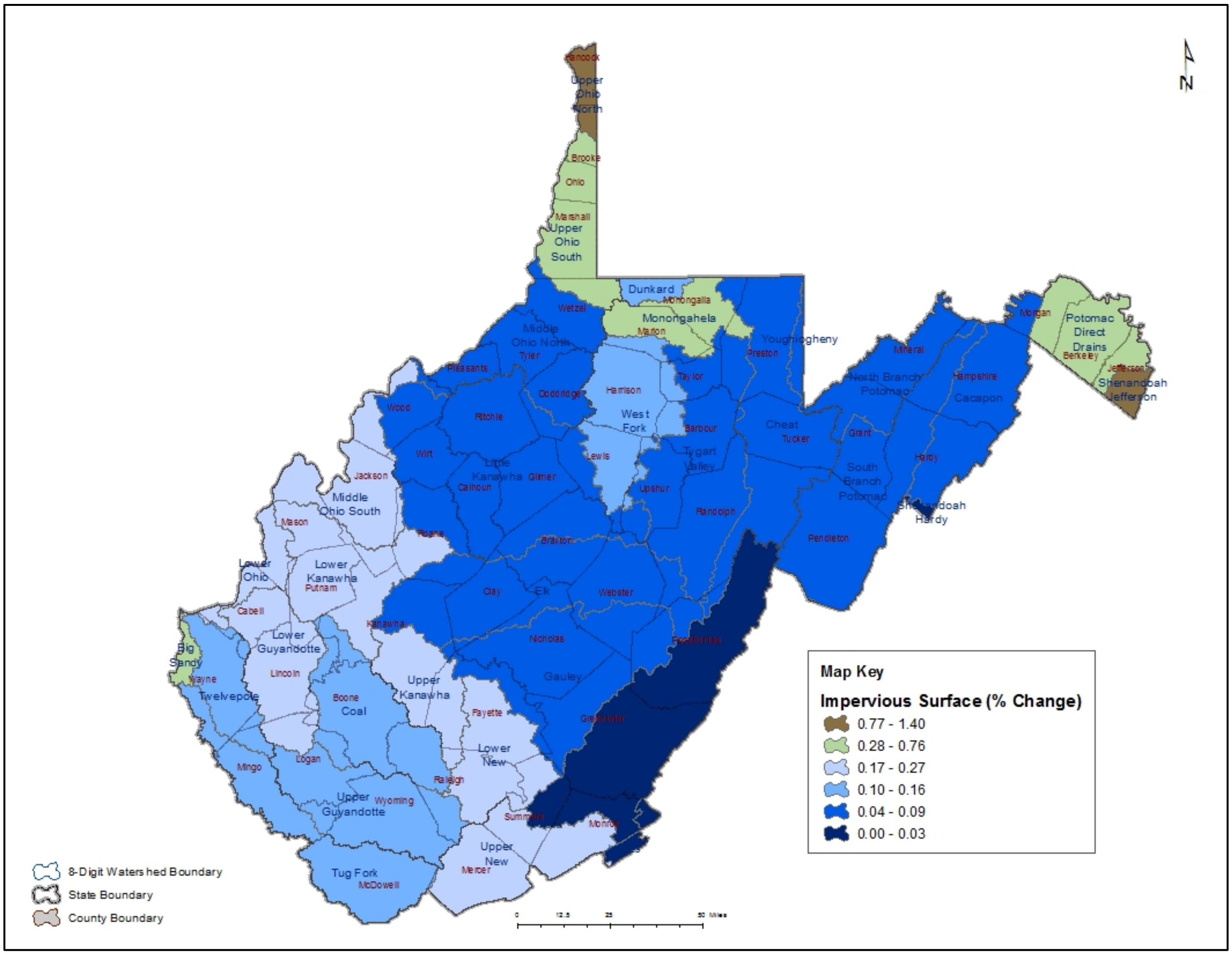



**Figure 5-5 Percent change in Impervious NLCD land cover database 2001 – 2006 by HUC-8 watershed.**

## 5.2.2 Dams

Dams alter the natural flow regime by reducing the high-flow peaks and artificially increasing flows during subsequent dam releases. Dams are designed to allocate waters in order to protect the downstream aquatic ecosystem by improving water quality, control flood events, generate power, provide water supply and recreational opportunities and advance navigation. These releases require a minimum flow during periods of drought or other extreme low-flow conditions. For a detailed breakdown of dams, please refer to Chapter 1.

Constructed in 1981, the Jennings Randolph Dam is a major reservoir of water supply for the Washington, D.C. Metropolitan Area. Jennings Randolph also provides flood control for the Upper Potomac. Most importantly the lake helps improve the water quality of the North Branch Potomac. The majority of the water that drains into the lake is from areas with vast amounts of abandoned coal mines. As water drains through the highly sulfuric mines, acidic conditions that are harmful to fish can be created. This acidic water tends to settle into layers upon entering the reservoir, allowing managers to select the best water to release into the North Branch. This process allows for improved water quality downstream and has resulted in a thriving trout fishery in a river that had virtually no aquatic life just prior to the reservoir construction.

Flood control dams are designed to reduce downstream flooding caused by large rainfall events. Many of these dams are maintained and operated by the WVCA. The stormwater is stored and later released slowly during lower streamflow conditions. Generally, these dams were designed as run-of-river and do not have minimum flow requirements. Run-of-river dams are less likely to impact low-flows as they have much less storage behind the dam, intercept only a portion of the river's flow and minimally regulate natural flows. However, by releasing during natural low-flow conditions flow variability is reduced.

Hydroelectric power is generated using the kinetic energy of falling water to turn a turbine connected to a generator. There are two types of dams used for generating electric power, conventional dams and run-of-river dams. Because conventional dams have a minimum release requirement, the introduction of a hydroelectric "flow-through"' turbine does not alter flows in and of itself. In other words, changes in the flow are not affected by the amount of power generated.

Water supply dams provide a dependable source of potable water by capturing significant portions of high-flow events. High-flows and low-flows can be impacted by the presence of water supply dams (Richter & Thomas, 2007). Recreation dams capture water during high-flow periods and store it to maintain a pool for recreational purposes. During dry periods, usually also low-flow periods, the reservoir level is likely to be lower due to managed releases, lack of inflow and increased evaporation. Regulatory conservation releases can be helpful to protect the aquatic ecosystems downstream of dams.

Each dam has allocated uses, determined pre-construction by the funding entities. USACE was approached with the question of potential reallocation to meet changing water demands. Because USACE dams are managed by a federal agency, reallocation would require a congressional authorization. For a description of how other dams are regulated, see Chapter 1.

The Middle Potomac River Watershed Assessment (MPRWA) Final Report found that impoundments may slightly increase the 7Q10, a low-flow metric defined as the lowest seven-day average flow likely to occur once every 10 years; increase the duration of low pulses; and may affect median flows sometimes increasing or decreasing the levels (U.S. Army Corps of Engineers et al., 2012). The study found a moderate link between an increase in the duration of low pulses and impoundments and withdrawals; however, it was difficult to statistically evaluate the impacts on flow alteration because there are so few large dams in the Potomac River basin.

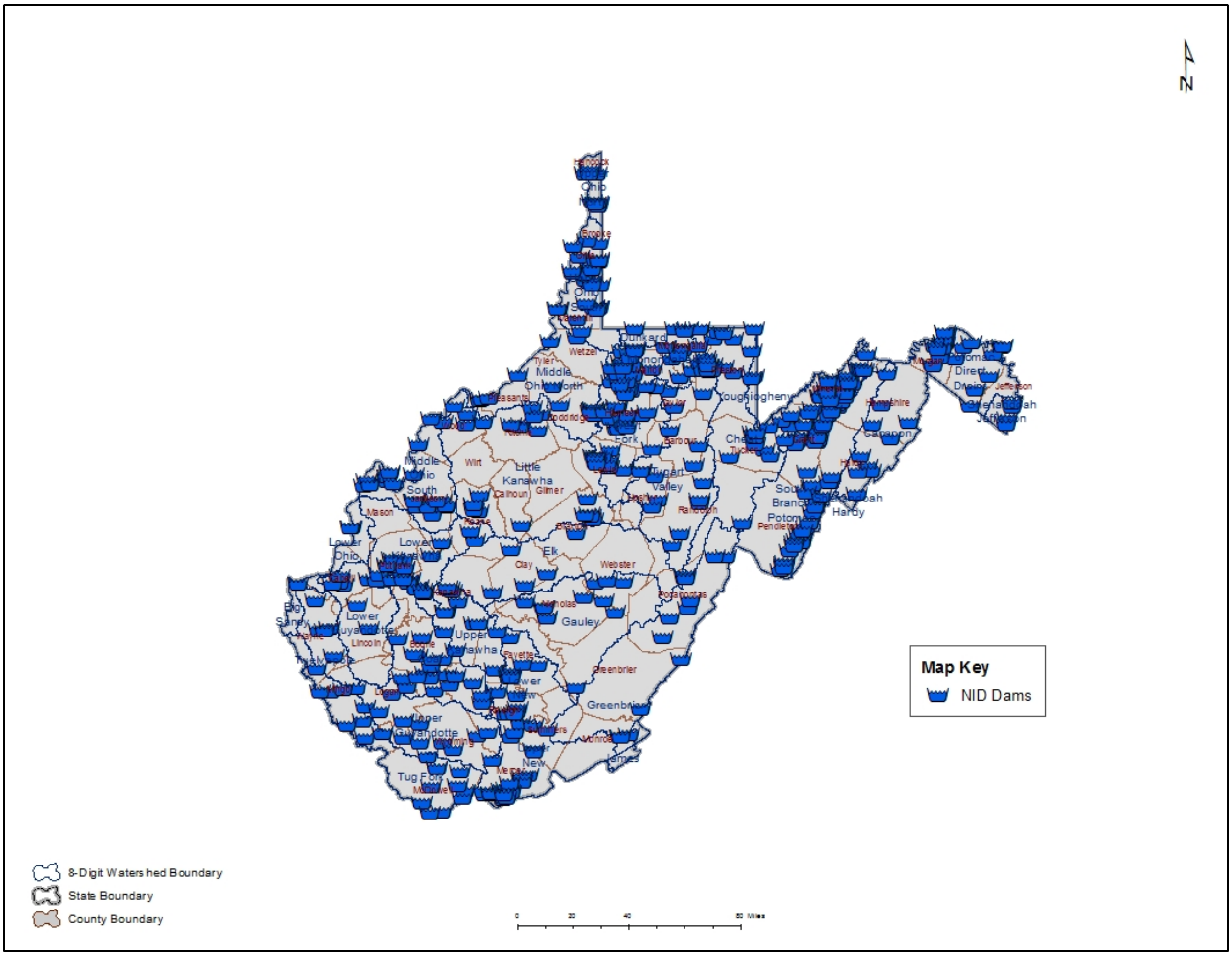



Figure 5-6 Location of NID dams within the state.

### 5.2.3 Surface Mining

Several studies have compared the streamflow characteristics in mined and un-mined watersheds. Surface mining activities include removal of layers of rock, "overburden," in order to gain access to the minerals. Associated with some surface mining (and to a lesser degree with underground mining) are valley fills which are usually adjacent to mining sites where the removed overburden is placed. These valleys frequently contain ephemeral or small first-order streams. Studies have found that mean monthly flows during "normally dry" periods, 90% duration flows and daily flows during low-flow periods, are greater in streams below valley fills than in un-mined watersheds. They also found that peak flows resulting from intense storms are greater below valley fills. High-flows resulting from less-intense storms, on the other hand, are frequently (but not consistently) lower below valley fills than in un-mined watersheds (EPA 2011; Messinger 2003; Messinger and Paybins 2003; Wiley and Brogan 2003; Wiley et al. 2001).

Table 5-4 shows the total area within each HUC-8 watershed and the percent of the total HUC-8 area that is within a surface mine permit area, valley fill or refuse pile area. The greatest total area of these surface mining activities in any HUC-8 watershed, as a percentage of the watershed area, was 18% in the Coal Watershed. Utilizing a DEP GIS permitted surface mining boundaries dataset (including quarries), the approximate location of surface mining activities, valleys fills and refuse pile structures may be viewed at the following DEP website: http://tagis.dep.wv.gov/mining/

**Table 5-4 Total area (sqmi) of active surface mining and related activities by HUC-8 and percent of the total HUC-8 area.**

| HUC-8 | Surface Mining Activities (sq.mi.) | Permitted Valley Fills (sq.mi.) | Permitted Mine Refuse (sq.mi.) | Percent of HUC-8 Area |
|---|---|---|---|---|
| South Branch Potomac | 1.6 | 0 | 0 | 0.1 |
| North Branch Potomac | 9.6 | 0 | 0 | 1.6 |
| Cacapon | 0.0 | 0 | 0 | 0.0 |
| Potomac Direct Drains | 3.3 | 0 | 0 | 0.6 |
| Shenandoah Hardy | 0.0 | 0.06 | 0.05 | 0.6 |
| Shenandoah Jefferson | 3.6 | 0 | 0 | 3.5 |
| James | 0.0 | 0.1 | 0.09 | 0.3 |

| HUC-8 | Surface Mining Activities (sq.mi.) | Permitted Valley Fills (sq.mi.) | Permitted Mine Refuse (sq.mi.) | Percent of HUC-8 Area |
|---|---|---|---|---|
| Tygart Valley | 15.3 | 0.06 | 0.05 | 1.1 |
| West Fork | 9.4 | 0.22 | 0 | 1.1 |
| Monongahela | 16.3 | 0.1 | 0.09 | 3.6 |
| Cheat | 8.2 | 0 | 0 | 0.6 |
| Dunkard | 2.3 | 0 | 0.07 | 2.1 |
| Youghiogheny | 0.2 | 0 | 0 | 0.3 |
| Upper Ohio North | 1.4 | 0 | 0 | 1.1 |
| Upper Ohio South | 5.1 | 0 | 0.04 | 0.9 |
| Middle Ohio North | 0.2 | 0 | 0 | 0.0 |
| Middle Ohio South | 1.8 | 0 | 0 | 0.3 |
| Little Kanawha | 0.1 | 0 | 0 | 0.0 |
| Upper New | 2.1 | 0 | 0.03 | 0.3 |
| Greenbrier | 2.4 | 0 | 0 | 0.1 |
| Lower New | 3.1 | 0.06 | 0.07 | 0.5 |
| Gauley | 59.3 | 0.49 | 0.08 | 4.2 |
| Upper Kanawha | 74.8 | 0.36 | 0.04 | 14.3 |
| Elk | 46.4 | 0.3 | 0.03 | 3.0 |
| Lower Kanawha | 1.8 | 0 | 0 | 0.2 |
| Coal | 156.6 | 0.19 | 0.25 | 17.5 |
| Upper Guyandotte | 79.1 | 0.31 | 1.29 | 8.5 |

| HUC-8 | Surface Mining Activities (sq.mi.) | Permitted Valley Fills (sq.mi.) | Permitted Mine Refuse (sq.mi.) | Percent of HUC-8 Area |
|---|---|---|---|---|
| Lower Guyandotte | 19.5 | 0.01 | 0 | 2.6 |
| Tug Fork | 106.4 | 0.62 | 0.59 | 11.5 |
| Big Sandy | 0.2 | 0 | 0 | 0.3 |
| Lower Ohio | 0.4 | 0 | 0 | 0.2 |
| Twelvepole | 25.1 | 0.04 | 0 | 5.6 |

### 5.2.4 Withdrawals and Discharges

Groundwater withdrawals can impact nearby streamflows by reducing the natural groundwater discharge that contributes a major portion of streamflow during low-flow conditions, especially in headwater streams. Surface water withdrawals directly affect streamflows by diverting some of the natural flow to off-stream uses. Discharges to streams have the opposite effect, adding water to natural flows. The result is a reduction in low-flows and an increase in high-flows. Refer to Chapter 2 for a detailed description of water use throughout the state.

The MPRWA (U.S. Army Corps of Engineers et al. 2012) found that withdrawals reduce the annual mean, median and August median flows; they increase the flashiness and the extreme low flow frequency, but decrease the high flow index metric and the high flow duration metric. Additionally, they cause a slight decrease in the 3-day maximum, 3-day minimum flows, number of reversals in flow change, high pulse frequency and a slight increase in the duration of low flow pulses (U.S. Army Corps of Engineers et al. 2012, Table 4 Appendix G). Discharges were found by this study to:

- Increase annual mean, annual median, August median, and 3-day minimum flows
- Decrease flashiness, low pulse duration
- Slightly decrease extreme low-flow frequency
- Slightly increase high-flow duration index metric

## 5.3 Aging Infrastructure and Access to Public Water Supply

### 5.3.1 Source Water Availability

The West Virginia Infrastructure and Capacity Development Office in the Department of Health and Human Resources (DHHR) was contacted in an effort to uncover any existing or potential future issues with source water availability, competition or population capacity of the source. This information could potentially be used to develop critical planning areas and for identification of the best placement areas for Large Quantity Users. They provided a baseline survey conducted with the water systems in 2011, which is due to be completed again in 2014. The survey was directed only at the public water systems that are classified as a community water system or a non-transient, non-community (NTNC) system which the EPA defines as "a public water system that regularly supplies water to at least 25 of the same people at least six months per year, but not year-round." There are approximately 490 community systems and 120 NTNC systems in the state. The 2011 baseline survey only had 301 complete, non-duplicate responses. A limitation of the DEP follow up to better understand the DHHR surveys was that systems in the Northern Panhandle did not receive the initial surveys.

The surveys were completed by either water operators or other facility staff. Of the 50, mostly "yes," "no" question responses, the two following questions were further investigated for the purposes of uncovering source water availability issues: "Do you believe that the source water quantity is adequate for the next five years?" and "Does the finished water meet or exceed SDWA (Safe Drinking Water Act) standards without extensive treatment?" There were 14 facilities that replied they did not believe their source water quantity would be adequate for the next five years and 15 facilities that replied their finished water required extensive treatment to meet SDWA standards (Table 5-5). Reports for each facility were generated based on relevant information found in the corresponding Public Service Commission (PSC) report, West Virginia Infrastructure and Job Development Council (WVIJDC) project website and the most recent Sanitary Survey, when available (Appendices X and Y). After compiling the relevant information, the DHHR district engineers were contacted as a follow-up to determine if any additional information about each system was available.

It is important to remember that the person who completed the survey may not have had the best available data. If it was administrative staff, they may have reported a problem when they had only a problematic event during the previous year. However, the operators may not have reported such an event in the same way. For this reason, the district engineers, who look at the technical operation of the systems (which include source, operation of the plant, distribution system, etc.), were deemed more likely to have reliable information about potential source water issues. In several cases, the engineers' assessment of the source was vastly different than what the system reported on the survey. Information regarding the source water quantity and quality at each facility was also requested from the Rural Watershed Association. The combined responses and solution suggestions of the associated DHHR district engineers and the Rural Watershed Association representative gathered by telephone or email correspondence are in Table 5-6 and Table 5-7 on the following pages.

The Infrastructure and Capacity Development Office completes an in depth assessment of approximately 25 facilities per year, but not solely based on the responses to the baseline survey. Systems seeking State Revolving Fund (SRF) dollars receive primary consideration, after which, the overall scores of the systems relating to viability (based on finances, long term planning, compliance, etc.) are considered. So, their source problems, while an issue for them, wouldn't necessarily be a triggering factor for a more in depth assessment of the system by DHHR.

**Table 5-5 Community (C) and Nont-Transient Non-Community (NTNC) systems with negative responses to DHHR Capacity Development 2011 baseline survey. *Some facilities were not contacted about completing a survey.**

| # | District DHHR Office | Source water not adequate quantity for the next 5 years | Finished water requires extensive treatment to meet SDWA standards |
|---|---|---|---|
| 1 | Beckley | Cool Ridge – FlatTop PSD (C)<br>Zela Elementary School (NTNC) | Ravencliff, McGraws, Salusville (C)<br>Summersville Municipal Water (C)<br>Town of Alderson (C)<br>Raleigh Co. PSD - Slab Fork (C)<br>Zela Elementary School (NTNC) |
| 2 | St. Albans | Buffalo Creek PSD (C)<br>Town of Hurricane (C)<br>Pt. Pleasant Water Works (C)<br>Coal River Energy (NTNC) | City of Ravenswood Water (C)<br>Town of Wayne Water (C)<br>Coal River Energy (NTNC) |
| 3 | Fairmont | NONE* | NONE* |
| 4 | Kearneysville | Valley Water & Sewer Services (C)<br>Cavaland Subdivision (C)<br>Glen Haven Utilities (C) | Berkeley Co. PSWD (C)<br>City of Romney Water (C)<br>Jefferson Util. – Burr Industrial (NTNC) |
| 5 | Wheeling | City of Cameron Water (C)<br>City of Saint Marys (C) | NONE* |
| 6 | Philippi | Century Volga PSD (C)<br>Chestnut Ridge PSD (C)<br>Preston Co. PSD #4 (C) | Cheat Mountain Water (C)<br>Town of Tunnelton (C)<br>Aurora School (NTNC)<br>Carter Roag - Pleasant Hill (NTNC) |

**Table 5-6 Combined explanations and suggested solutions from West Virginia Rural Water Association and DHHR District Engineers for facilties that responded "NO" to the DHHR baseline survey question; "Do you believe that the source water quantity is adequate for the next five years?"**

| Facility | Explanation/Suggestions |
|---|---|
| Cool Ridge - Flat Top PSD (C) | Purchases water from Beckley which draws water from two surface water reservoirs and one relatively new groundwater source, the Sweenyburg mine. Beckley has a growing population and the new groundwater source did not contain as much water as was thought. Additionally, the groundwater source is adjacent to a coal slurry impoundment; if the source failed the system would run out of water in approximately five days. |
| Zela Elementary School (NTNC) | Inactive Nov. 2012, according to the Public Service Commission |
| Buffalo Creek PSD (C) | The source wells have never been yield or draw down tested and the well heads are inside the 100 year flood plain. Additionally the supply is limited and low quality. A storage reservoir for untreated water that gravity feeds into the facility as needed may be a potential solution. |
| Town of Hurricane (C) | Heavy siltation of reservoir due to the three smaller raw water reservoirs that feed it and a growing population are supply problems. A line directly from the upper three to the lower may be beneficial but an additional large reservoir site may also be needed. |
| Point Pleasant Water Works (C) | Trichloroethylene (TCE) contamination in groundwater from adjacent factory caused the loss of some wells. New wells have been dug but production rates are lower than expected. More wells may be needed. |
| Coal River Energy (NTNC) | Well water not under the influence of surface water and has adequate supply. |
| Valley Water & Sewer Services (C) | Groundwater system in karst geology in Jefferson County which is directly influenced by surface water and in an area prone to shortages during droughts. Additional wells could supplement supply. |
| Cavaland Subdivision (C) | Groundwater system in karst geology in Jefferson County which is directly influenced by surface water and in an area prone to shortages during droughts. Additional wells could supplement supply. |
| Glen Haven Utilities (C) | Groundwater system in karst geology in Jefferson County which is directly influenced by surface water and in an area prone to shortages during droughts. Additional wells could supplement supply. |
| City of Cameron Water (C) | Has a raw water reservoir and is in an active area of mineral (coal and gas) mining. Consol Energy is considering a long wall operation under the reservoir but wants to provide additional groundwater sources. Purchasing from the City of Moundsville may also be a viable solution if long wall operations begin. |
| City of Saint Marys (C) | System has expanded and additional sources are needed but funding may be required to dig new wells. Additionally, the source water must have the $CO_2$ removed to prevent corrosion and deposition of heavy metals. The process may limit supply but finished water storage tanks could be a solution. |
| Century Volga PSD (C) | Purchase water from the City of Philippi which has a new water plant under construction which is due to be producing water within the year. |
| Chestnut Ridge PSD (C) | Purchase water from the City of Philippi which has a new water plant under construction which is due to be producing water within the year. |
| Preston County PSD #4 (C) | Going through line extensions and upgrades, supplies a federal prison with a growing population, and an additional prison is expected to be built. An additional well was recently added but there are concerns about new Marcellus withdrawals from surface water sources near wells or the potential sales to drillers. |

**Table 5-7 Combined explanations and suggested solutions from West Virginia Rural Water Association and DHHR District Engineers for facilities that responded "NO" to the DHHR baseline survey question: "Does the finished water meet or exceed SDWA (Safe Drinking Water Act) standards without extensive treatment?"**

| Facility | Explanation/Suggestions |
|---|---|
| Ravencliff, McGraws, Saulsville PSD (C) | Have received minimal violations and been put on a five-year sanitary survey cycle because of their virus reduction plan. The only recent chemical violations are for Trihalomethanes which will go down after the line expansion and replacements in progress are completed. Applied for a new treatment plant on RD Bailey through the American Reinvestment Act but the project was too big and could not be funded. The groundwater source is a flooded mine pool which seems to receive surface water, but it has been saline. Additionally there have been some problems with disinfection bi-products (DBPs) but can be removed with aeration at the plant and/or in storage tanks. |
| Summersville Municipal Water (C) | Has a newer treatment plant and the source water does not require any treatment outside of normal requirements for a surface water source. |
| Town of Alderson (C) | The source water does not require any treatment outside of what is normal for a surface water source. |
| Raleigh Co. PSD - Slab Fork (C) | Purchases water from Beckley which draws water from two surface water reservoirs and one relatively new groundwater source, the Sweenysburg mine. Additionally, the groundwater source is adjacent to a coal slurry impoundment; there may be some concerns about contamination if the impoundment were to fail. However, no excessive treatment is currently required to meet SDWA standards. This system may be able to get Abandoned Mine Land (AML) funds to secure a new source. |
| Zela Elementary School (NTNC) | Inactive Nov. 2012, according to the Public Service Commission. |
| City of Ravenswood Water (C) | The US EPA drilled new wells for the town and started a Superfund investigation due to contamination of the old wells with PCE, a dry cleaning solvent. High turbidity of the source water requires microfiltration and air stripping unit which has higher costs for treatment. |
| Town of Wayne Water (C) | The surface water source is Twelvepole creek that requires almost all available treatments, including but not limited to disinfection, coagulation, and taste improvement. This may seem extensive but is not necessarily unusual requirements for surface water sources. |
| Coal River Energy (NTNC) | Groundwater source is not under the influence of surface water but does require grain sand filtration but is not unusually excessive treatment. |
| Berkeley Co. PSWD (C) | Treats water from the Potomac River and have had some high quantities of disinfection bi-products in the finished water due to the high organics and/or bromide content of the source water. They have been blending a new groundwater source to reduce the concentration. |
| City of Romney Water (C) | Have usually had taste and odor problems in late summer months but have made operational changes including a chemical feed at a surface water intake location and at the plant to correct the problem. |
| Jefferson Utilities – Burr Industrial Park (NTNC) | Groundwater wells are under the influence of surface water so filtration is required but are having no problems meeting standards. |
| Cheat Mountain Water (C) | The surface water source is lake water that has had a blue-green algae problem but is still treatable. |
| Town of Tunnelton (C) | Had to abandon the groundwater wells and begin purchasing water from Rowlesburg. The water levels kept dropping, possibly due to underground mining. Rowlesburg uses the Cheat River as a surface water source whose quality changes frequently with rain events. The intake location may also need to be changed due a potential loss of fidelity to its proximity to active railroad tracks. |
| Aurora School (NTNC) | Groundwater system in karst geology which may be directly influenced by surface water which would require treatment beyond normal groundwater requirements such as filtration. |
| Carter Roag - Pleasant Hill Mine (NTNC) | No known issues with treatment. |

### 5.3.2 Access to Public Utility

> 42% of the state's population is not currently on public water supply. Additionally, more than 66% are not on public sewage.

Formed in 1994 by an act of the West Virginia Legislature, The West Virginia Infrastructure and Jobs Development Council (IJDC) was developed to become the state's funding clearinghouse for water and wastewater projects. The council regularly reviews project submissions for funding assistance determinations. To make these decisions, it is critical to identify areas within the state that currently provide public water supply and sewage services. Updated service information is available on the IJDC webpage: http://gis.wvinfrastructure.com/.

Using structural data from the Statewide Addressing and Mapping Board (SAMB), (See Chapter - 2, Section 2.3 for detailed data descriptions), which accounts for all structures regardless of occupancy, IJDC was able to estimate those that are being served and not being served by public water systems, as well as sewage service. These estimates are based on structures that are within a distance of 500 feet from a known existing line and the 2010 US Census. IJDC determined that 42% of the state's population is not currently on public water supply (Table 5-8 and Figure 5-7). Additionally, more than 66% are not on public sewage (Table 5-8, Figure 5-9).

**Table 5-8 IJDC statewide estimates of population served with public water supply and public sewage (due to data restraints, estimates may run high).**

| | Estimated Served Population | Percentage Served | Estimated Unserved Population | Percentage Unserved |
|---|---|---|---|---|
| **Public Water** | 1,079,137 | 58.24% | 773,857 | 41.76% |
| **Public Sewage** | 632,478 | 34.13% | 1,220,516 | 65.87% |

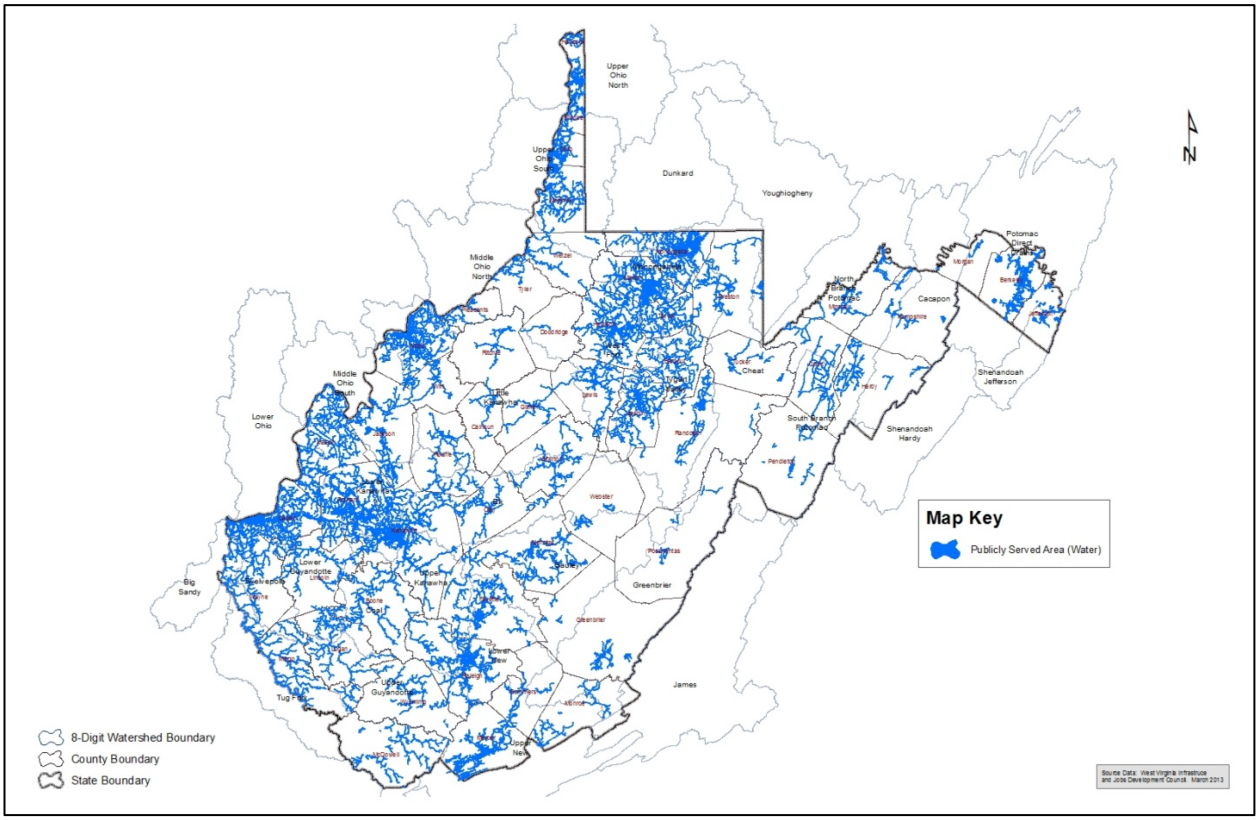



**Figure 5-7 IJDC identified areas of public water supply serviced areas.**

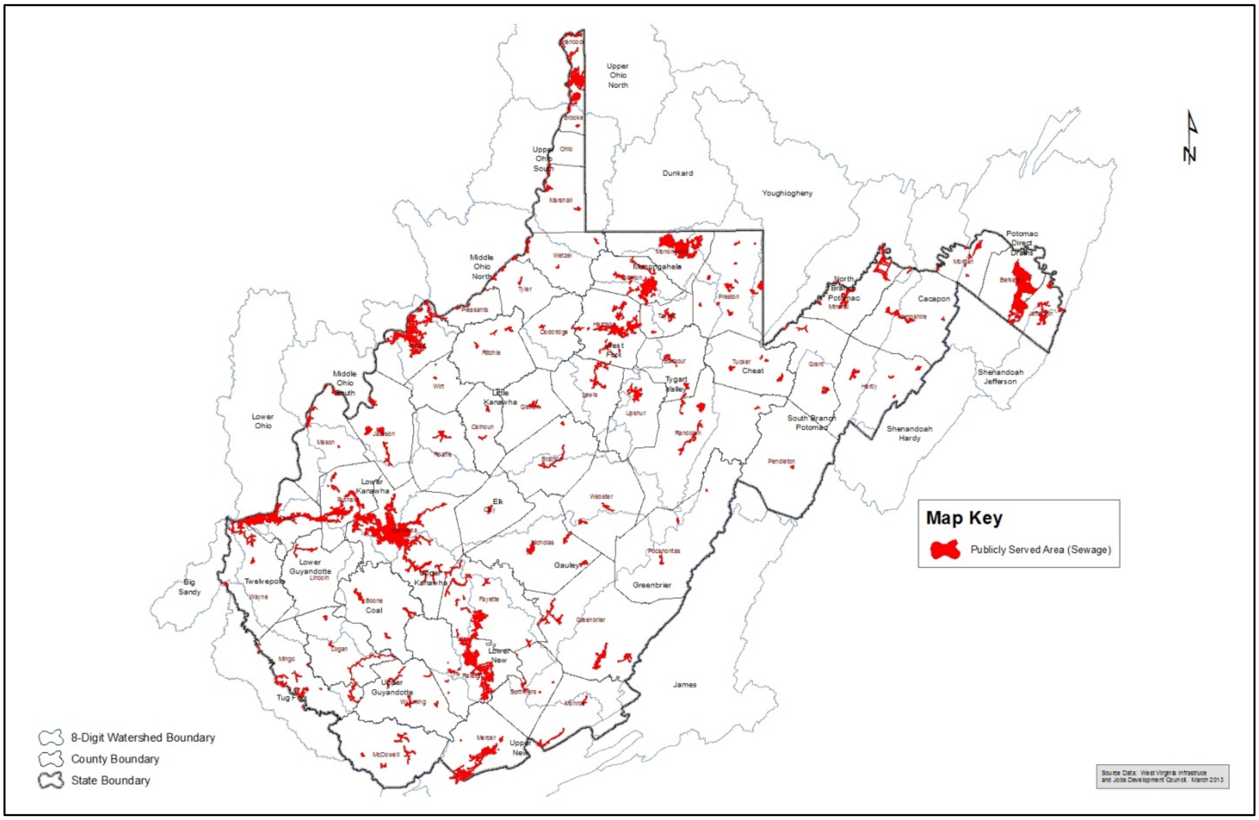



**Figure 5-8 IJDC identified areas of public sewage serviced areas.**

Shown in Table 5-9 is a county-by-county breakdown of population and percentage of those not on public water supply or sewage.

**Table 5-9 IJDC county estimates of those served by public water supply and sewage.**

| County | Population | Estimated Unserved Population (water) | Percentage of Unserved Population (water) | Estimated Unserved Population (sewage) | Percentage of Unserved Population (sewage) |
|---|---|---|---|---|---|
| Barbour | 16,589 | 6,937 | 41.82% | 13,156 | 79.31% |
| Berkeley | 104,169 | 86,279 | 82.83% | 66,365 | 63.71% |
| Boone | 24,629 | 3,724 | 15.12% | 20,253 | 82.23% |
| Braxton | 14,523 | 8,717 | 60.03% | 12,572 | 86.56% |
| Brooke | 24,069 | 5,847 | 24.29% | 14,774 | 61.38% |
| Cabell | 96,319 | 3,621 | 3.76% | 72,490 | 75.26% |
| Calhoun | 7,627 | 5,871 | 76.97% | 7,145 | 93.68% |
| Clay | 9,386 | 5,599 | 59.65% | 9,003 | 95.92% |
| Doddridge | 8,202 | 7,125 | 86.87% | 7,249 | 88.39% |
| Fayette | 46,039 | 13,161 | 28.59% | 30,635 | 66.54% |
| Gilmer | 8,693 | 4,259 | 49.00% | 5,585 | 64.24% |
| Grant | 11,937 | 6,632 | 55.56% | 9,837 | 82.41% |
| Greenbrier | 35,480 | 22,941 | 64.66% | 23,823 | 67.14% |
| Hampshire | 23,964 | 19,444 | 81.14% | 20,581 | 85.88% |
| Hancock | 30,676 | 7,985 | 26.03% | 22,012 | 71.76% |
| Hardy | 14,025 | 10,593 | 75.53% | 13,811 | 98.47% |
| Harrison | 69,099 | 18,188 | 26.32% | 32,298 | 46.74% |
| Jackson | 29,211 | 13,899 | 47.58% | 22,032 | 75.42% |
| Jefferson | 53,498 | 33,952 | 63.46% | 37,178 | 69.49% |
| Kanawha | 193,063 | 4,597 | 2.38% | 38,052 | 19.71% |
| Lewis | 16,372 | 7,121 | 43.49% | 11,854 | 72.41% |
| Lincoln | 21,720 | 12,178 | 56.07% | 19,730 | 90.84% |
| Logan | 36,743 | 8,742 | 23.79% | 29,924 | 81.44% |
| Marion | 56,418 | 18,697 | 33.14% | 30,552 | 54.15% |
| Marshall | 33,107 | 12,197 | 36.84% | 23,193 | 70.05% |
| Mason | 27,324 | 26,314 | 96.30% | 26,466 | 96.86% |
| McDowell | 22,113 | 9,388 | 42.46% | 18,209 | 82.34% |
| Mercer | 62,264 | 22,790 | 36.60% | 53,665 | 86.19% |
| Mineral | 28,212 | 13,216 | 46.85% | 17,802 | 63.10% |
| Mingo | 26,839 | 6,722 | 25.05% | 19,087 | 71.12% |
| Monongalia | 96,189 | 80,775 | 83.97% | 81,848 | 85.09% |
| Monroe | 13,502 | 9,450 | 69.99% | 11,861 | 87.84% |
| Morgan | 17,541 | 15,163 | 86.45% | 14,815 | 84.46% |
| Nicholas | 26,233 | 14,797 | 56.41% | 20,637 | 78.67% |
| Ohio | 44,443 | 41,493 | 93.36% | 41,843 | 94.15% |
| Pendleton | 7,695 | 6,296 | 81.82% | 7,248 | 94.19% |
| Pleasants | 7,605 | 6,686 | 87.92% | 5,696 | 74.90% |
| Pocahontas | 8,719 | 6,663 | 76.42% | 8,402 | 96.36% |
| Preston | 33,520 | 21,768 | 64.94% | 26,329 | 78.55% |
| Putnam | 55,486 | 8,468 | 15.26% | 32,052 | 57.77% |
| Raleigh | 78,859 | 22,039 | 27.95% | 38,694 | 49.07% |
| Randolph | 29,405 | 15,318 | 52.09% | 19,338 | 65.76% |
| Ritchie | 10,449 | 7,495 | 71.73% | 9,084 | 86.94% |

| County | Population | Estimated Unserved Population (water) | Percentage of Unserved Population (water) | Estimated Unserved Population (sewage) | Percentage of Unserved Population (sewage) |
|---|---|---|---|---|---|
| Roane | 14,926 | 8,996 | 60.27% | 13,206 | 88.48% |
| Summers | 13,927 | 9,019 | 64.76% | 11,241 | 80.71% |
| Taylor | 16,895 | 5,352 | 31.68% | 12,441 | 73.64% |
| Tucker | 7,141 | 5,409 | 75.74% | 5,124 | 71.75% |
| Tyler | 9,208 | 5,961 | 64.74% | 6,749 | 73.30% |
| Upshur | 24,254 | 7,675 | 31.64% | 16,560 | 68.28% |
| Wayne | 42,481 | 3,650 | 8.59% | 37,304 | 87.81% |
| Webster | 9,154 | 6,346 | 69.32% | 7,450 | 81.38% |
| Wetzel | 16,583 | 7,929 | 47.82% | 11,388 | 68.67% |
| Wirt | 5,717 | 3,363 | 58.82% | 5,174 | 90.51% |
| Wood | 86,956 | 15,259 | 17.55% | 28,388 | 32.65% |
| Wyoming | 23,796 | 11,746 | 49.36% | 18,309 | 76.94% |
| Total | 1,852,994 | | 41.76% | 1,220,516 | 65.87% |

### 5.3.3 Stormwater Management

Stormwater runoff occurs when rainfall cannot infiltrate the soil. Impervious surfaces are typically the reason rainfall cannot be absorbed into the soil. Impervious surfaces are often the result of land development and include surfaces such as rooftops, parking lots, driveways and streets, but can also include rock formations and compacted soil.  As watersheds are developed and urbanized, the naturally vegetated areas are replaced by impervious surfaces that exacerbate the effects of stormwater runoff. Pollutants such as oils, grease, bacteria, metals, sediment, fertilizers, salt and chemicals run off of impervious surfaces during periods of rainfall and are carried into the nearest stream, lake or river untreated.  Extended periods of rainfall can saturate the soil preventing stormwater from percolating to the subsurface and intensifying the resulting runoff. Increases in the amount of stormwater runoff also increase the likelihood of more frequent and severe flooding.

Polluted stormwater runoff is one of the leading causes of water pollution in the United States. The list below highlights some of the problems associated with unmanaged or improperly managed stormwater:

- Pollution
- Incised streams, causing increased sedimentation
- Lower quality of fish and benthic habitat
- Reduced economic stimulus from fishing and recreational industries
- Flooding and the associated property damage

Natural streams and floodplains provide millions of dollars' worth of "clean-water" treatment, much of which is lost as streams downcut, erode and adjust to increased runoff. Well-designed and implemented stormwater management practices not only treat runoff for pollutants, but also help to prevent streams from eroding, maintain natural storage of flood flows, capture sediments and other pollutants and maintain stable habitat that occurs in and alongside healthy streams. Preventing pollution from entering streams is far less expensive than trying to remove the pollutant later. Additionally, application of Low Impact Development (LID) and runoff reduction techniques have, in many cases, lowered the cost of infrastructure over conventional developments, while preserving the natural integrity and services of streams and riparian areas. Low Impact Development is a stormwater management technique that seeks to maintain or restore the natural site hydrology and keep rainfall on site. The implementation of LID principles and techniques help to promote water management by reducing the impact of construction/development and encouraging the natural flow of water within a system.

#### 5.3.3.1 Stormwater Regulations in West Virginia

The State of West Virginia does not currently have comprehensive statewide stormwater management regulations. The requirements that do exist are contained within four stormwater general permits, which are described below. New land development activities are not subject to stormwater control measures, post-construction, unless the development is located within a regulated Municipal Separate Storm Sewer System (MS4), and the system actively enforces their authority under the permit.

> West Virginia does not currently have comprehensive statewide stormwater management

#### 5.3.3.2 Stormwater Permits

The DEP Division of Water and Waste Management has four stormwater general permits that are issued to designated entities on a statewide level:

- Multi-Sector Stormwater General Permit
- Municipal Separate Storm Sewer System (MS4) General Permit
- Construction Stormwater General Permit
- Oil and Gas Construction Stormwater General Permit

Each of these general permits requires regulated dischargers to meet certain terms and conditions before they can discharge stormwater into waters of the state. These general permits are issued on a statewide basis and cover pertinent dischargers regardless of their location within West Virginia. The permits are described below.

The DEP has issued a State General Water Pollution Control permit to regulate the discharge of stormwater runoff from oil and gas related construction activities. The permit authorizes discharges composed entirely of stormwater associated with oil and gas field activities or operations associated with exploration, production, processing or treatment operations or transmission facilities, disturbing one acre or greater of land area, to the waters of the state.

The Multi-Sector permit regulates stormwater discharges from industries such as sawmills, paper manufacturing, chemical manufacturing, glass, cement and concrete manufacturing, salvage yards, vehicle maintenance areas, metal fabrication and other similar industrial activities. The permit requires that certain best management practices be installed and practiced onsite to “treat” the stormwater discharge before it flows offsite. The Multi-Sector permit does not directly address flooding problems that could be caused by the facility or flooding as a result of runoff from impervious surfaces at the facility.

The Municipal Separate Storm Sewer System (MS4) General permit covers stormwater discharges from municipalities and operators of certain publically owned storm sewer systems. MS4 program areas that are located within U.S. Census Bureau designated Urbanized Areas are covered under this permit as well as municipalities with a population of 10,000 or greater. However, there are many municipalities in West Virginia that are not covered under this permit due to their location. It is a complicated process to determine whether or not a municipality is covered under the MS4 permit. The MS4 program is the most comprehensive and requires the municipality to regulate and manage permanent stormwater controls. The MS4 program requires the permittee to regulate discharges from construction stormwater and stormwater discharges from its own industrial facilities. For all new development or redevelopment projects, the MS4 permit requires the developer to install practices that will permanently control stormwater flows from the property. Table 5-10 below identifies the current status and location of approved MS4 permitted areas.

The existing Stormwater Construction permits regulate stormwater discharges from active construction sites when there is a soil disturbance of one acre or greater. The intent of these permits is to control erosion and sediment while soil is disturbed and exposed. Sediment-laden runoff from construction sites can cause downstream property damage and deposit unnatural loads of sediment into stream beds which then damages fish and benthic habitat. Permit coverage is terminated once the construction project is completed and the soil stabilized. The Construction Stormwater permits do not require post-construction stormwater management practices to be maintained after the construction is complete. The lack of permanent post-construction stormwater controls can cause long-term stream damage due to the increased and unmitigated flow of stormwater runoff and pollutants. Groundwater recharge rates can also be negatively affected when post-construction stormwater controls are not maintained. Of the state’s stormwater related general permits, only the MS4 permit requires the maintenance of post-construction stormwater management controls. The MS4 permit’s post-construction authority is from the federal CWA NPDES regulations. The agency believes some increased level of post-construction stormwater control is needed for both environmental and equity reasons. Relative to equity, there are currently differing requirements depending on whether new development is in, or outside, an MS4 area. West Virginia’s neighboring states, excluding Kentucky, have in place statewide post-construction stormwater management regulations that govern all new development. The DEP will be further evaluating the need for post-construction stormwater management outside of MS4 areas.

Table 5-10  Status and location of current MS4 permits

**Status and Location of Current MS4 Permits**

| WVR03 | Permittee | Status |
|---|---|---|
| WVR030011 | Barboursville | Approved |
| WVR030009 | Beckley | Approved |
| WVR030025 | Bethlehem | Approved |
| WVR030008 | Bluefield | Approved |
| WVR030006 | Charleston | Approved |
| WVR030034 | Clarksburg | Approved |
| WVR030031 | Dunbar | Approved |
| WVR030038 | Fairmont | Approved |
| WVR030033 | Huntington | Approved |
| WVR030010 | Hurricane | Approved |
| WVR030043 | Marshall University | Approved |
| WVR030017 | Martinsburg | Approved |
| WVR030003 | Milton | Approved |
| WVR030030 | Morgantown Utility Board | Approved |
| WVR030013 | Moundsville | Approved |
| WVR030029 | Parkersburg | Approved |
| WVR030001 | South Charleston | Approved |
| WVR030005 | St. Albans | Approved |
| WVR030032 | Vienna | Approved |
| WVR030042 | West Virginia University | Approved |
| WVR030020 | Williamstown | Approved |
| WVR030004 | WV Dept. of Transportation | Approved |
| WVR030041 | WV Turnpike Authority | Approved |

## 5.4 Water Conflicts

Water conflicts in West Virginia are rare, due to water resource availability and abundance. However, even in a water-rich state, there are areas of potential concern. These factors include, but are not limited to the following: drought, infrastructure limitations, population expansion of metropolitan areas, incidental contamination of water supply, and development of rural areas that may negatively impact the quantity, quality and/or access to water sources.

Aging infrastructure is an issue all across America. Collaboration among multiple agencies will be required to keep up with development and population increases. As development continues, the potential for compromising the water supply will increase. There is a brief synopsis of aging infrastructure and potential demand issues in Section 5.3.

There is also potential concern for the inability for water supply to meet the needs of population growth within metropolitan areas. For example, the Potomac River is the primary water supply source for the Washington, D.C., metropolitan area. According to a recent ICPRB study, the 2040 water demand estimates indicate inadequacies of the current water supply for the Washington, D.C. metropolitan area. This report is included in Appendix Z.

## 5.5 Conservation Practices

The sustainable management of water resources through conservation is essential to protecting current and future human and ecosystem demands. There are a number of conservation practices being implemented across West Virginia. This section identifies projects and practices underway in West Virginia, as well as activities being implemented elsewhere that may be applicable in West Virginia to reduce the amount of consumptive use, improve the efficiency of water use, provide for reuse and recycling of water, increase the supply of water and/or increase groundwater recharge.

This evaluation was conducted based on large quantity use-types in the DEP database which contains descriptions of implemented and planned water conservation programs. The user-reported conservation programs were grouped into three categories:

1) Improving water use efficiency through implementation of use reduction methods or equipment (Category 1 method)
2) Reusing or recycling water onsite (Category 2 method)
3) Reducing water loss due to leaks and unaccounted water (Category 3 method)

Table 5-11. Number of water conservation plans by category and type.

| Use type | Conservation category 1 | Conservation category 2 | Conservation category 3 |
|---|---|---|---|
| Agriculture/ aquaculture | 0 | 3 | 1 |
| Chemical | 5 | 2 | 0 |
| Frac Water | No Data | No Data | No Data |
| Hydroelectric | 0 | 0 | 0 |
| Industrial | 6 | 0 | 2 |
| Mining | 26 | 22 | 2 |
| Petroleum | 3 | 1 | 1 |
| Public water supply | 15 | 3 | 37 |
| Recreation | 12 | 0 | 1 |
| Thermoelectric (coal) | 1 | 3 | 0 |
| Timber | 2 | 1 | 0 |

The majority of conservation plans, 71%, were created for withdrawals in the public water supply and mining sectors. The hydroelectric sector has no reported water conservation plans because it is flow-through. The chemical and mining sectors report the largest water savings from implementation of the conservation plans, over 400 million gallons per year (Mgal/y).

The following sections evaluate conservation practices that may be applicable to each water use-type, as well as document conservation practices by the categories described above that are currently underway by the large quantity users in West Virginia.

### 5.5.1 Agriculture and Aquaculture

Conservation in aquaculture projects involves the beneficial use of water that would otherwise be discharged into streams with a lower level of treatment and thus potentially reducing demands on other water sources. In certain instances, the water being used is presently unsuitable for other out-of-stream uses and even has to be treated prior to use in aquaculture. A number of projects demonstrate the potential of using water from underground mines in West Virginia and surrounding states for aquaculture (Semmens and Jacobs, 2012; Semmens and Miller, 2010; Miller, 2008). These projects have shown aquaculture with mine water to be an economically viable opportunity (D'Souza, Miller, Semmens, & Smith, 2004).

West Virginia University and a private mining company raised fish using water discharged from a mine water treatment system to demonstrate that treated mine water can be used to raise healthy fish for stocking public waters and for consumption. In fact, (Miller, 2008) asserts that some underground coal mines in Appalachia have desirable water quality characteristics for aquaculture (temperature, alkalinity, pH and pathogen free). A mining company operating mines in West Virginia and Maryland worked in cooperation with the Maryland Department of Natural Resources (MD DNR) to construct and operate a trout-rearing facility in the mine's acid-mine-drainage treatment system settling pond from January of 1994 through May 2007[7]. This facility produced trout used by MD DNR to re-stock the North Branch of the Potomac River and other streams in West Virginia and Maryland. There are several other commercial-scale facilities currently producing trout and other for-fee fishing and consumption.

Agricultural water use for irrigation and livestock represents a very small portion of the total water use in West Virginia. In the Natural Resources Conservation Service (NRCS) Census of Agriculture, conducted in 2007, it was reported that there were 692,003 acres of harvested cropland in West Virginia. Of those, only 2,189 acres (0.3%) were irrigated. Water use for irrigated lands could be estimated with additional information on the crops grown in those areas. The next NRCS Census of Agriculture (2012) is scheduled to be released in 2014.

Also in 2007, there were 370 dairy farms in West Virginia with 11,744 milk cows (USDA, 2009). Milk cows can be estimated to generally use 35 gallons of water per day (Jarrett & Roudsari, 2007), making the total daily water use by the dairy farms over 411,000 gallons. Despite the small agricultural water uses (when compared to other sectors), there are still opportunities for water conservation. Conservation opportunities associated with milk cows and irrigation are discussed below.

In 1997, 252 million pounds of milk were produced from milk cows in West Virginia, worth an estimated $38 million. Almost three-quarters of the milk was produced in Jefferson, Mason, Berkeley, Preston, Greenbrier and Monroe counties (Baniecki & Dabaan, 1999).

Water is used at dairy farms for livestock consumption, cooling milk and cows and cleaning the facilities. Sufficient quantities of clean water are essential for these uses. Dairy operators may reuse water for

[7] Mettiki Trout Farm, http://www.arlp.com/involvement/mettiki-trout-farm.htm, accessed 1/28/2013.

multiple purposes to reduce the amount of water used. For example, once withdrawn from surface or groundwater, the relatively cool water can be used to cool the milk just after collection. Cooling the milk prevents bacterial contamination. As a result of this process, the water is warmed. The warmed water can be used as drinking water for the cows, subsequently increasing milk production, washing the facilities and cooling water for the cows during the summer months. The portion of the water that is not consumed could be recycled again as long as the water quality is sufficient for the intended use.

To conserve water, irrigation should assist in meeting the water needs of the plants without over-saturating. Over-saturation can cause a loss of irrigation water to groundwater percolation or to surface water runoff. Conservation practices appropriate for a particular application will be site-specific. A great deal of research is available to assist landowners in identifying options. For example, the Agricultural Water Conservation Clearinghouse[8] contains easily accessible information and tools on agricultural water conservation. Literature at this site is available on water conservation policy, recovery and recycling, economics, crop water use, cropping systems, drought tolerance, water conveyance and delivery and supply and storage to name a few. Tools are also compiled in the clearinghouse from numerous sources including irrigation schedulers, cost estimation tools and water use estimators.

In general, ensuring that irrigation water is applied at the right times and in the right amounts saves money, energy and water. One method for conserving irrigation water includes switching from high and medium pressure systems to low pressure or drip irrigation (NRCS, 2006). Drip irrigation slowly releases water directly onto or just under the soil, losing less water to evaporation than traditional types of irrigation due to limited wind exposure and reduction in opportunities for surface runoff. Watering at the coolest time of day can also reduce water lost to evaporation.

The LQU database lists 14 (12 currently operating) users in the agriculture/aquaculture use type. One is a commercial nursery which does not recycle water but does monitor and minimize the amount of water used, a Category 3 conservation method. One aquaculture operation had water recirculation systems (Category 1 method) in place but ceased operations in 2008. The other users are either commercial fish hatcheries or hatcheries producing fish for West Virginia Division of Natural Resources (DNR) stocking programs. Four of the users have identified water conservation programs utilizing recycled water (Category 2 method) and reduction of losses through leaks or unaccounted water (Category 3 methods) with a total reported savings of 21 Mgal/y. This represents a savings of 0.4% of the total annual average

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[8] http://www.agwaterconservation.colostate.edu/Default.aspx, accessed 2/26/2013.

of reported agriculture and aquaculture withdrawals. Given the few large agricultural withdrawals, enhancing agricultural water conservation may require outreach to the small quantity water users.

### 5.5.2 Chemical, Industrial, Petroleum, and Timber

Chemical, industrial, petroleum and timber product processors or manufacturers who are currently operating, account for 16% of the total average withdrawals (excluding hydroelectric) listed in the LQU database. These industries generally use water for uses such as boiler water, cooling, in-plant processes, equipment such as vacuum pumps, general washing and fire protection. Water conservation opportunities include installation of air-cooled equipment and forced air cooling equipment in place of water-cooled equipment. Replacement of once-through cooling systems with recirculating cooling systems reduces water use if water-cooled systems are required. All possible opportunities for water recovery and reuse or alternative water supplies should be considered, such as filtration and membrane processes and capturing condensate drain water from cooling systems, or recycling of process water for boiler makeup water. Timber industry users are included in this group due to the similarities in water use practices to the other industries in this group.

A water conservation program should start with an audit or survey of existing water use within the facility. There are guidelines and examples available of water use audits or surveys from several sources (EPA, 2011; NC-DENR, 2009; GE Water, 2007). A number of examples from across the country illustrate the types of conservation activities in this sector. Boiler operators remove built-up scale and other chemicals in boilers by expelling water from the boiler in a process called "blowdown." This water is usually discharged due to its high chemical content. Automated boiler blowdown systems can reduce blowdown water losses by up to 20% and reduce the boiler's energy use by 2- 5% (NC-DENR, 2009). Clean wastewater from other in-plant processes or equipment can be used as boiler makeup water reducing overall water use.

There are a number of case studies that could inform conservation practices for this sector in West Virginia:

- A glass manufacturer in North Carolina used water from air compressors and hydraulic fluid cooling water for boiler makeup. The reuse practice saved 8.5 Mgal of city water per year and was implemented for $3,000. Simple payback period for this modification was two months (NC-DENR, 2009).

- A ConAgra potato processing plant in Idaho installed a tank, pump, and piping to capture compressor cooling water and reuses the heated water in the waste treatment plant. These changes had an equipment cost of $10,000 but an energy cost savings of $96,000 per year and 44.35 Mgal of water savings per year (GEMI, 2007).
- A Roche pharmaceutical plant in Boulder, Colorado, upgraded the seal systems on two of six wastewater treatment system pumps and started using process water instead of city water for seal flushing on the other four pumps. The upgraded seals allowed the seal flush to be eliminated or replaced with used process water without any adverse effects on the pumps. Aggregate annual water savings were about 3.7 Mgal and $17,500 per year. With a total project cost of $23,300, the simple payback was 16 months (GEMI, 2007).

Timber industry facilities listed in the LQU database are manufacturers of paper, wood or timber-related products. As these manufacturers use water for similar processes such as making steam, processing raw materials and cooling, the same types of conservation practices are applicable as for the other industrial users. One of the timber industry users reports that they installed air-cooled air conditioning units to replace their water-cooled units and implemented a water reuse system, the same types of systems applicable to other industrial users.

The LQU database lists 16 chemical users (14 currently operating). Six of these users have conservation plans with a total savings listed as 300 Mgal/y or 0.2% of the average annual withdrawals reported for the chemical users in the state. The LQU database lists 16 (13 currently operating) industrial users with eight having conservation plans. Total water savings for these users is listed as 87 Mgal/y or 0.4% of average annual withdrawals in the industrial use sector. The LQU database lists six petroleum users (five currently operating) with three having conservation plans and total water savings listed as 800,000 gal/y or 0.2% of annual petroleum withdrawals. There are seven timber users (four currently operating) in the LQU with two users reporting having conservation plans with a total of 568,000 gal/y or 0.05% of total annual timber withdrawals. Eighty-four percent of the responding chemical, industrial, petroleum and timber users identified having Category 1 conservation methods, 21% report Category 2 methods, and 16% report including Category 3 methods.

These groups of industries represent 16% of all water withdrawn, as listed in the LQU database, but were responsible for 67% of the water that was conserved. These industries are making investments in water conservation and efficiency that should be encouraged and expanded.

### 5.5.3 Mining

Coal mining operations use water for washing and processing raw coal, separation of coal from rock, dust suppression on roadways and potable uses for employees. In addition, underground coal mines in West Virginia use water for "cooling the cutting surfaces of mining machinery and for inhibiting friction-induced ignition of coal fines or gas" (Mavis, 2003). Informal reports suggest, though, that the majority of water is used at coal mines for dust control (Mavis, 2003). On average, coal mines use 50-59 gallons of water per ton of coal produced (USGS, 2009). Mining activities, therefore, pose a significant opportunity for water conservation and reuse in the state. Two ways that coal mining-related water conservation activities can be implemented are by initiating programs to conserve and reuse water during the mining process and by finding ways to reuse mine pool water for other purposes. Many of the surface mining operations have a collection basin that they capture the runoff from dust suppression activities and reuse that water many times over.

Mining operations can implement onsite water conservation activities and reuse water for multiple mining-related purposes. The amount of water used for dust suppression, being the major type of onsite water use, can be reduced through the addition of salts to the water. Specifically, magnesium chloride solution and calcium chloride are added to facilitate dust suppression (Mavis, 2003). However, over time this process may have negative environmental impacts, including increased salt loads in the soil, shallow groundwater, and local streams as well as associated impacts to fish, wildlife and vegetation (EPA, 2002).

Where possible, many coal mines reuse water for multiple onsite operations because of the sheer quantity of water needed and due to the economic incentives. Water reuse capabilities are determined by water quality requirements, water availability and discharge considerations (Mavis, 2003). For example, wastewater from the mine that is generated through seepage into the mine area can be reused for firefighting and underground dust suppression. Other types of onsite wastewater that can be reused are the process wastewater and domestic wastewater.

Mine pool water can also be used for water supplies in other, non-mining sectors. There are an estimated 100,000 abandoned underground mines in West Virginia. Although many of these are small and would likely not be an economically viable source of water, the larger mines may prove to be valuable additional supplies. For example, the National Mineland Reclamation Center mapped 130 underground coal mines in Pennsylvania and West Virginia with an estimated combined storage of 250 billion gallons (Veil, Kupar, & Puder, 2003).

Reuse of mine pool water for cooling in thermoelectric power generation plants has been recently investigated (Feeley et al., 2005; Donovan et al., 2004; Veil et al., 2003). As an example, Veil et al. (2003) evaluated the feasibility of using underground coal mine pool water for power plant cooling in Pennsylvania and West Virginia. This methodology was considered for the following types of power plants: steam electric power plants with closed-cycle cooling technology, closed-cycle cooling reservoir and as a source of once-through cooling water. Donovan et al. (2004) found that there are several potential mines in the Pittsburgh Coal Basin of northeastern West Virginia. The practicality of use is dependent on several factors such as the water quality characteristics of the mine water. Curtright and Giglio (2012) also suggested that mine water could be used in Marcellus Shale hydraulic fracturing activities.

Mine pool water may provide additional supplies for public drinking water, where water quality conditions are adequate. Loudoun Water in the Potomac Basin is considering utilizing quarries as an additional source of water to meet anticipated water shortages. The water supplier would fill the quarry with Potomac River water during high-flows and utilize the quarry water during times of low river flow. One quarry being considered for this purpose has a one billion gallon storage capacity (Black and Veatch, 2008).

There are 100 mining users listed (81 currently operating) in the LQU database. Forty-five of these users report having water conservation plans in place. Of these users, 58% reported Category 1 conservation methods, 49% reported Category 2 methods, and 4% reported Category 3 methods. The conservation measures include paving or applying chemical treatments to roadways for dust suppression, recycling water from settling ponds for coal preparation and reduction of losses from leaking or malfunctioning equipment. A total of 101 Mgal/y, or 0.8% of annual withdrawals, is reported as being conserved by mining users. The other 55% of mining water users not reporting conservation programs may be an opportunity for additional outreach, education,and potential future water savings or reuse.

### 5.5.4 Public Water Supply

Public water suppliers withdraw water, treat it for human consumption and deliver it to their customers. Water conservation methods available to public suppliers focus on water use efficiency in the distribution system and by their customers. Conservation methods include: conservation of water through leak detection in the distribution system and conservation programs to reduce use by customers (Templin, Herbert, Stainaker, Horn, & Solley, 1980).

Due to aging infrastructure, administrative and data handling errors, and problems with water metering, a significant portion of water for public supplies is "lost" or goes unaccounted (EPA, 2009). Resources are available to assist public water suppliers in identifying losses in the system. For example, the American Water Works Association developed a free tool that identifies water losses and identifies parts of the system needing improvement and is available on their webpage: http://www.awwa.org/ (AWWA, 2009).

Conservation in the public water supply system has many benefits including the potential to use up to 20% less water, making additional water available for human and ecosystem uses (Penn State, 2008). Conservation programs targeted to users of public water supplies include public education, retrofitting existing plumbing fixtures with low-flow fixtures, providing water conservation consulting services to industrial and commercial users, and implementing use-based rate structures (Templin et al., 1980).

Education and outreach to the general public promotes the use of in-home water conservation activities in people's daily lives, such as limiting showering time, not leaving water running during dish washing and teeth brushing and purchasing water efficient appliances, to name a few.

A Pioneer Institute study found that voluntary practices and education programs are less effective at conserving water than well-enforced mandatory programs, suggesting the need for additional water conservation policies (Olmstead & Stavins, 2007).

The LQU database list 251 public water suppliers (215 currently operating) in West Virginia. Fifty-two of these users reported having water conservation plans. The majority of these public suppliers (71%) reported having conservation plans that include Category 3 methods, detecting and repairing leaks within the distribution system. Also identified were Category 1 measures (29%), specifically, water conservation measures by customers during periods of low supply, public education and the installation of water use meters at customer facilities. Only 6% of public suppliers reported Category 2 methods as part of their conservation programs. The total savings is 54 Mgal/y or 0.08% of the average annual withdrawals by all currently operating public water suppliers.

### 5.5.5 Recreation

Recreation users listed in the LQU database are primarily golf course resorts, which include water uses for irrigation; food services; heating, ventilation, and air conditioning (HVAC); maintenance; and general potable use. Another category of users in the recreation category is ski resorts. In addition to using water for the same general uses as golf course resorts, ski resorts use water for snowmaking.

Conducting a water use audit should be the first step of any conservation program. Understanding where and how water is used will allow identification of conservation and/or reuse opportunities. There are many water saving opportunities in the resort setting. Guidelines and best management practices for conserving water in this sector have been developed by states and other organizations (FL DEP, 2009; EPA, 2004). Several organizations and states have developed best management practices specifically for golf courses (Water Management Committee of the Irrigation Association, 2010; Carrow et al., 2007; CT DEP, 2006). New Hampshire has developed a fact sheet providing guidelines for water conservation for snowmaking (NHDES, 2010).

Conservation methods by golf courses include installation of high efficiency irrigation control systems and equipment, a Category 1 method. Some operators reported reducing the level of irrigation water to only keep the grass alive, not “lush and green” and operating the irrigation systems manually to deliver water only to the areas needing water, not the entire golf course (a Category 2 type conservation method, reducing loses). Another potential water-saving opportunity on golf courses is wastewater reuse. A golf course and residential community in Pennsylvania evaluated diverting some of the treated water from its wastewater treatment system to fill the golf course irrigation ponds as a way to recycle water and reduce withdrawals from wells and surface water sources. The existing size of the community does not make the treatment system modifications economical yet, but when the community build-out is reached the builder is expecting to make this change to the system (personal comm., White Run Regional Authority System, 6/20/2012).

Ski resorts also present an opportunity for water conservation activities. An example of ski resorts implementing a water conservation method for snowmaking operations is at Ski Liberty in Pennsylvania. Ski Liberty uses surface runoff-fed ponds as the supply for snowmaking water and augments the natural surface precipitation runoff feeding the ponds by using highly treated wastewater from the facility’s treatment system. This reduces withdrawals from groundwater or other surface water sources (personal comm., Ski Liberty – PA, 2010).

Of the 20 recreation users (18 currently operating), 12 reported having water conservation plans in place that included installation of improved irrigation systems or reducing irrigation by additional monitoring of course conditions (Category 1 conservation methods). Other Category 1 conservation measures included installation of high efficiency equipment and plumbing fixtures. The total water savings reported by these recreation users with conservation plans was 9 Mgal/y or 0.6% of the reported annual average withdrawals occurring among the currently operating recreational users.

### 5.5.6 Hydroelectric Power Generation

Hydroelectric power generation is the largest use type in the LQU database representing 93% of the total average annual withdrawals. However, the withdrawals listed for hydroelectric power generation are almost completely non-consumptive with only a small amount of water lost to evaporation from the pool upstream of the dam at the generating facility. The majority of the hydroelectric plants are run-of-river facilities with relatively little storage in the pool behind the dam. None of the listed hydroelectric users reported conservation programs.

### 5.5.7 Thermoelectric Power Generation

Thermoelectric power generation uses large quantities of water (Gerdes & Nichols, 2008) to produce steam to drive electrical power generating turbines, cool and condense the steam, provide boiler make-up water, use in flue gas desulfurization (FGD) technology and other plant processes. One of the other processes that use significant amounts of water is carbon dioxide recovery systems. There are three basic types of cooling systems used in thermoelectric power plants: once-through, recirculating and dry cooling. In a once-through system, water is drawn from the source, used to cool and condense the steam and returned to the source. In a recirculating system, the steam is passed through large cooling towers where the water is used to cool and condense the steam which is then captured in ponds and recirculated through the cooling tower. A much larger amount of the water is lost to evaporation so the consumptive loss in a recirculating system is greater than in a once-through system even though the amount withdrawn is smaller. A study by the U.S. Department of Energy (DOE) (Feeley, et al., 2005) compared the water use per kilowatt hour produced in thermoelectric plants using once-through and recirculating cooling systems. The average withdrawal for once-through cooling was 37.7 gallons per kilowatt hour (gal/kWh) with consumption of 0.1 gal/kWh while the withdrawal for recirculating cooling was 1.2 gal/kWh with consumption of 1.1 gal/kWh produced (Feeley, et al., 2005). Dry cooling systems pass the steam through air-cooled heat exchangers to cool and condense the steam. The only water used in this process is for boiler make-up water. Dry cooling systems use a larger amount of energy, generally need more area and are more expensive than systems using water for cooling.

The DOE funded a project to evaluate the potential to extract water vapor from coal-fired power plant flue gases in order to reduce makeup water requirements for the plant's cooling water system (Folkedahl, et al., 2006). The project concluded that although economic models indicate this technology can provide positive return on investment, it will take several years of development and continued focus on water resource management before these systems will yield the return that will make these systems attractive in the industry.

The use of freshwater in thermoelectric power generation may be reduced through the use of water in flooded and abandoned coal mines as a source of cooling water (Donovan, et al., 2004). This is a potential future water conservation activity for West Virginia.

Thermoelectric power plants account for the second largest amount of withdrawals, after hydroelectric power generation, listed in the LQU database and have 15 users (14 currently operating) listed. The specific uses listed include cooling water, boiler make-up water and service water for other plant processes. Three of the users reported having water conservation plans. All users listed reusing or recycling water (Category 2 conservation method) and one also listed the conversion to closed-loop type of cooling system (Category 1 method). These programs resulted in reported water savings of 4 Mgal/y which is less than 0.001% of total annual withdrawals occurring among the currently operating thermoelectric facilities.

### 5.5.8 Hydraulic Fracturing

Large amounts of water are used for hydraulic fracturing in the process of gas extraction wells in the Marcellus Shale and other unconventional shale gas plays. Sand and various chemicals are pumped under high pressure into the well bore to create many micro-fractures in the shale rock holding the natural gas. These micro-fractures allow the gas contained in the rocks to be released and extracted through the well. Some amount of this water, commonly referred to as "flowback" or "frac water," returns to the surface and is recovered. The percentage of water captured as flowback varies depending on geology and formation characteristics, but typically ranges from 10- 12%. Over the life of the well, more water returns to the surface. This "production water" is comprised of remnant water used during the fracturing process or also water pre-existing in the fractured formation. Water reuse is high among horizontal drillers. Approximately 15% of the water used for hydraulic fracturing in 2011 originated as flowback or production water from a previously drilled well. The recycled frac water represents nearly 75% of the total amount of water recovered, with the remainder disposed of via underground injection (UIC) wells.

Continued water conservation efforts in this industry should focus on operational improvements to use less water while reusing all available flowback. Since 2009, total water demands have significantly increased while reported per-well needs have decreased from 11.4 million gallons to 5.3 million gallons. As the technologies have developed, the dependence on water resources has decreased. The reuse of flowback has also increased. From 2010 to 2011, the amount of recycled frac water used in subsequent operations increased from 5.7% to 14.6% of total water used. West Virginia Water Research Institute conducted a project under contract to DOE to evaluate technologies and develop and evaluate a mobile onsite treatment system. The system was designed to treat flowback and recovered water so it can be used for additional fracing operations (Ziemkiewicz, et al., 2012). The resulting system was installed in a trailer-mounted shipping container and deployed at a Utica Shale well site in Ohio and a Marcellus Shale well site in West Virginia. Over 600,000 gallons of flowback water were treated at the two sites with 98.6% of the water being recycled (Ziemkiewicz, et al., 2012).

Estimates on total water savings through conservation practices are difficult due to the rapidly growing nature of the industry. However, if the trend of reusing flowback continues hundreds of millions of gallons of water could be saved annually.

### 5.5.9 Summary

Implementation of water conservation and reuse activities in West Virginia may be an essential component of meeting the growing demands on water resources. Fortunately, there are numerous methods for conservation and reuse in each water use sector, as evidenced by the available literature from the Mid-Atlantic region and across the country. Existing programs and opportunities for future conservation efforts in the state have been identified through an evaluation of the DEP's LQU database. One way the DEP intends to encourage water conservation is through the addition of a water conservation award to be given annually to an entity that demonstrates sound, sustainable water conservation practices.

The database identifies users by industry category, user provided information on water conservation plans such as what conservation measures the plan includes and expected water savings produced by the plans. This analysis categorized the conservation plans by the types of measures they contained;

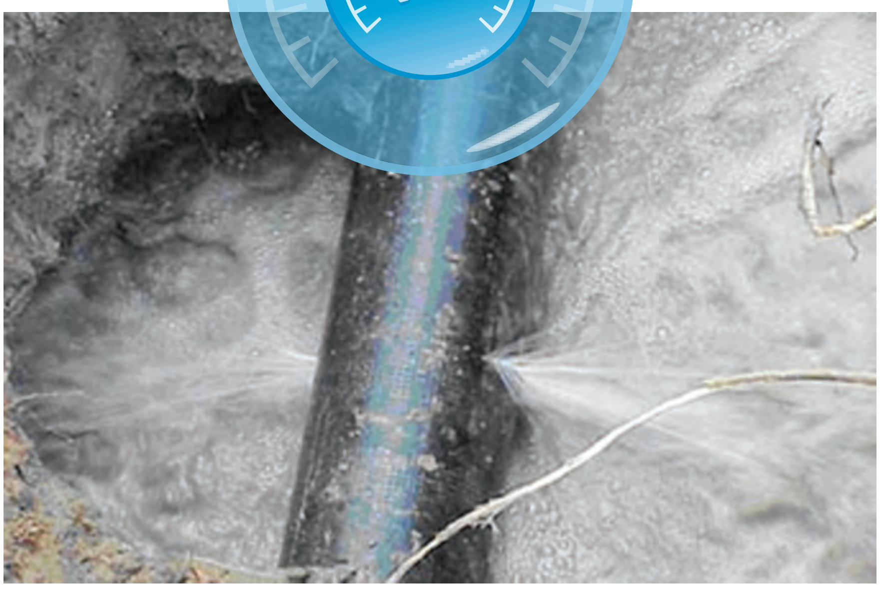
improving water use efficiency through use reduction methods or installing improved-efficiency equipment, onsite water reuse or recycling, and loss reduction due to leakage or waste. Water conservation methods applicable to each of the 10 industry types, plus hydraulic fracturing, were reviewed. The number of users implementing conservation programs was identified. The reported savings resulting from these conservation plans was totaled.

Public water suppliers had the largest number of users reporting conservation plans with 52 users, followed by mining with 45 users reporting conservation plans. The industry reporting the largest total savings however was the chemical industry with 300 Mgal/y savings. Mining had the second largest with 101 Mgal/y total savings from conservation plans. In terms of the percentage of withdrawals saved by conservation plans, no industry reported total savings to be as much as 1% of the total reported withdrawals. In total, the conservation efforts of the large quantity users with conservation plans resulted in 578 Mgal/y of annual water savings. However, this is 0.03% of all withdrawals by large quantity users, so there are many more opportunities for additional water conservation.

Dam at Elizabeth, WV

# CHAPTER SIX
# REGIONAL WATERSHED MANAGEMENT AND CRITICAL PLANNING AREAS

**WATER USE SECTION** west virginia department of environmental protection



Leaking Waterlines

# Chapter - 6 Regional Watershed Management and Critical Planning Areas

## 6.1 Regional Watershed Management

The Act states that any county or municipal government can file, as part of the Plan, its own water resources management plan provided that it complies with the Secretary's requirements. While inclusion does not grant regulatory authority, more localized plans will highlight water resource concerns with greater detail than is possible at a statewide scale.

The Pocahontas County Commission created the Pocahontas County Water Resources Task Force to draft a water resources management plan for that county. In order to make sure that the county plan met the Secretary's requirements, the DEP worked closely with the task force throughout the entire process. At various stages of development, the DEP provided data, directed them to funding sources and offered technical assistance in the writing process. After final review, the Pocahontas County Water Resources Management Plan has been accepted and can be found in Appendix AA. The Pocahontas County plan was made possible with funding from: United States Environmental Protection Agency; Environmental Justice Small Grants Program; United States Forest Service; and the DEP. The Pocahontas County plan is available for use as a model for other counties or municipalities in their pursuit of a localized water management plan. The DEP acknowledges and appreciates the foresight, leadership and dedication of Pocahontas County officials in pursuit of their plan.

## 6.2 Critical Planning Areas

### 6.2.1 Introduction

The Act stipulates that through the Plan, the Secretary may designate an area as a critical planning area (CPA). To that end, a process must first be established to allow such areas to be nominated, evaluated and ultimately designated as a CPA. Through this process, the Secretary has the authority to define a set of minimum requirements which must be met in order for a potential CPA to be formally nominated. This set of requirements may include adherence to specified timetables for nomination and/or plan development.

### 6.2.2 CPA Designation Process

In order to be designated as a CPA in the Plan, potential areas must pass through a four-stage process summarized below.

***Stage 1*** **– Application**

The Secretary will receive applications for potential CPAs and conduct a basic review of the nomination to ensure that the minimum required elements have been included. The applicant shall be notified within 60 days of receipt whether the submittal meets the minimum requirements for further consideration.

Each nomination must include the following information:

a) Delineation of the proposed CPA on a suitable scale map
b) Name of the primary stream or hydrologic unit or units within the proposed CPA
c) Detailed description of the reason for proposed designation
d) Evidence of notification of intent to file a nomination (Class 1 legal ad) as well as solicited comments from stakeholders
e) Designation of lead entity and contact person responsible for coordination and communication of the nomination, including signature and declaration of accuracy

Additionally, each nomination should include as much supplemental information as is available to support designation as a CPA. The following items are broadly categorized into background information, research, and funding, but this list is by no means exhaustive:

a) Research
    a. Inventory of current withdrawals, discharges and storage within the proposed CPA (available from the DEP)
    b. Description of changes to withdrawal, discharge, and/or storage capacity in the next five years within the proposed CPA (consult with the DEP)
    c. Supporting information documenting the reason for proposed designation as a CPA, including any supporting technical studies

b) Background
    a. Documents describing, or references to, any relevant water resources management plans or actions already existing within the proposed CPA
    b. Documents describing, or references to, any pending or proposed water resources management plans or actions that may address the critical issues identified in this CPA nomination
    c. Documents describing, or references to, any existing adopted municipal and/or county comprehensive plans covering all or part of the proposed CPA
    d. Identification of additional resources which may be available to assist in data development
    e. Letters of support for designation as a CPA

c) Funding
    a. Proposed budget, including potential sources of funding
    b. Letters of commitment for funding

***Stage 2* – Data Analysis**

If the minimum requirements for consideration as a CPA are met, the application will be subjected to a detailed data analysis. All supplementary documentation submitted with the application shall be reviewed. The Secretary may also require additional data from the applicant for further consideration. This information must be submitted within 90 days of notification.

***Stage 3* – Designation**

After analyzing all the evidence for the proposed CPA, the Secretary will either designate the area as a CPA or notify the applicant that the area will not be further considered for CPA designation.

***Stage 4* – Post-Designation**

To the extent resources and authority allow, the Secretary will facilitate project implementation. The area's designation as a CPA will be provided to pertinent funding and resource agencies, considered when analyzing funding priorities and will be publicized on the DEP's webpage.

CHAPTER SEVEN

# SUMMARY, FUTURE PURSUITS AND RECOMMENDATIONS

WATER USE SECTION

west virginia department of environmental protection

# Chapter - 7 Summary, Future Pursuits and Recommendations

## 7.1 Summary

The Water Resources Protection Act, W.Va. Code § 22-26-1, et seq., enacted March 2004, authorized the establishment of the Joint Legislative Oversight Commission on State Water Resources (the Commission). As the implementing agency for the Act, the DEP was required to submit a yearly progress report to the Commission and a final report to the Joint Committee on Government and Finance by November 30, 2013. A final report titled "Water Resources Protection Act - Water Use Survey" was submitted in December of 2006. Program recommendations from the 2006 report included the following:

- Develop a statewide water management program.
- Address program data deficiencies.
- Add five groundwater monitoring wells in high-growth areas.
- Electronically log non-residential water wells.
- Add three stream gages in western West Virginia.
- Continue the Large Quantity Users Registration program.

The DEP has addressed completion of these program recommendations in the previous chapters of this Plan. Further, in accordance with the Act, the DEP is to "propose methods of implementing various recommended actions, programs, policies, projects or management activities." *See*, W. Va. Code § 22-26-8(c)(15). Completion of this Plan was an important water management step taken by the Legislature, and it marks a major milestone in water resource protection and management in the state. Never before have West Virginia's citizens, businesses, or government officials had a Plan containing this much information on the state's water resources.

Water is essential both to life and to West Virginia's economy. It will forever increase in value. That is why wise management of the state's water resources is so important. Economic growth and water sustainability can coexist as long as the state's resources are managed properly. This Plan will inform all who are involved in developing, sustaining and growing the state's economy. This Plan was written to comprehensively describe the water resource, its stress points, successes in management, and opportunities for improvement. The water resource information within this Plan is conveniently assembled on the DEP's website at the following address: http://dep.wv.gov/WVWaterPlan/.

## 7.2 Future Pursuits of the Water Use Section

Submission of this plan to the Legislature marks an important step in our journey toward wise management and understanding of our state's water resources. Even though West Virginia has abundant water resources, the state can experience challenges when faced with prolonged drought conditions. In order to develop the Plan, the DEP established its Water Use Section and assigned it many tasks associated with water resource management. This group currently performs several functions for the DEP and has many future goals. Set forth below are a series of responsibilities and plans for future work and research that will be pursued by the Water Use Section as resources allow.

- Host an Annual Statewide Water Resources Conference in different locations across the state. The principal objectives of the conference will be:

    1. To keep flood and drought issues on the forefront of state concerns.
    2. Update contact lists for the state's drought and flood management plans.
    3. Presentations to update key water resources issues and conservation BMPs.
    4. Encourage other counties and local planning officials to pursue localized WRPM Plans and provide them a forum to present their finished products.
    5. Community and business outreach and education.
    6. Water resource-centered training with CEUs.

- Publish online reports in order to update data contained within the Plan. The proposed progress report would include an update on water use trends, new large quantity water users, data sets, certified critical planning areas, new county water management plan submissions and other water resource data.

- Continue to enhance the water withdrawal tool by incorporating the results of scientific studies and continuing stream flow data collection at partial record stations. These enhancements are intended to improve the capabilities of the tool, which is currently used by the horizontal natural gas industry, regulators, and the general public. Additionally, the improvements are intended to enhance the ability of the tool to protect headwater streams.

- In cooperation with the Division of Natural Resources and other appropriate agencies, develop a guidance document describing the appropriate procedures for protection against spread of invasive species and other best management practices relative to water withdrawals.

- Gather water quality data for mine pool waters in order to improve the Mine Pool Atlas and better identify the resource's potential for use by new and existing industry.

- Better identify the state's groundwater by improved data collection methods, ongoing USGS studies, and computer modeling.

- Survey regional water resource issues, with an annual focus based on a five-year rotating concept for the five defined water regions of the state.

- Present a Water Conservation Award in conjunction with DEP's annual Environmental Excellence Awards Ceremony.

- Evaluate the need for post-construction stormwater management outside of MS4 areas. The lack of permanent post-construction stormwater controls can lead to increased and unmitigated flow of stormwater runoff and pollutants.

- Establish partial flow record stations in collaboration with the Watershed Assessment Branch of the DEP and the USGS in order to continue to improve knowledge of the state's water resources.

- Continue to collect the scientific literature regarding water resource management and place them in an accessible database.

- Collect coordinates and depth to water data for existing private groundwater wells.

- Continue to improve and maintain the DEP's Water Use Website and GIS programs.

- Collaborate with the West Virginia Department of Agriculture to evaluate the counties with significant agricultural water use on a regional scale to provide more detailed data.

- Catalog and study both surface and groundwater affected by mine subsidence.

- Gather and analyze historic records on temperature, precipitation, and stream flow and relate the information to varying carbon emission scenarios. This analysis could provide insight into the potential effects of extreme weather events on water resources.

- Conduct a consumptive use survey to better define the consumptive use of all water users. This would require comparison of other states' methods and some site-by-site investigations.

- Encourage counties, municipalities, and local governments to perform groundwater and other water resource related studies.

- Evaluate requiring continuous flow monitoring on select discharges that have the ability to impact stream gage readings.

- Develop an online tool where landowners can report to the DEP the location of springs or water wells on their property.

- Continue to improve the LQU registration process by creating and updating online registration forms, audit registrations for accuracy and identify previously overlooked LQUs.

## 7.3 Agency Recommendations

The following recommendations describe actions the Commission may want to consider to improve water management in West Virginia.

- **The Commission should consider amending the statutory definition of "large quantity user" at W. Va. Code § 22-26-2(i).** Changing the definition from "any person who withdraws over 750,000 gallons of water in a calendar month" to "any person who withdraws 300,000 gallons or more of water in any 30-day period (10,000 gallons per day)" would allow the state to more accurately measure and assess its water resources, in addition to making West Virginia's registration requirements consistent with those of surrounding states. Having information about this broader universe of water withdrawals would aid the state in water resource management planning and better equip decision makers should drought-driven withdrawal or conservation restrictions become necessary. This recommendation was also made by the Legislative Auditors in their report dated November, 2011 (PE-11-11-500).

- **The Commission should consider amending the statutory survey and registration requirements of the Act to eliminate variances.** The Act currently requires a LQU to certify "that the amount [of water] withdrawn in the previous calendar year varies by no more than 10% from the user's baseline average." *See*, W. Va. Code § 22-26-3(d). This was initially intended to make it easier for LQUs to report; however, in reality it has resulted in a potential 20% error in the calculation of total statewide water use. This wide discrepancy complicates database calculations and results in less-than-desirable survey accuracy, which hampers the DEP's efforts to study, develop and protect the state's water resources.

- **The Commission should consider assisting in efforts to continue funding stream gages and amending the Act to require notification if a funding partner becomes unable to contribute.** The United States Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers (USACE) and several state agencies, maintains a system of approximately 85 streamflow gages in West Virginia (down from 115 in 1977), which cost approximately $1.36 million per year. This system must be maintained, as stream gages are the best and most important source of water resource data. In order to manage our state's water resources, we must first know how much water there is. The only way to determine the total quantity of water in the state is through calculations based on the data provided by the stream gaging network. Historically, state funding for the gage network has been pieced together each year. The DEP recommends that the funding for the stream gaging network be continued by the involved agencies. In addition, should a partner agency become unable to maintain its contribution level, it should notify the DEP, USGS, and the Commission so alternative funding sources can be identified. The Commission should consider codifying this notification as a requirement of the Act.

- **The Commission should consider whether the state should acquire Light Detection and Ranging (LIDAR) coverage for the 70% of the state that has not yet been so mapped**. The current available digital elevation models for our state allow us to determine the height above sea level of any point on the land surface to an accuracy of approximately 10 feet, without physically surveying the location. Many of the maps that are commonly used for flood inundation, identification of contours, and stormwater runoff have intervals of 20 to even 40 feet. Light Detection and Ranging (LIDAR) coverage across the state would reduce the contour interval to two feet or less. Statewide LIDAR coverage would enable scientists and engineers to produce accurate flood plain modeling, precise runoff calculations, trace resilient stratigraphic layers, identify mine portals, delineate wetlands, calculate slopes of valleys and stream beds, and much more from a desk top computer. According to the NOAA and NWS Ohio River Forecast Center, LIDAR would not only improve river forecasting in West Virginia but would enhance forecasts with the potential for dynamic flood inundation mapping. Nearly every state agency and many private sector companies would benefit from LIDAR coverage. Roughly 30% of the state has been flown utilizing LIDAR technology. Based on estimates from WVU's NRAC and the DEP's TAGIS group, it would cost approximately $1.2 million to obtain LIDAR coverage of the remaining 70% of the state. While the costs and benefits of LIDAR have been discussed at interim Commission meetings, the issue of funding was never addressed. The Commission should consider an interim study to further explore the benefits of statewide LIDAR coverage; a funding source(s) for the same; and the appropriate recipient(s) of that funding.

- **The Commission should encourage continued collaboration among all affected agencies to improve data collection regarding the state's water resources.** An area where the state struggles with a dearth of information is data about private water wells. If the Code was amended to require the drillers and/or sanitarians to report latitude, longitude and depth-to-groundwater of all new private water wells, the state could better characterize and map the groundwater resource. This information would be useful to public and private water managers, oil and natural gas well drillers and water well drillers. Collaboration among the Commission, DEP, DHHR, County Health Departments and County Sanitarians would be needed to acquire this pertinent data.

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# Appendix A

Water Resources Protection and Management Act

**WEST VIRGINIA CODE**

**CHAPTER 22. ENVIRONMENTAL RESOURCES.**
**ARTICLE 26. WATER RESOURCES PROTECTION ACT.**

**§22-26-1. Short title; legislative findings.**
(a) *Short title*. -- This article may be known and cited as the Water Resources Protection and Management Act.

(b) *Legislative findings*. --

(1) The West Virginia Legislature finds that it is the public policy of the State of West Virginia to protect and conserve the water resources for the state and to provide for the public welfare. The state's water resources are vital natural resources of the state that are essential to maintain, preserve and promote quality of life and economic vitality of the state.

(2) The West Virginia Legislature further finds that it is the public policy of the state that the water resources of the state be available for the benefit of the citizens of West Virginia, consistent with and preserving all other existing rights and remedies recognized in common law or by statute, while also preserving the resources within its sovereign powers for the common good.

(3) The West Virginia Legislature further finds that the water use survey conducted by the Department of Environmental Protection is a valuable tool for water resources assessment, protection and management.

(4) The West Virginia Legislature further finds that the water resources of this state have not been fully measured or assessed and that a program to accurately measure and assess the state's water resources is necessary to protect, conserve and better utilize the water resources of this state.

(5) The West Virginia Legislature further finds that the survey information collected and analyzed by the Department of Environmental Protection has identified the need for a statewide water resources management plan.

(6) The West Virginia Legislature further finds that the development of a state water resources management plan is in the best interest of the state and its citizens and will promote the protection of this valuable natural resource; promote its use for the public good; and enhance its use and development for tourism, industry and other economic development for the benefit of the state and its citizens.

(7) The West Virginia Legislature further finds that incomplete data collection from an inadequate groundwater monitoring system continues to hamper efforts to study, develop and protect the state's water resources and will be a major obstacle in the development of a water resources management plan.

**§22-26-2. Definitions.**
For purposes of this article, the following words have the meanings assigned unless the context indicates otherwise:

(a) "Baseline average" means the average amount of water withdrawn by a large quantity user over a representative historical time period as defined by the secretary.

(b) "Beneficial use" means uses that include, but are not limited to, public or private water supplies, agriculture, tourism, commercial, industrial, coal, oil and gas and other mineral extraction, preservation of fish and wildlife habitat, maintenance of waste assimilation, recreation, navigation and preservation of cultural values.

(c) "Commercial well" means a well that serves small businesses and facilities in which water is the prime ingredient of the service rendered.

(d) Community water system" means a public water system that pipes water for human consumption to at least fifteen service connections used by year-round residents or one that regularly serves at least twenty-five residents.

(e) "Consumptive withdrawal" means any withdrawal of water which returns less water to the water body than is withdrawn.

(f) "Farm use" means irrigation of any land used for general farming, forage, aquaculture, pasture, orchards, nurseries, the provision of water supply for farm animals, poultry farming or any other activity conducted in the course of a farming operation.

(g) "Industrial well" means a well used in industrial processing, fire protection, washing, packing or manufacturing of a product excluding food and beverages or similar nonpotable uses.

(h) "Interbasin transfer" means the permanent removal of water from the watershed from which it is withdrawn.

(i) "Large quantity user" means any person who withdraws over seven hundred fifty thousand gallons of water in a calendar month from the state's waters and any person who bottles water for resale regardless of quantity withdrawn.

(j) "Maximum potential" means the maximum designed capacity of a facility to withdraw water under its physical and operational design.

(k) "Noncommunity nontransient water system" means a public water system that serves at least twenty-five of the same persons over six months per year. (l) "Nonconsumptive withdrawal" means any withdrawal of water which is not a consumptive withdrawal as defined in this section.

(m) "Person", "persons" or "people" means an individual, public and private business or industry, public or private water service and governmental entity.

(n) "Secretary" means the Secretary of the Department of Environmental Protection or his or her designee.

(o) "Transient water system" means a public water system that serves at least twenty-five transient people at least sixty days a year."

(p) "Test well" means a well that is used to obtain information on groundwater quantity, quality, aquifer characteristics and availability of production water supply for manufacturing, commercial and industrial facilities.

(q) "Water resources", "water" or "waters" means any and all water on or beneath the surface of the ground, whether percolating, standing, diffused or flowing, wholly or partially within this state, or bordering this state and within its jurisdiction and includes, without limiting the generality of the foregoing, natural or artificial lakes, rivers, streams, creeks, branches, brooks, ponds, impounding reservoirs, springs, wells, watercourses and wetlands: *Provided,* That farm ponds, industrial settling basins and ponds and waste treatment facilities are excluded from the waters of the state.

(r) "Watershed" means a hydrologic unit utilized by the United States Department of Interior's geological survey, adopted in one thousand nine hundred seventy-four, as a framework for detailed water and related land-resources planning.

(s) "Withdrawal" means the removal or capture of water from water resources of the state regardless of whether it is consumptive or nonconsumptive: *Provided,* That water encountered during coal, oil, gas, water well drilling and initial testing of water wells, or other mineral extraction and diverted, but not used for any purpose and not a factor in low-flow conditions for any surface water or groundwater, is not deemed a withdrawal.

**§22-26-3. Waters claimed by state; water resources protection survey; registration requirements; agency cooperation; information gathering.**

(a) The waters of the State of West Virginia are hereby claimed as valuable public natural resources held by the state for the use and benefit of its citizens. The state shall manage the quantity of its waters effectively for present and future use and enjoyment and for the protection of the environment. Therefore, it is necessary for the state to determine the nature and extent of its water resources, the quantity of water being withdrawn or otherwise used and the nature of the withdrawals or other uses: *Provided,* That no provisions of this article may be construed to amend or limit any other rights and remedies created by statute or common law in existence on the date of the enactment of this article.

(b) The secretary shall conduct an ongoing water resources survey of consumptive and nonconsumptive surface water and groundwater withdrawals by large quantity users in this state. The secretary shall determine the form and format of the information submitted, including the use of electronic submissions. The secretary shall establish and maintain a statewide registration program to monitor large quantity users of water resources of this state beginning in two thousand six.

(c) Large quantity users, except those who purchase water from a public or private water utility or other service that is reporting its total withdrawal, shall register with the Department of Environmental Protection and provide all requested survey information regarding withdrawals of the water resources. Multiple withdrawals from state water resources that are made or controlled by a single person and used at one facility or location shall be considered a single withdrawal of water. Water withdrawals for self-supplied farm use and private households will be estimated. Water utilities regulated by the Public Service Commission pursuant to article two, chapter twenty-four of this code are exempted from providing information on interbasin transfers to the extent those transfers are necessary to provide water utility services within the state.

(d) Except as provided in subsection (f) of this section, large quantity users who withdraw water from a West Virginia water resource shall comply with the survey and registration requirements of this article. Registration shall be maintained by every large quantity user by certifying, on forms and in a manner prescribed by the secretary, that the amount withdrawn in the previous calendar year varies by no more than ten percent from the users' baseline average or by certifying the change in usage.

(e) The secretary shall maintain a listing of all large quantity users and each such user's baseline average water withdrawal.

(f) The secretary shall make a good faith effort to obtain survey and registration information from persons who are withdrawing water from in-state water resources, but who are located outside the state borders.

(g) All state agencies and local governmental entities that have a regulatory, research, planning or other function relating to water resources, including, but not limited to, the State Geological and Economic Survey, the Division of Natural Resources, the Public Service Commission, the Bureau for Public Health, the Commissioner of the Department of Agriculture, the Division of Homeland Security and Emergency Management, Marshall University, West Virginia University and regional, county and municipal planning authorities may enter into interagency agreements with the secretary and shall cooperate by: (i) Providing information relating to the water resources of the state; (ii) providing any necessary assistance to the secretary in effectuating the purposes of this article; and (iii) assisting in the development of a state water resources management plan. The secretary shall determine the form and format of the information submitted by these agencies.

(h) Persons required to participate in the survey and registration shall provide any reasonably available information on stream flow conditions that impact withdrawal rates.

(i) Persons required to participate in the survey and registration shall provide the most accurate information available on water withdrawal during seasonal conditions and future potential maximum withdrawals or other information that the secretary determines is necessary for the completion of the survey or registration: *Provided,* That a coal-fired electric generating facility shall also report the nominal design capacity of the facility, which is the quantity of water withdrawn by the facility's intake pumps necessary to operate the facility during a calendar day.

(j) The secretary shall, to the extent reliable water withdrawal data is reasonably available from sources other than persons required to provide data and participate in the survey and registration, utilize that data to fulfill the requirements of this section. If the data is not reasonably available to the secretary, persons required to participate in the survey and registration are required to provide the data. Altering locations of intakes and discharge points that result in an impact to the withdrawal of the water resources by an amount of ten percent or more from the consecutive baseline average shall also be reported.

(k) The secretary shall report annually to the Joint Legislative Oversight Commission on State Water Resources on the survey results. The secretary shall make a progress report every three years on the development of the state water resources management plan and any significant changes that may have occurred since the survey report was submitted in two thousand six.

(l) In addition to any requirements for completion of the survey established by the secretary, the survey must accurately reflect both actual and maximum potential water withdrawal. Actual withdrawal shall be established through metering, measuring or alternative accepted scientific methods to obtain a reasonable estimate or indirect calculation of actual use.

(m) The secretary shall make recommendations to the joint legislative oversight commission created in section five of this article relating to the implementation of a water quantity management strategy for the state or regions of the state where the quantity of water resources are found to be currently stressed or likely to be stressed due to emerging beneficial or other uses, ecological conditions or other factors requiring the development of a strategy for management of these water resources.

(n) The secretary may propose rules pursuant to article three, chapter twenty-nine-a of this code as necessary to implement the survey registration or plan requirements of this article.

(o) The secretary is authorized to enter into cooperative agreements with local, state and federal agencies and private policy or research groups to obtain federal matching funds, conduct research and analyze survey and registration data and other agreements as may be necessary to carry out his or her duties under this article.

**§22-26-4. Confidentiality.**
(a) Information required to be submitted by a person as part of the water withdrawal survey and registration that may be a trade secret, contain protected information relating to homeland security or be subject to another exemption provided by the state freedom of information act may be deemed confidential. Each such document shall be identified by that person as confidential information. The person claiming confidentiality shall provide written justification to the secretary at the time the information is submitted stating the reasons for confidentiality and why the information should not be released or made public. The secretary has the discretion to approve or deny requests for confidentiality as prescribed by this section.

(b) In addition to records or documents that may be considered confidential under article one, chapter twenty-nine-b of this code, confidential information means records, reports or information, or a particular portion thereof, that if made public would:

(1) Divulge production or sales figures or methods, processes or production unique to the submitting person;

(2) Otherwise tend to adversely affect the competitive position of a person by revealing trade secrets, including intellectual property rights; or

(3) Present a threat to the safety and security of any water supply, including information concerning water supply vulnerability assessments.

(c) Information designated as confidential and the written justification shall be maintained in a file separate from the general records related to the person.

(d) Information designated as confidential may be released when the information is contained in a report in which the identity of the person has been removed and the confidential information is aggregated by hydrologic unit or region.

(e) Information designated as confidential may be released to governmental entities, their employees and agents when compiling and analyzing survey and registration information and as may be necessary to develop the legislative report required by this section or to develop water resources plans. Any governmental entity or person receiving information designated confidential shall protect the information as confidential.

(f) Upon receipt of a request for information that has been designated confidential and prior to making a determination to grant or deny the request, the secretary shall notify the person claiming confidentiality of the request and may allow the person an opportunity to respond to the request in writing within five days.

(g) All requests to inspect or copy documents shall state with reasonable specificity the documents or type of documents sought to be inspected or copied. Within ten business days of the receipt of a request, the secretary shall: (1) Advise the person making the request in writing of the time and place where the person may inspect and copy the documents which, if the request addresses information claimed as confidential, may not be sooner than twenty days following the date of the determination to disclose, unless an earlier disclosure date is agreed to by the person claiming confidentiality; or (2) deny the request, stating in writing the reasons for denial. If the request addresses information claimed as confidential, then notice of the action taken pursuant to this subsection shall also be provided to the person asserting the claim of confidentiality.

(h) Any person adversely affected by a determination regarding confidential information under this article may appeal the determination to the appropriate circuit court pursuant to the provisions of article five, chapter twenty-nine-a of this code. The filing of a timely notice of appeal shall stay any determination to disclose confidential information pending a final decision on appeal. The scope of review is limited to the question of whether the portion of the records, reports, data or other information sought to be deemed confidential, inspected or copied is entitled to be treated as confidential under this section. The secretary shall afford evidentiary protection in appeals as necessary to protect the confidentiality of the information at issue, including the use of in camera proceedings and the sealing of records when appropriate.

**§22-26-5. Joint Legislative Oversight Commission on State Water Resources.**
(a) The President of the Senate and the Speaker of the House of Delegates shall each designate five members of their respective houses, at least one of whom shall be a member of the minority party, to serve on a joint legislative oversight commission charged with immediate and ongoing oversight of the water resources survey, registration and development of a state water resources management plan. This commission shall be known as the Joint Legislative Oversight Commission on State Water Resources and shall regularly investigate and monitor all matters relating to the water resources survey and plan.

(b) The expenses of the commission, including the cost of conducting the survey and monitoring any subsequent strategy and those incurred in the employment of legal, technical, investigative, clerical, stenographic, advisory and other personnel, are to be approved by the Joint Committee on Government and Finance and paid from legislative appropriations.

**§22-26-6. Mandatory survey and registration compliance.**
(a) The water resources survey and subsequent registry will provide critical information for protection of the state's water resources and, thus, mandatory compliance with the survey and registry is necessary.

(b) All large quantity users who withdraw water from a West Virginia water resource shall complete the survey and register such use with the Department of Environmental Protection. Any person who fails to complete the survey or register, provides false or misleading information on the survey or registration, or fails to provide other information as required by this article may be subject to a civil administrative penalty not to exceed five thousand dollars to be collected by the secretary consistent with the secretary's authority pursuant to this chapter. Every thirty days after the initial imposition of the civil administrative penalty, another penalty may be assessed if the information is not provided. The secretary shall provide written notice of failure to comply with this section thirty days prior to assessing the first administrative penalty.

**§22-26-7. Secretary authorized to log wells; collect data.**
In order to obtain important information about the state's surface and groundwater, the secretary is authorized to collect scientific data on surface and groundwater and to enter into agreements with local and state agencies, the federal government and private entities to obtain this information.

(1) Any person who installs a community water system, noncommunity nontransient water system, transient water system, commercial well, industrial or test well, shall notify the secretary of his or her intent to drill a water well no less than ten days prior to commencement of drilling. The ten-day notice is the responsibility of the owner, but may be given by the drilling contractor.

(2) The secretary has the authority to gather data, including driller and geologist logs, run electric and other remote-sensing logs and devices and perform physical characteristics tests on nonresidential and multifamily water wells.

(3) The drilling contractor shall submit to the secretary a copy of the well completion forms submitted to the Division of Health for a community water system, noncommunity nontransient water system, transient water system, commercial well, industrial or test well. The drilling contractor shall provide the well GPS location on the well report.

(4) Any person who fails to notify the secretary prior to drilling a well or impedes collection of information by the secretary under this section is in violation of the Water Resources Protection and Management Act and is subject to the civil administrative penalty authorized by section six of this article.

(5) Any well contracted for construction by the secretary for groundwater or geological testing must be constructed at a minimum to well design standards as promulgated by the Division of Health. Any wells contracted for construction by the secretary for groundwater or geological testing that would at a later date be converted to a public use water well must be constructed to comport to state public water design standards.

**§22-26-8. State Water Resources Management Plan; powers and duty of secretary.**
(a) The Secretary of the Department of Environmental Protection shall oversee the development of a State Water Resources Management Plan to be completed no later than the thirtieth day of

November, two thousand thirteen. The plan shall be reviewed and revised as needed after its initial adoption. The plan shall be developed with the cooperation and involvement of local and state agencies with regulatory, research or other functions relating to water resources including, but not limited to, those agencies and institutions of higher education set forth in section three of this article and a representative of large quantity users. The State Water Resources Management Plan shall be developed utilizing the information obtained pursuant to said section and any other relevant information available to the secretary.

(b) The secretary shall develop definitions for use in the State Water Resources Management Plan for terms that are defined differently by various state and federal governmental entities as well as other terms necessary for implementation of this article.

(c) The secretary shall continue to develop and obtain the following:

(1) An inventory of the surface water resources of each region of this state, including an identification of the boundaries of significant watersheds and an estimate of the safe yield of such sources for consumptive and nonconsumptive uses during periods of normal conditions and drought.

(2) A listing of each consumptive or nonconsumptive withdrawal by a large quantity user, including the amount of water used, location of the water resources, the nature of the use, location of each intake and discharge point by longitude and latitude where available and, if the use involves more than one watershed or basin, the watersheds or basins involved and the amount transferred.

(3) A plan for the development of the infrastructure necessary to identify the groundwater resources of each region of this state, including an identification of aquifers and groundwater basins and an assessment of their safe yield, prime recharge areas, recharge capacity, consumptive limits and relationship to stream base flows.

(4) After consulting with the appropriate state and federal agencies, assess and project the existing and future nonconsumptive use needs of the water resources required to serve areas with important or unique natural, scenic, environmental or recreational values of national, regional, local or statewide significance, including national and state parks; designated wild, scenic and recreational rivers; national and state wildlife refuges; and the habitats of federal and state endangered or threatened species.

(5) Assessment and projection of existing and future consumptive use demands.

(6) Identification of potential problems with water availability or conflicts among water uses and users including, but not limited to, the following:

(A) A discussion of any area of concern regarding historical or current conditions that indicate a low-flow condition or where a drought or flood has occurred or is likely to occur that threatens the beneficial use of the surface water or groundwater in the area; and

(B) Current or potential in-stream or off-stream uses that contribute to or are likely to exacerbate natural low-flow conditions to the detriment of the water resources.

(7) Establish criteria for designation of critical water planning areas comprising any significant hydrologic unit where existing or future demands exceed or threaten to exceed the safe yield of available water resources.

(8) An assessment of the current and future capabilities of public water supply agencies and private water supply companies to provide an adequate quantity and quality of water to their service areas.

(9) An assessment of flood plain and stormwater management problems.

(10) Efforts to improve data collection, reporting and water monitoring where prior reports have found deficiencies.

(11) A process for identifying projects and practices that are being, or have been, implemented by water users that reduce the amount of consumptive use, improve efficiency in water use, provide for reuse and recycling of water, increase the supply or storage of water or preserve or increase groundwater recharge and a recommended process for providing appropriate positive recognition of such projects or practices in actions, programs, policies, projects or management activities.

(12) An assessment of both structural and nonstructural alternatives to address identified water availability problems, adverse impacts on water uses or conflicts between water users, including potential actions to develop additional or alternative supplies, conservation measures and management techniques.

(13) A review and evaluation of statutes, rules, policies and institutional arrangements for the development, conservation, distribution and emergency management of water resources.

(14) A review and evaluation of water resources management alternatives and recommended programs, policies, institutional arrangements, projects and other provisions to meet the water resources needs of each region and of this state.

(15) Proposed methods of implementing various recommended actions, programs, policies, projects or management activities.

(d) The State Water Resources Management Plan shall consider:

(1) The interconnections and relationships between groundwater and surface water as components of a single hydrologic resource.

(2) Regional or watershed water resources needs, objectives and priorities.

(3) Federal, state and interstate water resource policies, plans, objectives and priorities, including those identified in statutes, rules, regulations, compacts, interstate agreements or comprehensive plans adopted by federal and state agencies and compact basin commissions.

(4) The needs and priorities reflected in comprehensive plans and zoning ordinances adopted by a county or municipal government.

(5) The water quantity and quality necessary to support reasonable and beneficial uses.

(6) A balancing and encouragement of multiple uses of water resources, recognizing that all water resources of this state are capable of serving multiple uses and human needs, including multiple uses of water resources for reasonable and beneficial uses.

(7) The distinctions between short-term and long-term conditions, impacts, needs and solutions to ensure appropriate and cost-effective responses to water resources issues.

(8) Application of the principle of equal and uniform treatment of all water users that are similarly situated without regard to established political boundaries.

(e) In November of each year, the secretary shall report to the Joint Legislative Oversight Commission on State Water Resources on the State water Resources Management Plan. The report on the water resources plan shall include benchmarks for achieving the plan's goals and time frames for meeting them.

(f) Upon adoption of the State Water Resources Management Plan by the Legislature, the report requirements of this article shall be superseded by the plan and subsequent reports shall be on the survey results and the water resources plan. If the plan is not adopted a detailed report discussing the provisions of this section as well as progress reports on the development of the plan shall be submitted every three years.

**§22-26-9. Regional water resources management plans; critical planning areas.**
(a) As part of the State Water Resources Management Plan, the secretary may designate areas of the state as regional or critical water planning areas for the development of regional or critical area water resources management plans.

(b) The secretary shall establish a timetable for completion of regional and critical area plans which may be developed.

(c) The secretary shall identify all federal and state agencies, county commissions, municipal governments and watershed associations that should be involved in the planning process and any compacts or interstate agreements that may be applicable to the development of a regional or critical area water resource management plan.

(d) The secretary shall establish the minimum requirements for any issues to be addressed by regional and critical area plans within twelve months of the amendment and reenactment of this article during the two thousand eight regular session of the Legislature. The plan requirements and issues to be addressed by regional and critical area plans shall be consistent with the state plan requirements of this article.

(e) The secretary shall establish timetables for the completion of tasks or phases in the development of regional and critical area plans. County commissions and municipal governments may recommend changes in the order in which the tasks and phases must be completed. The secretary shall have final authority to determine the schedule for development of a plan.

(f) Any county or municipal government may enter into an agreement with the secretary to designate a local planning area and develop a local plan which may include all or part of a region. The secretary shall assist in development of any such plan to the extent practicable with existing staff and funding.

(g) Plans developed by a county or municipal government shall comply with the secretary's requirements and shall be filed as part of the State Water Resources Management Plan.

# Appendix B

## West Virginia Water Resources Management Plan Website Instructions

# Instructions

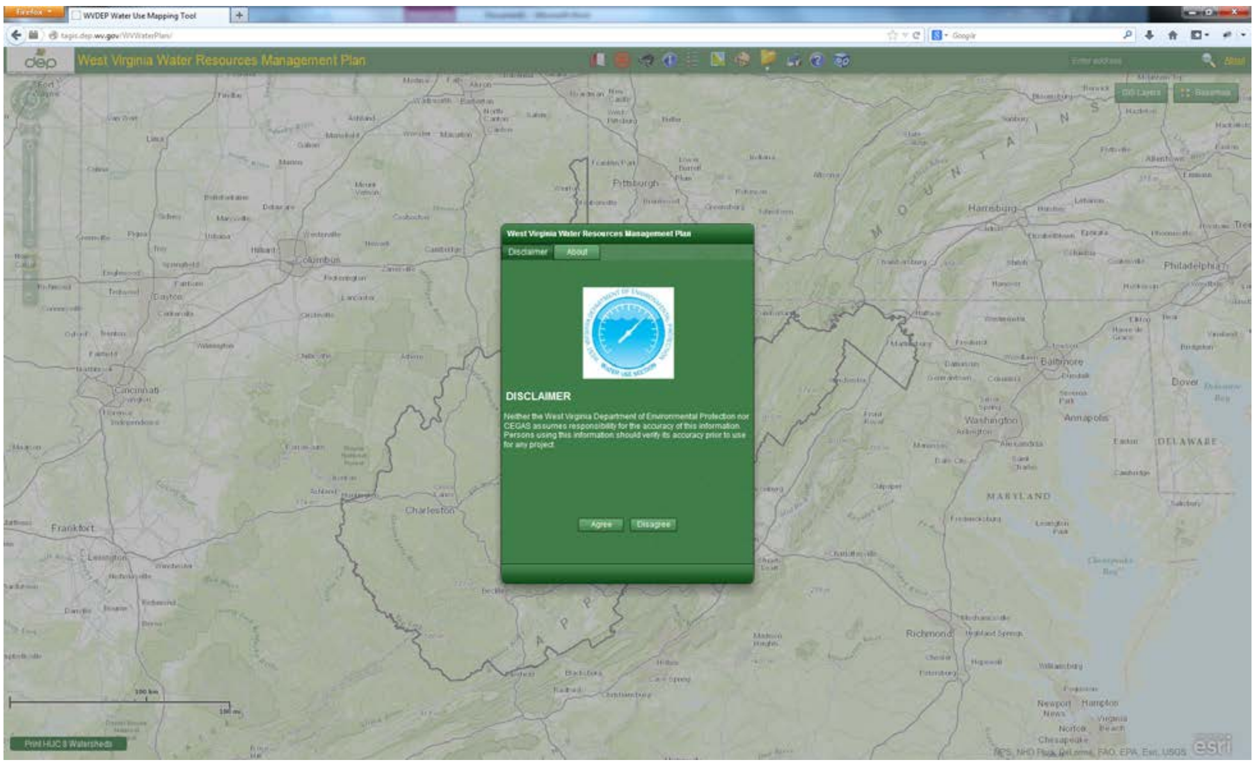
*West Virginia Water Resources Management Plan Tool*

This document includes instructions on using the West Virginia Water Resources Management Plan Tool.

*11/12/2013*

# Table of Contents

The West Virginia Department of Environmental Protection (WVDEP) Water Resources Management Plan Mapping tool was developed in cooperation with the Center for Environmental, Geotechnical and Applied Sciences (CEGAS) at Marshall University. It serves as a public information portal for data related to water resources in the state of West Virginia. The Water Use Section of the WVDEP created this tool to meet the general requirements of the Water Resources Protection and Management Act of 2008. This site provides access to Large Quantity water user reports as well as other GIS data layers pertinent to water resource management in the state of West Virginia.

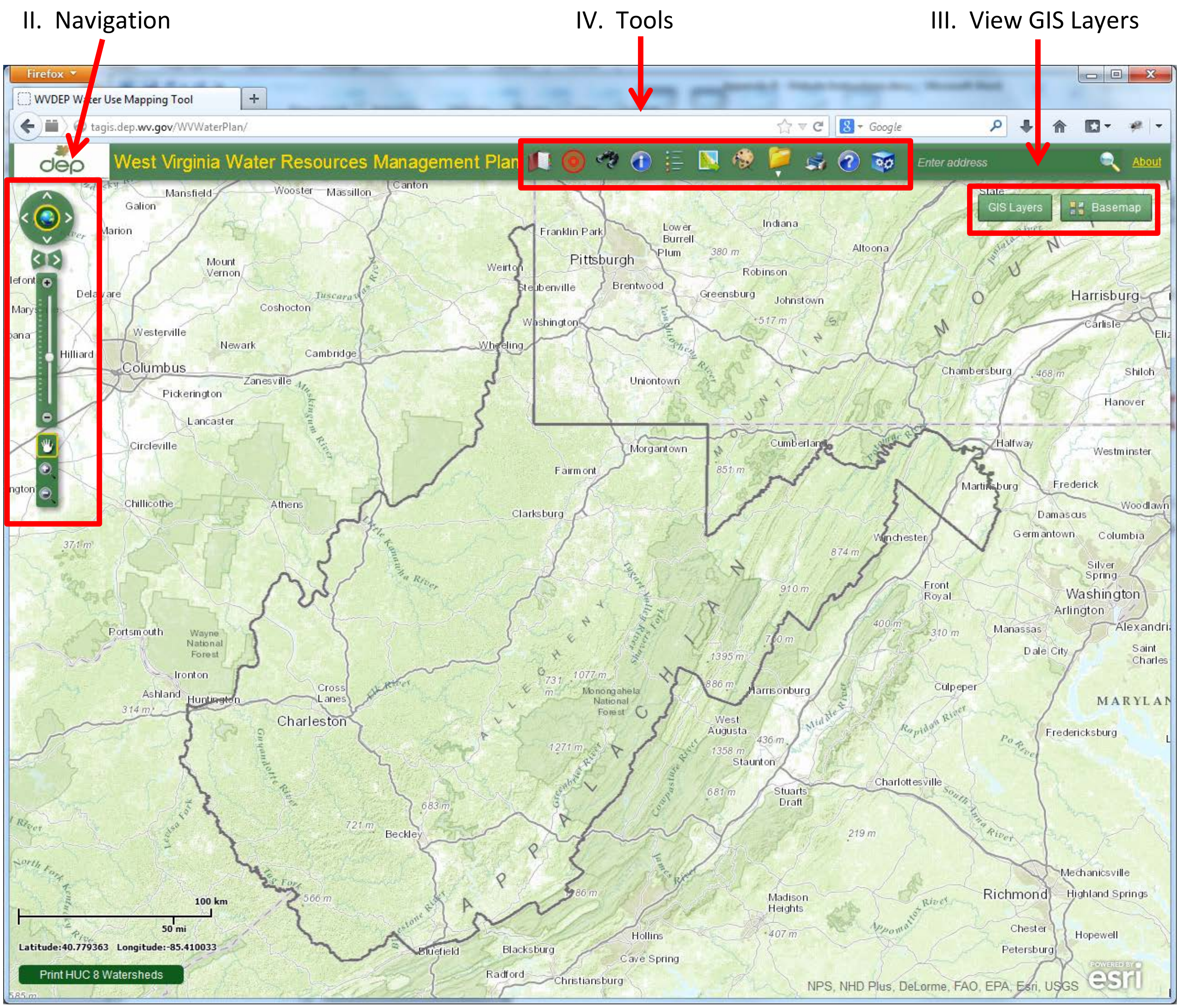



DISCLAIMER

Neither the West Virginia Department of Environmental Protection nor CEGAS assumes responsibility for the accuracy of this information. Persons using this information should verify its accuracy prior to use for any project.

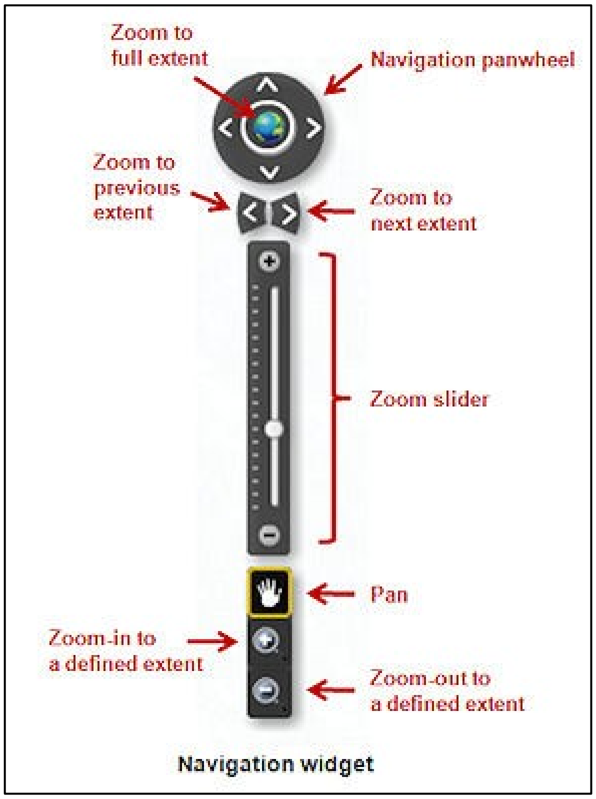
# I. Map Viewer Overview

The layout of the map viewer is shown below and will be discussed further in the following sections.




# II. Navigation

This section briefly describes how to navigate around the map viewer. Pictured below is the navigation widget. It is found on the left side of the map viewer. It becomes transparent when the cursor is not hovering over the navigation control.

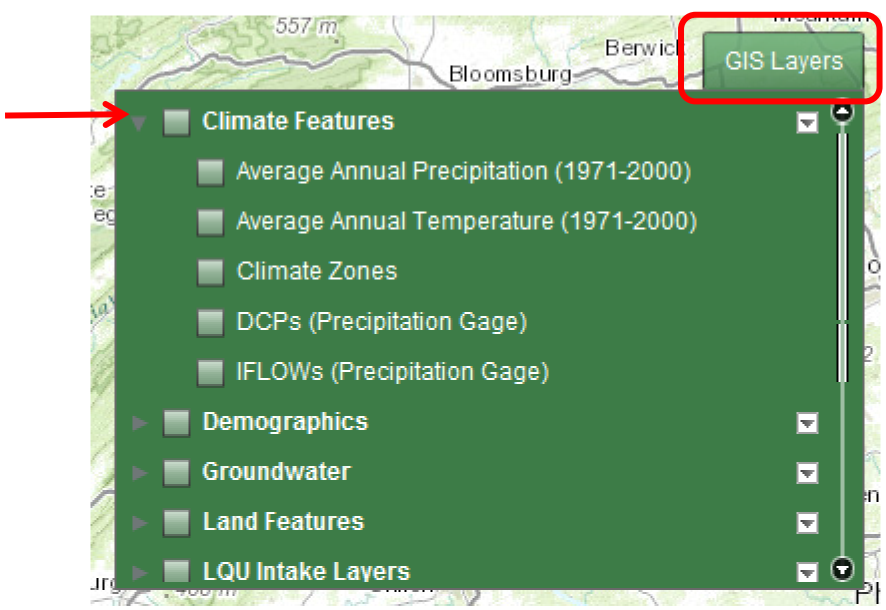



In addition to using the Zoom slider on the navigation widget, you can also roll the mouse wheel forward or backwards to zoom in or out respectively.

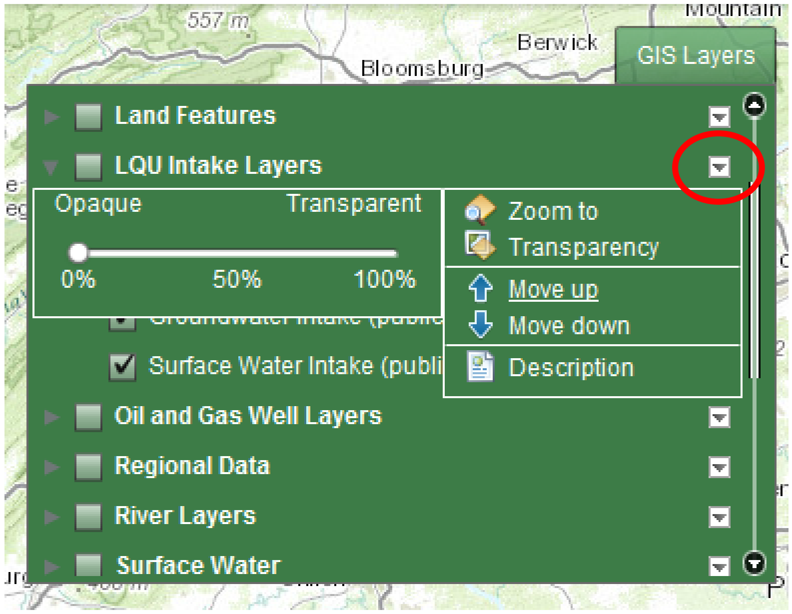
## III. View GIS Layers

By using the Basemap button, you can easily switch between base layers by selecting the option that you would like to view. Base layers are used in the viewer to display background imagery and street data. You can select one of the following as a basemap for your viewer: Imagery, Imagery with Labels, Streets, Topographic, Terrain with Labels, Light Gray Canvas, National Geographic, Oceans, and Open Street Map – as seen below.


In addition you can also add several GIS Layers on top of your basemap by selecting the GIS Layers button, and then selecting the checkbox beside the layer to display those features. Please note the arrow next to each group. That means that there are multiple layers within that group that you can turn-on or off. Please open up the group and select the layers you wish to view. Also, not all layers will be displayed at all scales/zoom levels.



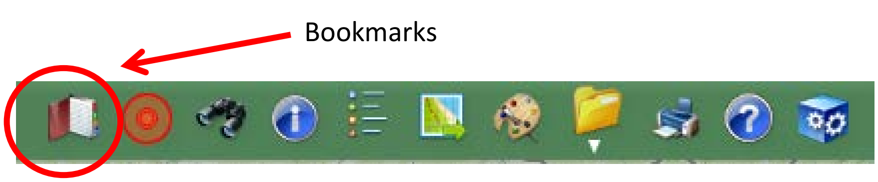
The transparency of layers can also be set by simply clicking the button on the right of the layers name. Additionally, you also have the option of zooming directly to those features, moving the layer up or down, and reading a description about the layers.

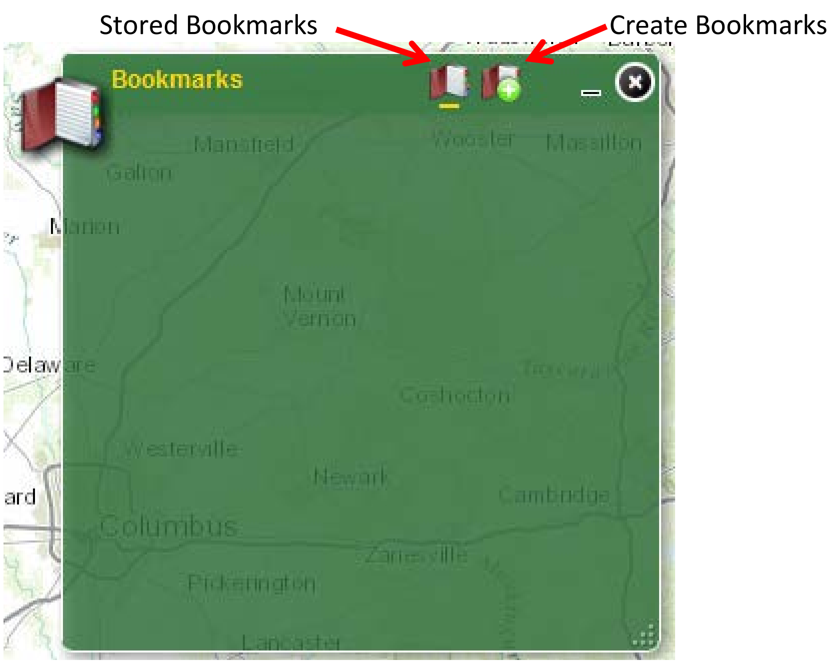



# IV. Tools

## A. Bookmarks

The Bookmark button allows you to save certain map view extents of the data contents displayed in the viewer.

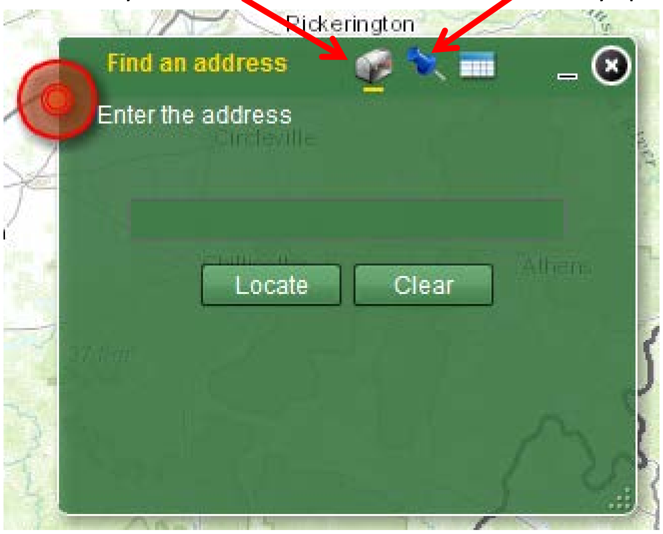





## B. Find Address

The Find Address button allows you to find a precise location on the map. The tool provides two ways to find a location: by either entering an address or by specifying a longitude/latitude coordinate value.

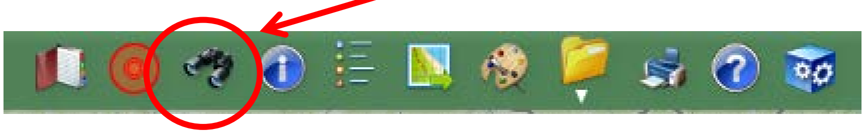
Find by address    Find by specifying longitude/latitude coordinates

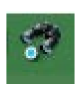



## C. Search

The Search button allows searching for groundwater and surface water intakes of Large Quantity User (LQU). The tool provides two options to perform a search: spatially (using a graphical search tool) or by the LQU's attributes.

Search



### i. Spatial Search 

First select one of the following: Surface Water Intake (non-public water supply), Surface Water Intake (public water supply), Groundwater Intake (non-public water supply), or Groundwater Intake (public water supply) from the search layer dropdown box.

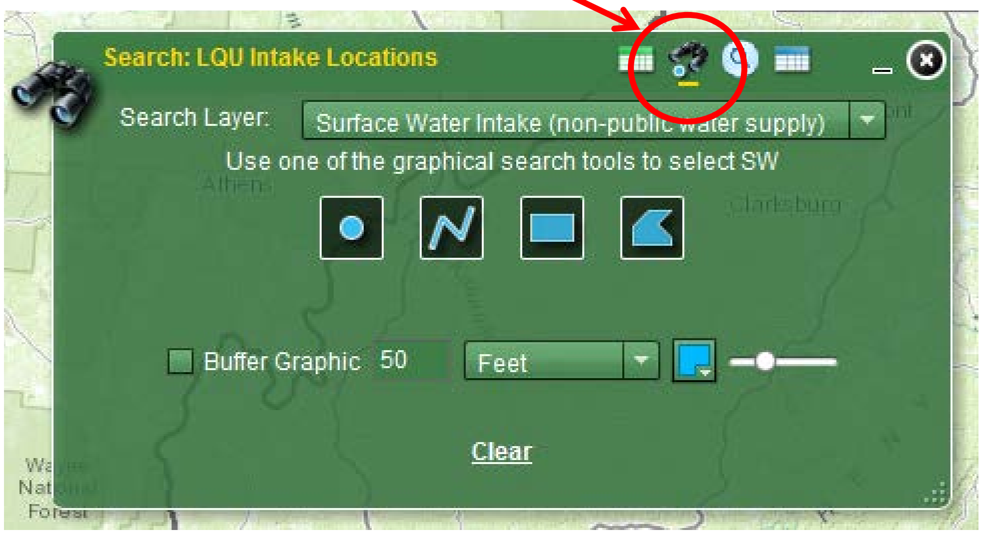
Choose one of the graphical search tools (from left to right):

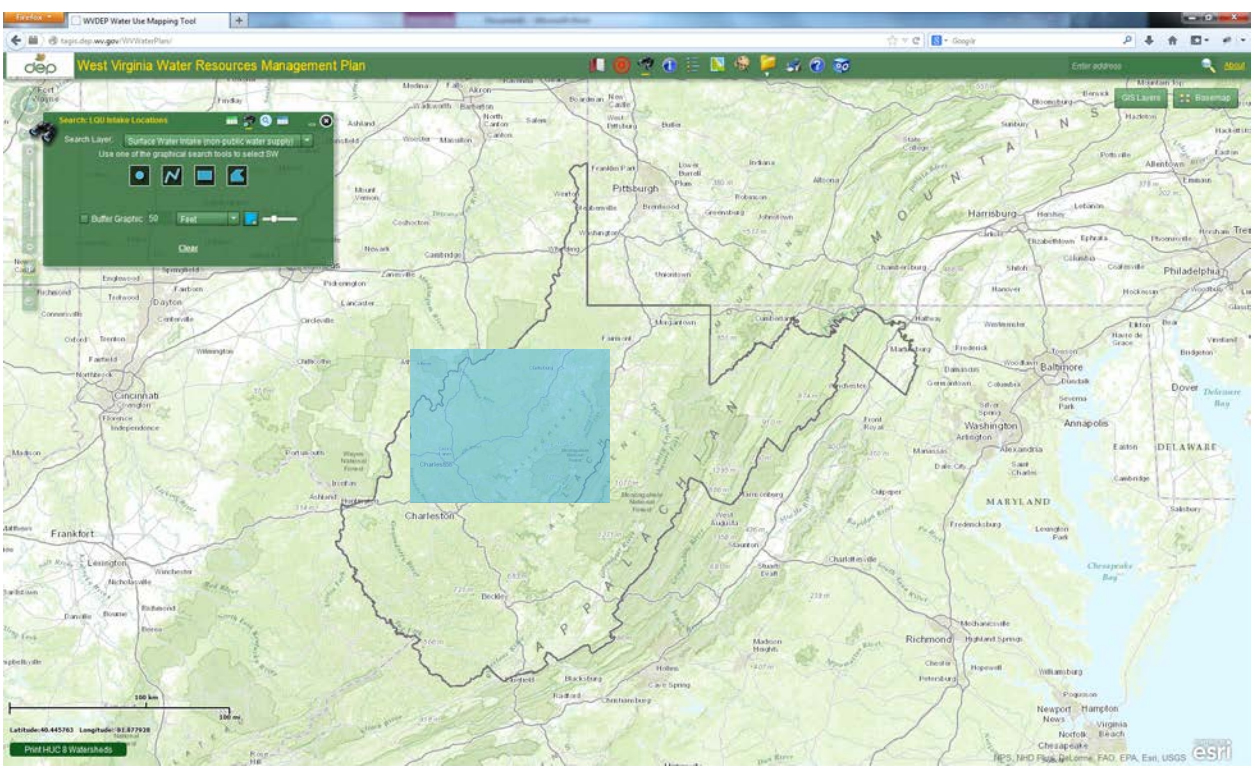
- point

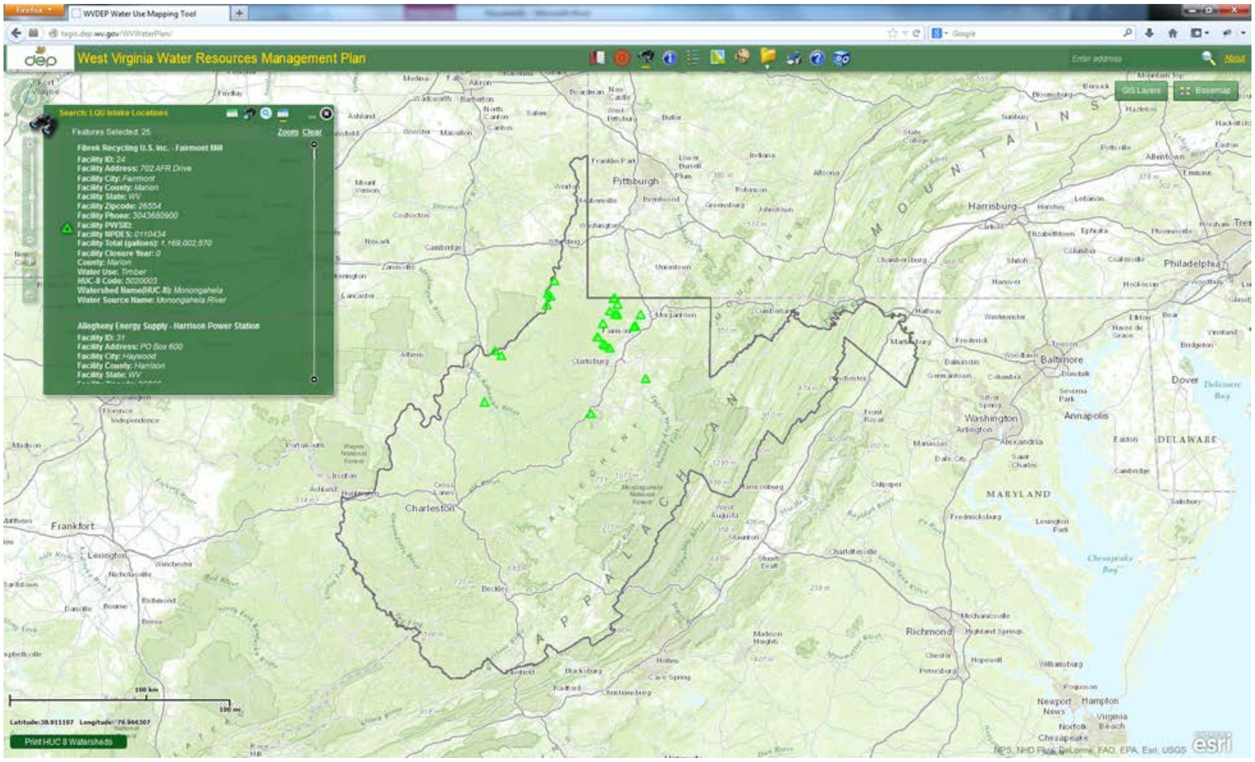
- polyline
- rectangle
- polygon

Optionally, you can add a distance buffer to your spatial search by selecting the "Buffer Graphic" checkbox and entering your preferred buffer distance.

Spatial Search






### ii. Search by Attributes

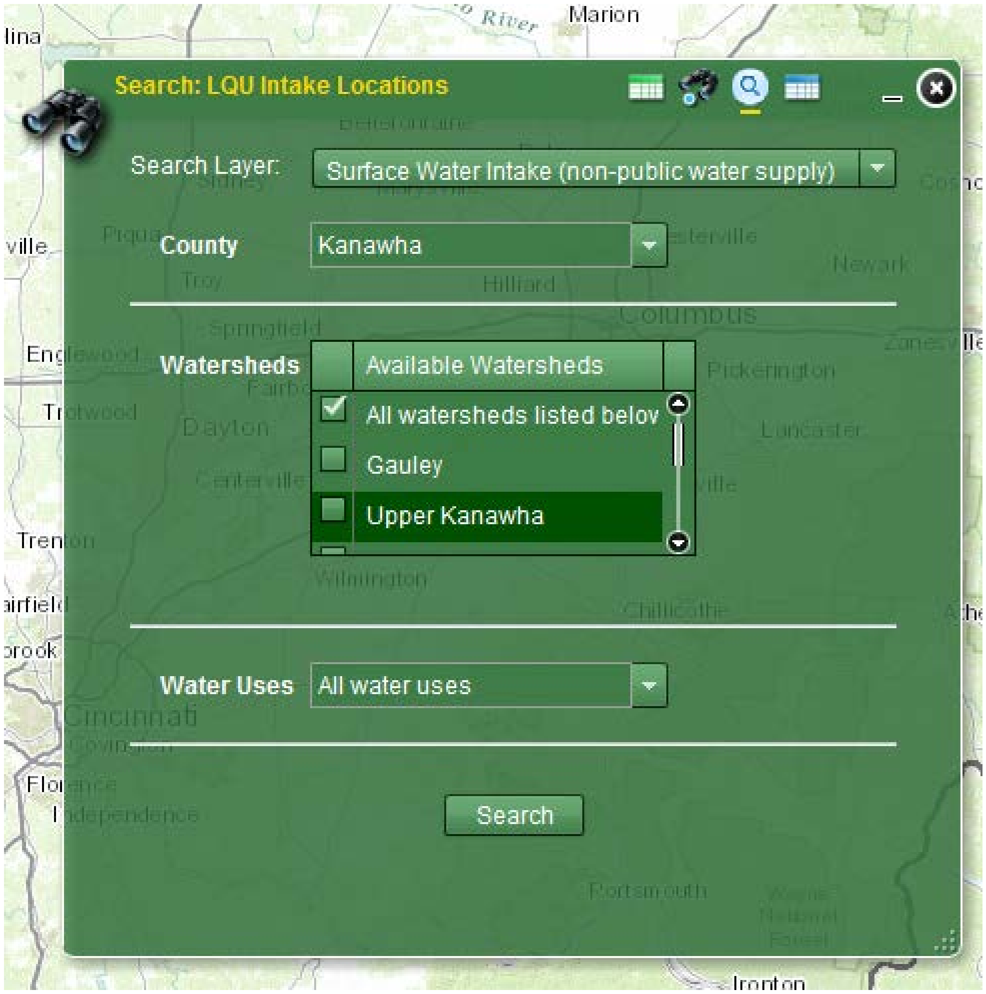
First select one of the following: Surface Water Intake (non-public water supply), Surface Water Intake (public water supply), Groundwater Intake (non-public water supply), or Groundwater Intake (public water supply) from the search layer dropdown box.

You have the capability to search LQU intakes by the following attributes:

- County
  - All 55 West Virginia Counties
- Watershed
  - All 32 HUC-8 Watersheds (with the states boundaries)
- Water Use Type
  - Agriculture/aquaculture, Chemical, Frac Water, Hyrdoelectric, Industrial, Mining, Petroleum, Public Water Supply, Recreation, Thermoelectric, and Timber

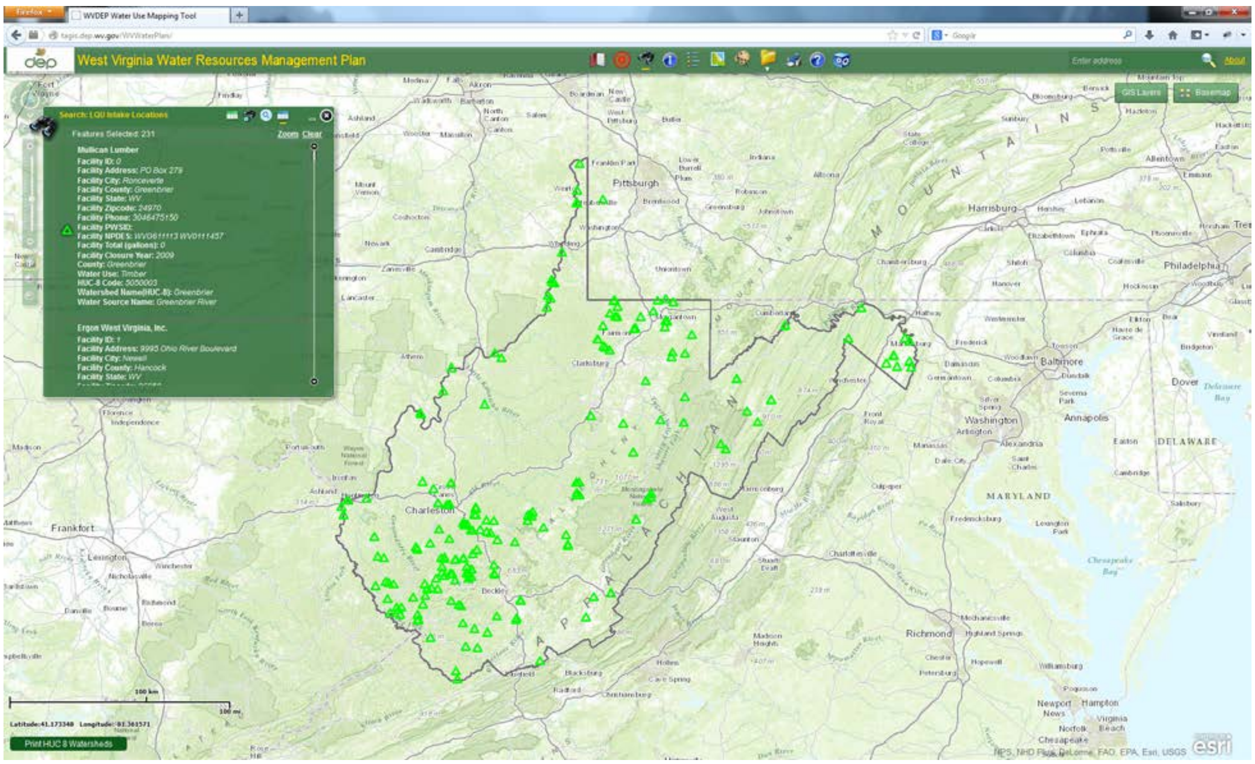
Search by Attribute

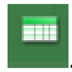
If you select a county to search from, you must also choose a watershed within that county. If you are unsure of what watershed within the county you would like to search, simply check "All watersheds listed below", and then all search results within the county will show up.

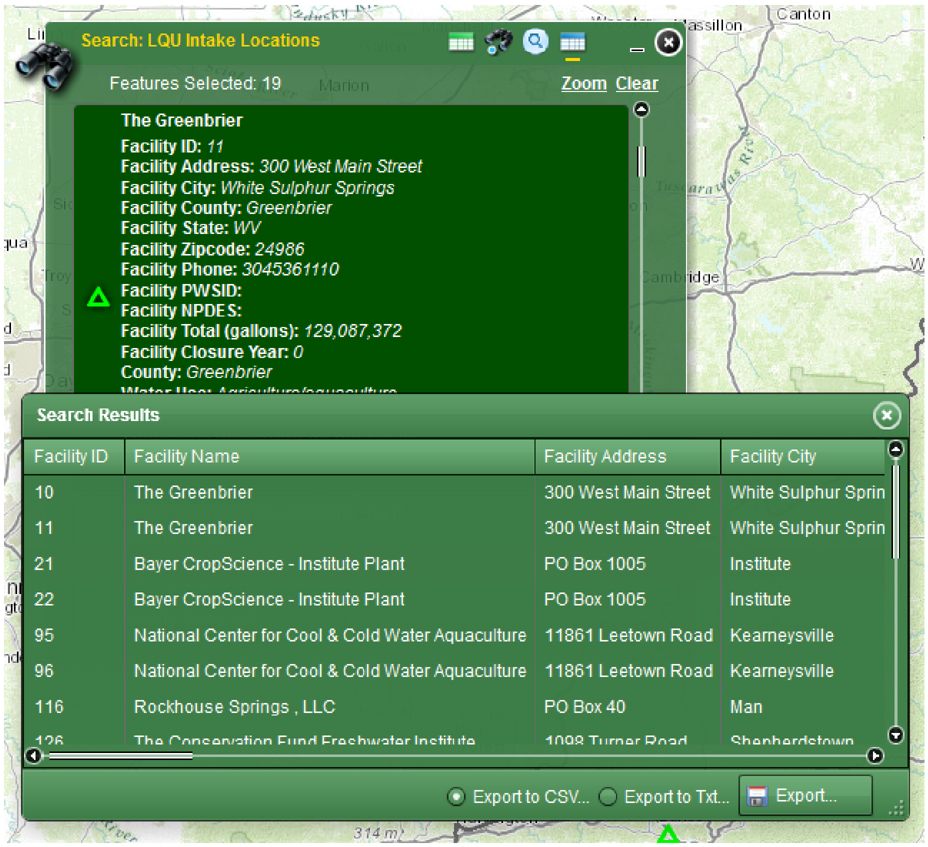


### iii. View Results

After a search is completed, the results are displayed under the results tab and are highlighted on the map. Public water supply is shown as ◯ non-public water supply is shown as △

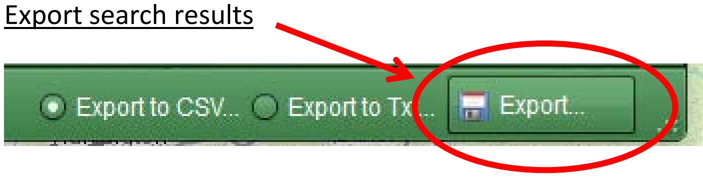


The search results can also be viewed in a table by selecting the “Show Results in Grid” button .




The search results can then be exported to a CSV or text file from the table/grid view. Both formats can be imported into a common spreadsheet application like Microsoft Excel.

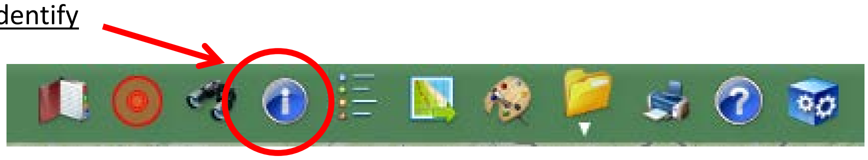
Export search results



## D. Identify

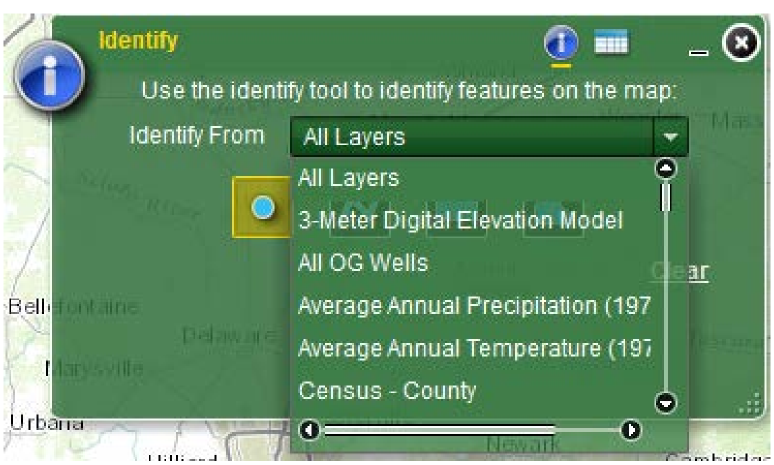
The Identify button displays certain attributes about the GIS layers that are visible on the map. See section III of this document for more information on displaying "GIS Layers".

Identify



Begin by choosing one of the graphical search tools (from left to right):

- point
- polyline
- rectangle
- polygon

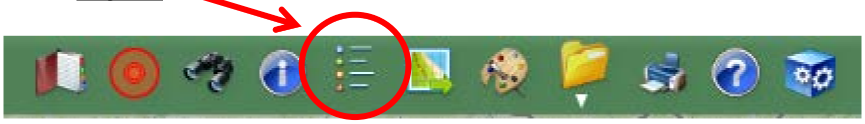



If a graphical search tool has been selected, define the area to search by drawing on the map with your mouse.

## E. Legend

The Legend button conveys the meaning of the symbols used to represent features on the map.

Legend

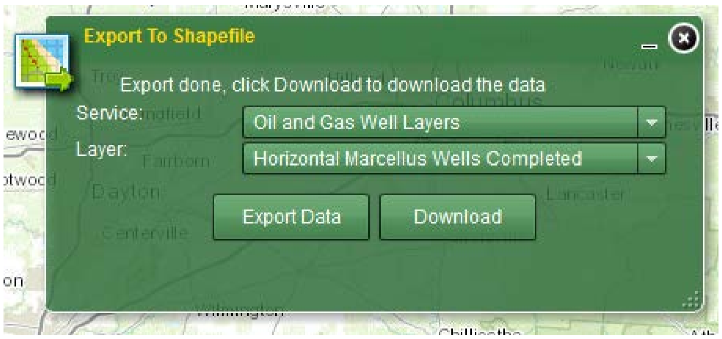



## F. Export Layer to Shapefile

The Export Layer to Shapefile button allows for exporting map layers to ESRI shapefile format. After the layer has been exported it can then be opened and viewed within GIS software that supports ESRI shapefile formats.

Export layer to shapefile

To begin, select the service where the layer resides. Then select the layer to export by clicking the “Export Data” button. After export is done, click the “Download” button to download a zipped shapefile.

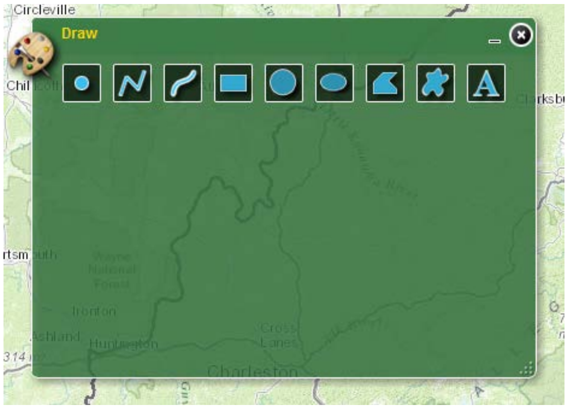


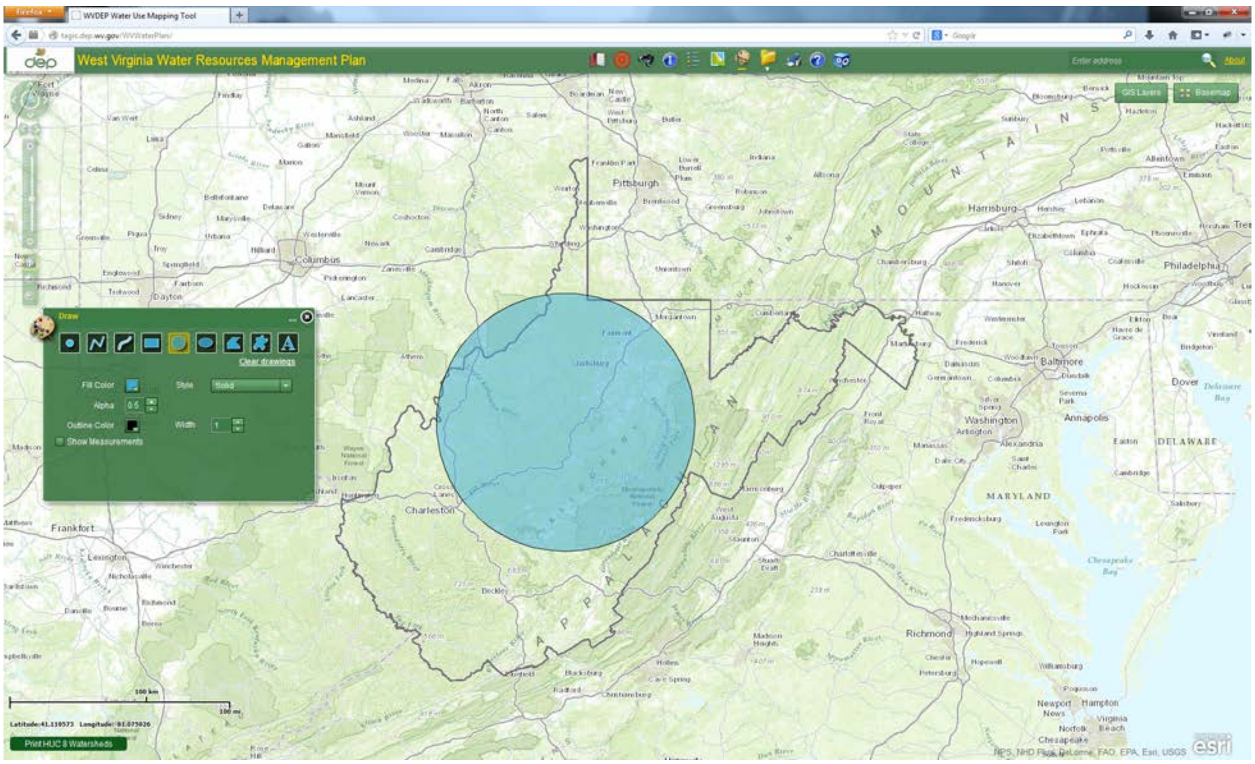

## G. Paint

The paint button allows you to draw (shapes, lines, text) onto the map you are viewing.


You can do the following (left to right)

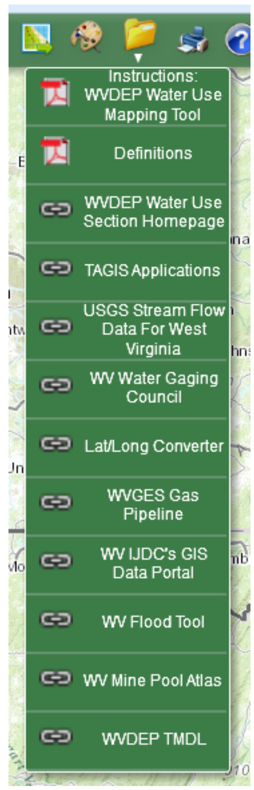
- Point
- Line
- Freehand Line
- Rectangle
- Circle
- Ellipse
- Polygon
- Freehand Polygon
- Add text (you must first add the text in the dialog, chose your color, font etc., and then select the Add text button.  Next you will click inside the mapviewer and the text is added)


Draw


West Virginia Water Resources Management Plan
Draw
Clear drawings
Fill Color
Style
Solid
Alpha
0.5
Outline Color
Width
Show Measurements
Print HUC 8 Watersheds

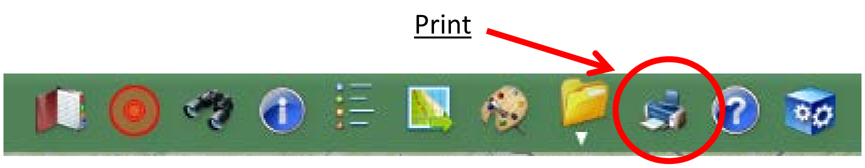
## H. Links

The Links button contains links to important documents and websites.

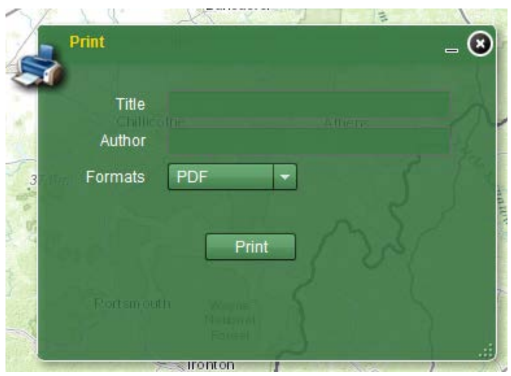
## I. Print

The Print button allows you to print what you see. All map display content that is currently visible will be printed.

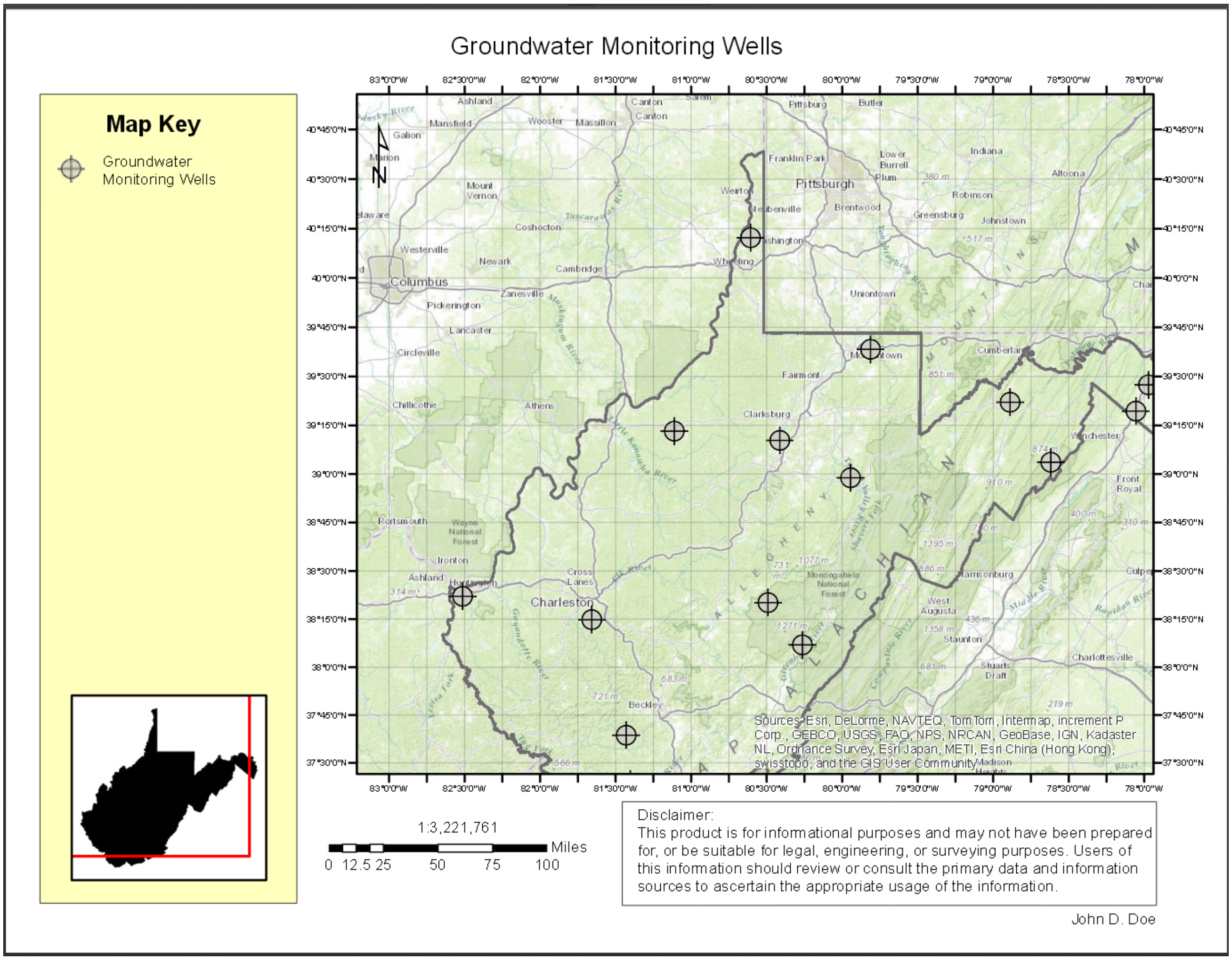



You also have the option to give your map a title and author. Then select the format you would like and hit print, and your map is created. You can choose one of the following formats:

- PDF
- PNG32
- PNG8
- JPG
- GIF
- EPS
- SVG
- SVG2

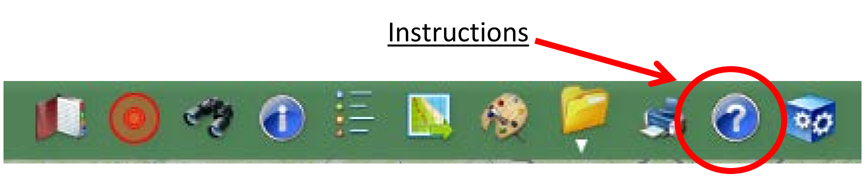



When physically printing your map, it is recommended that you print it in landscape view (for easier viewing purposes). Additionally, if you are trying to print the entire state, please make sure you click "Zoom to full extent". Outside of this extent, some features may not be viewable.




## J. Instructions

The Instructions button links you to a copy of the map viewer's instructions (like the one you are viewing now).

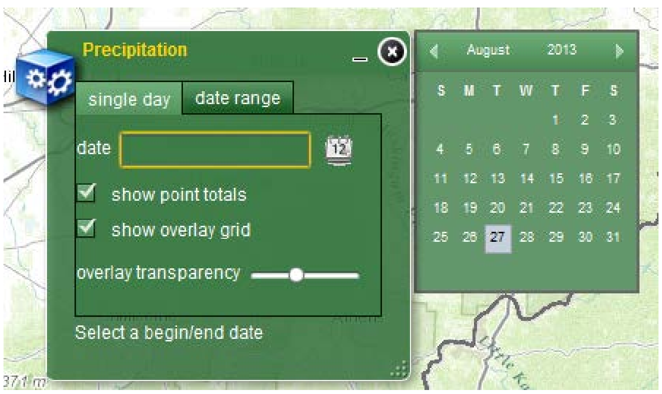


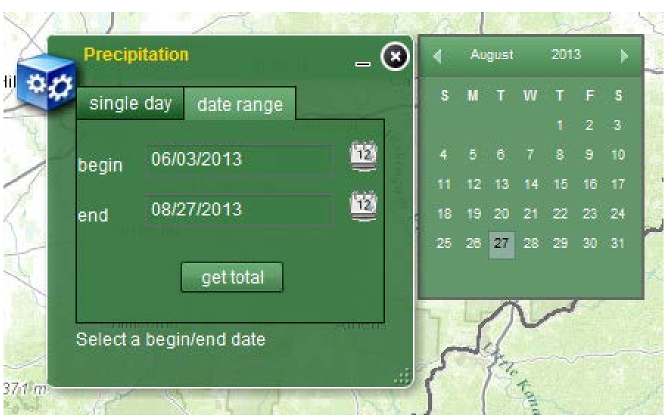
## K. Precipitation

The Precipitation button allows you to view current and past precipitation values.

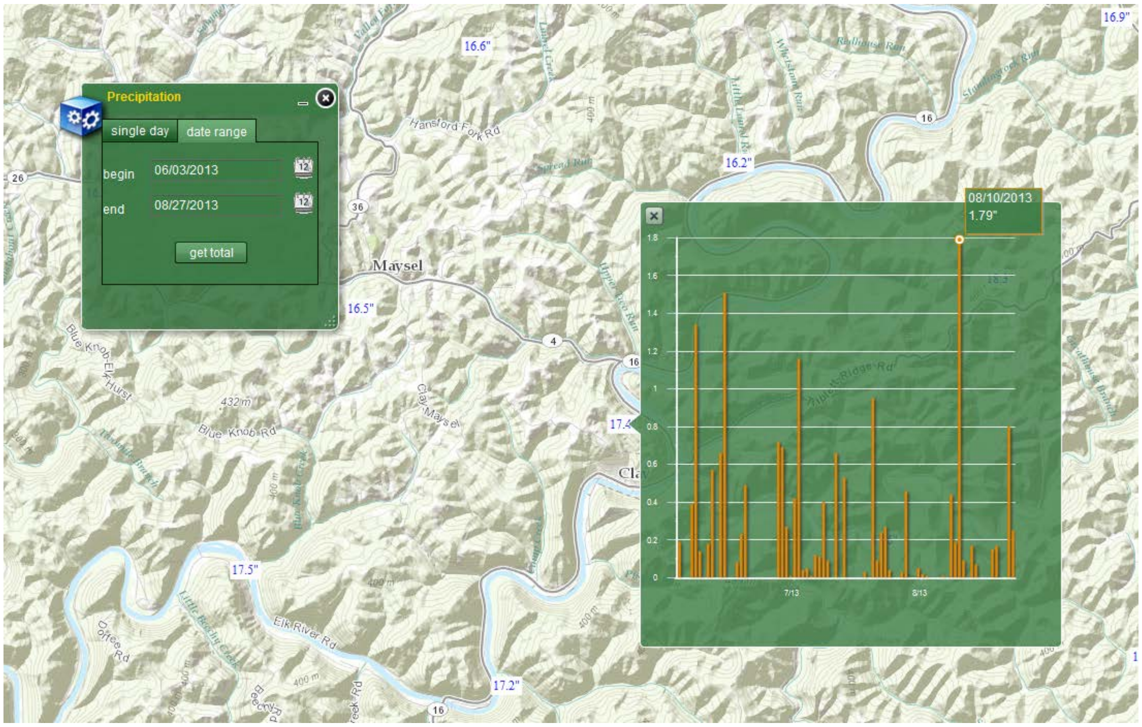
Precipitation

You can view a single day, or you may search a date range – as far back as to January 1st 2010.




Once the time period is selected, press the "get total" button. You will then need to zoom in on the map in order to display point values. By clicking on the precipitation value you can then view a bar graph showing the day by day total(s).




If you have any questions, concerns, or problems with this web viewer please contact:

Jon Michael Bosley
phone - 304-926-0499 x. 1644
email - Jon.M.Bosley@wv.gov

# Appendix C

## Watershed Meetings and Stakeholder Involvement

## Stakeholder Involvement Process

In accordance with the objectives to be considered in the State Water Resources Management Plan outlined in §22-26-8(d), stakeholders listed in §22-26-9(c) and others were engaged through local meetings that were organized by HUC8 watershed. The meetings were held in central locations within each watershed at various locations ranging from the DEP headquarters training rooms, local fire departments and conference centers such as the Summersville Arena to hotel meeting spaces. Accommodations such as beverages, snacks, and lunches were provided in consideration of the various distances stakeholders may have had to travel to attend meetings. Invitations were sent to stakeholders in each watershed (including, but not limited to, state agency representatives, county commissioners, mayors and other elected officials, watershed association members, economic development council members, city planners and engineers, flood plain managers, and large quantity users).

Stakeholders in attendance (Figure 1) were provided with a thorough presentation to educate and inform them about the purpose, progress, and future plans regarding the State Water Resources Management Plan and the information currently collected relating to their respective watershed. In the second half of the daylong meeting, the attendees were provided with group discussion questions aimed at obtaining local information that should be considered in the plan. Issues addressed during discussions were future industrial development, population shifts, groundwater concerns, reservoir construction, drought response, storm-water runoff and any other topics related to water resource management relevant to the given watershed meeting being conducted. Specific questions were developed to guide the discussions and touched on the following topics; development, population trends, drought/flood issues, groundwater and wells, local water agreements, precipitation data, recreational uses, resource areas, and competition for resources.

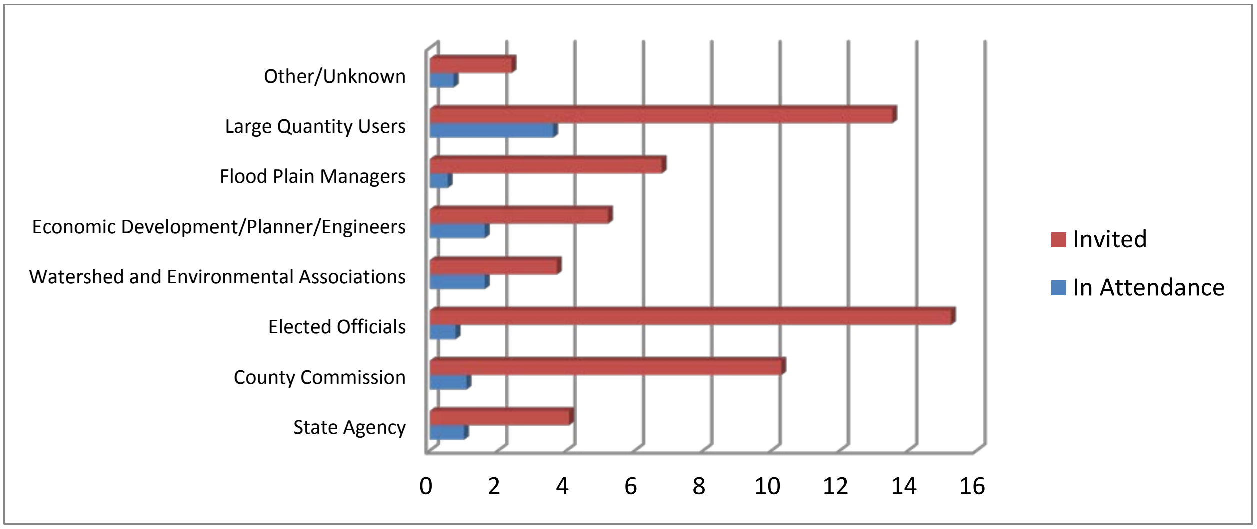



**Figure 1 Average Invited Vs. In Attendance to Each Watershed Meeting by Group.**

Information was collected at every meeting in regard to those in attendance, local information they provided, and suggestions for improvements in the meeting format. Attendance was counted and the agencies and organizations represented were recorded, the discussion questions were in the form of short answer, and the final questionnaire was yes/no format with an opportunity for additional comments and suggestions at the end. Additionally, attendees were given the opportunity to volunteer to serve as a contact for the DEP as a support group member.

Unfortunately not all of the 32 watershed discussion questions were exactly the same. The first half of the meetings were held under different management with more than a year break before the second half of the meetings were conducted. In an attempt to create some uniformity for evaluation purposes the newer question sets were sent out to all who attended each of the watershed meetings that used the initial question set, but only one answer has come back from each of the other watersheds meaning it was completed by only one person instead of a group and two (S. Branch and W. Fork) have no responses at all. This inconsistency has created some difficulty in evaluation and causes further problems with graphical representation due uniformity issues. Additionally, having the group discussions questions in short answer format, not scaled or graded with y/n for example, increases the difficulty in representing the answers graphically.

We do have sign- in sheets for each meeting with the people who attended and who they were there representing. The final questionnaire was a set of Y/N questions about the presentation itself such as;

was the map section useful? Was the meeting valuable to you? Did you feel anything was left out? Will you be able to use the information presented? Do you have suggestions for improving the meeting?

## Information Provided by Stakeholders

The following figures present the aggregate responses from all of the watershed meetings with similar group questions. The final questionnaire also follows.

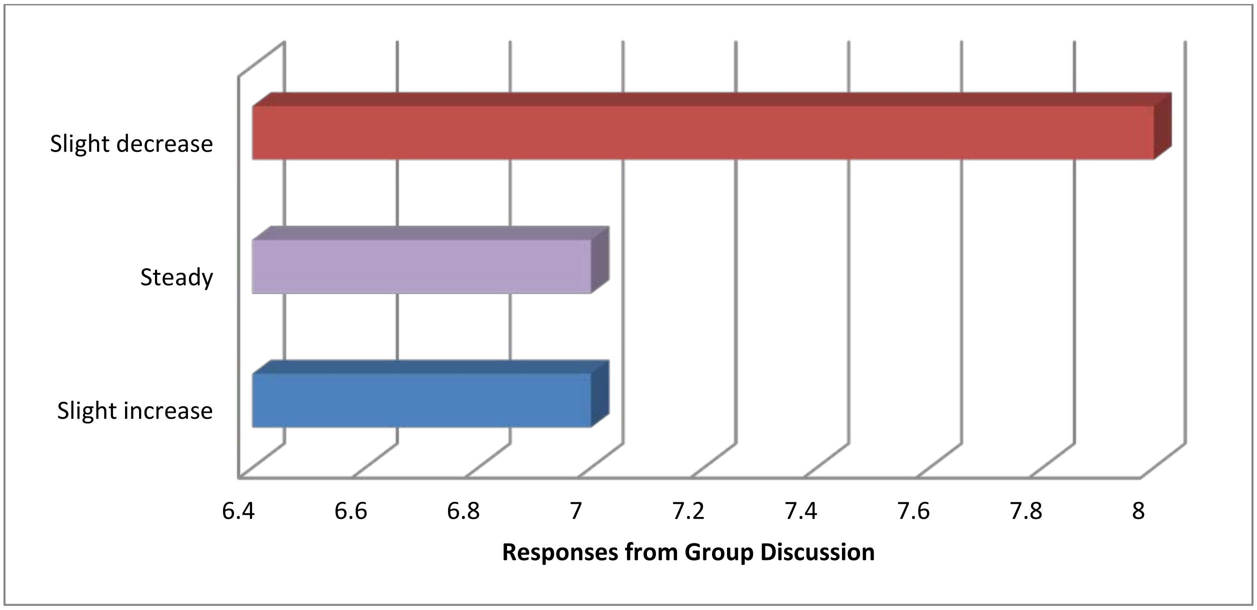



**Figure 2 Group Question #2; How do you expect the local population to change in the next 10 years?**

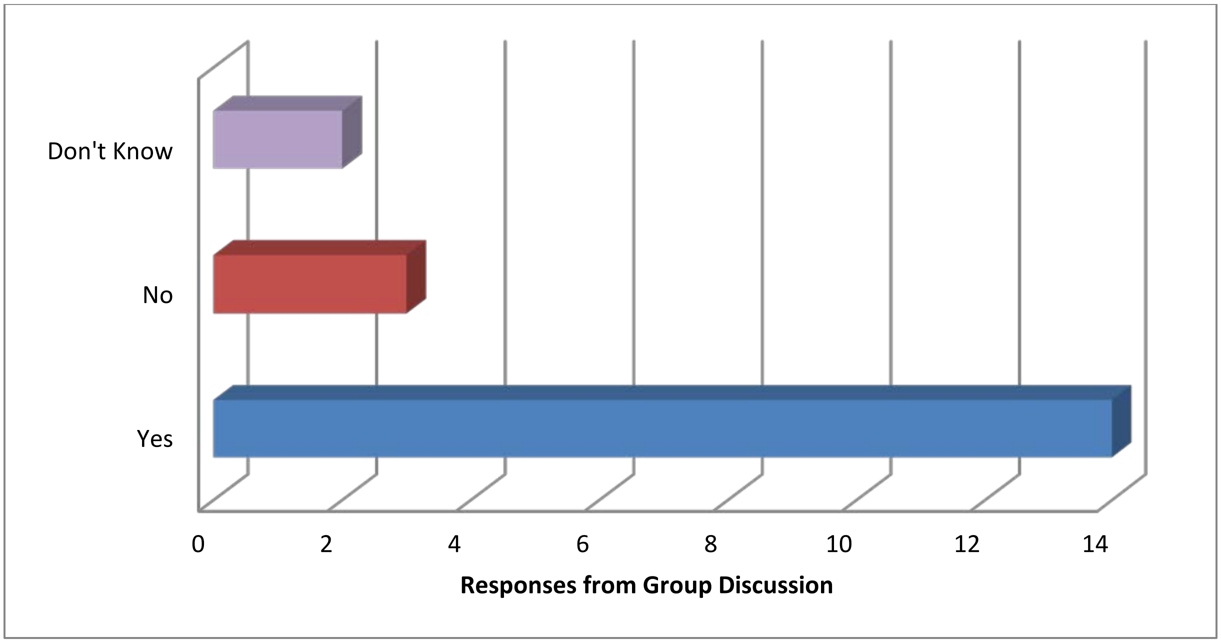


**Figure 3 Group Question #3a; Are there new sub-divisions or commercial developments planned?**

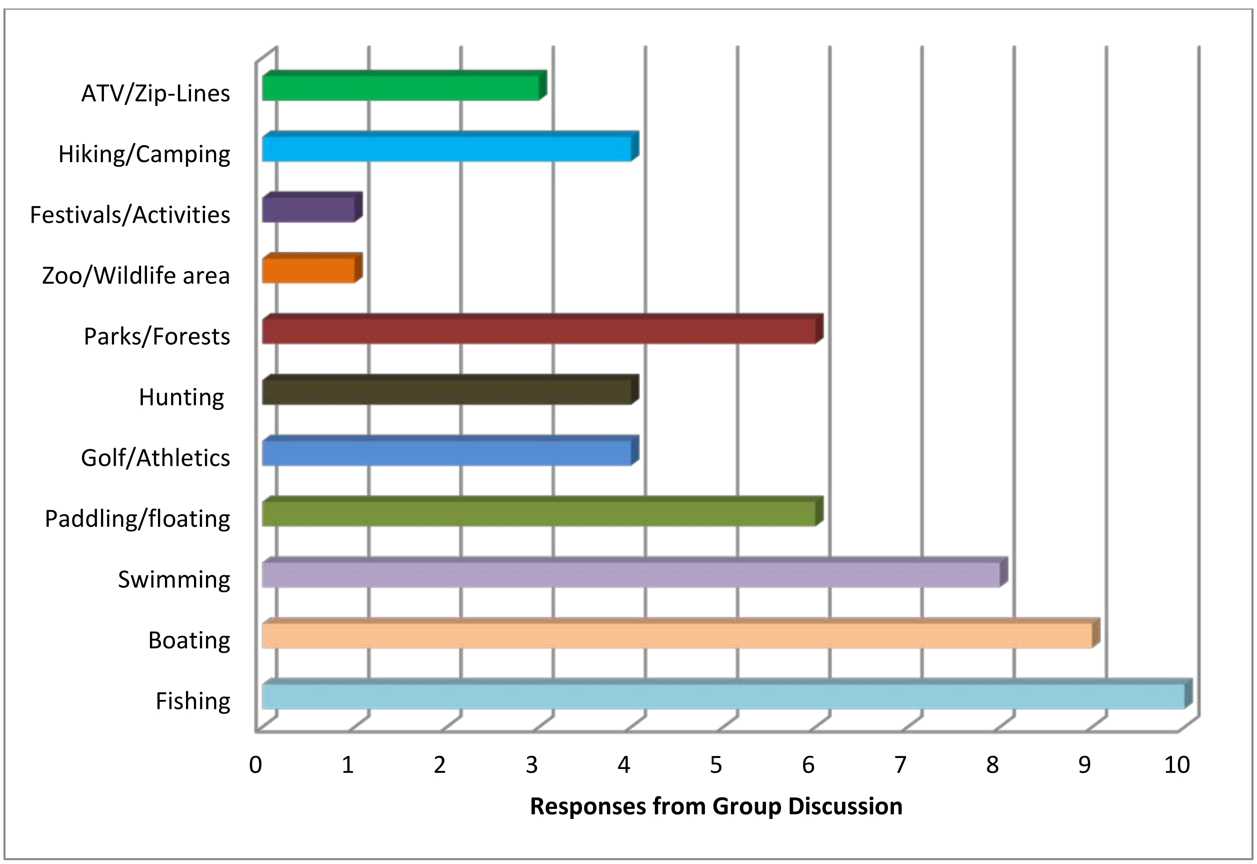


**Figure 4 Group Question #4; What are the important recreational uses in the area that are dependent on water?**

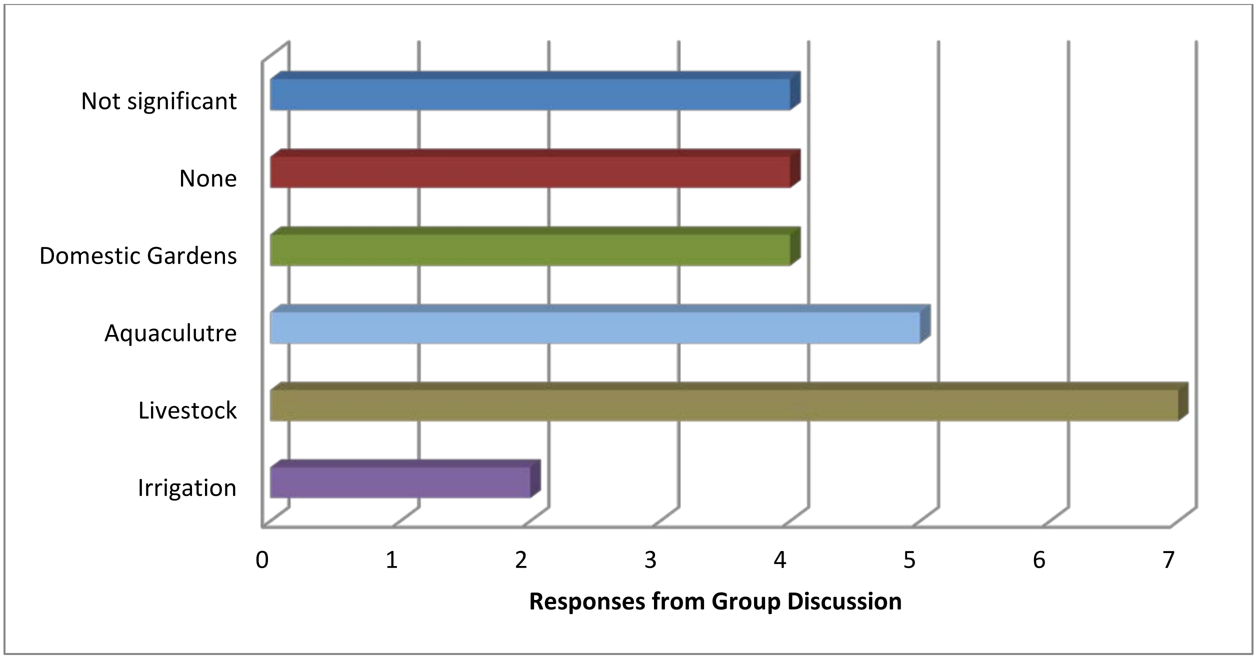



Figure 5 Group Question #6; What is the predominant agricultural water use in the area?

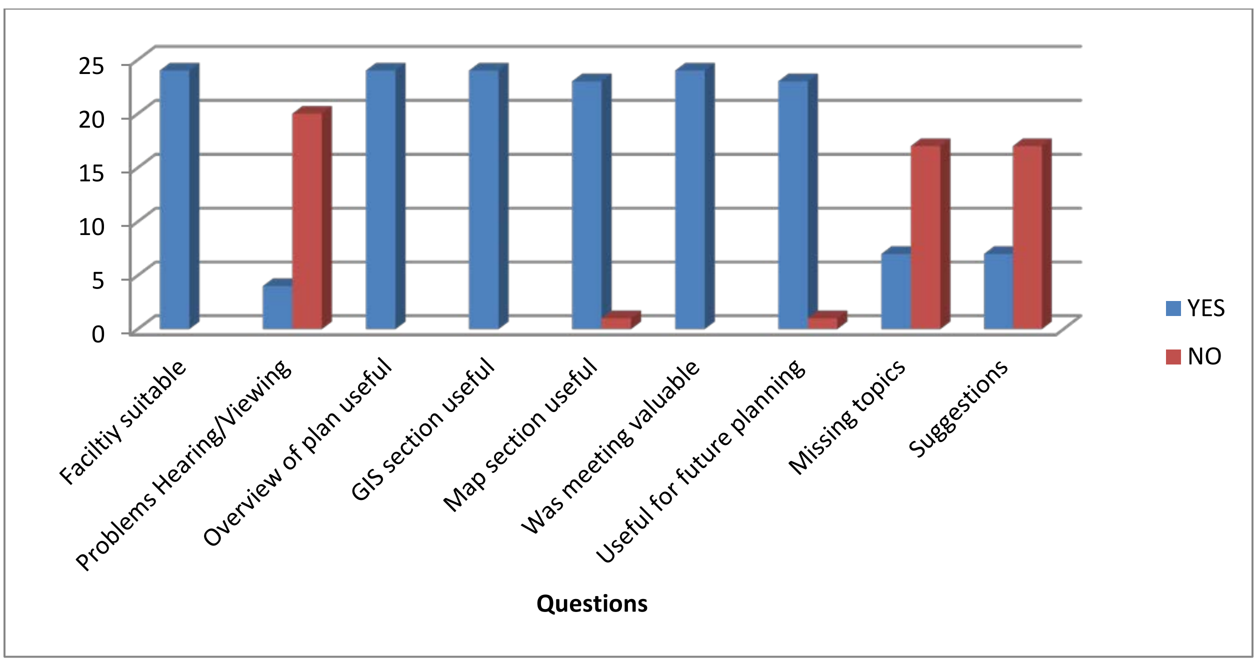



Figure 6 Final Questionnaire Responses from meetings in 2009, 2010, and 2012.

# Watershed Group Questions V.1

1. Are there any publically owned water wells in the area that could be used in the ground water well monitoring network?

2. Does anyone plan to install a water well for their business?

3. Do you have any figures for how many people are dependent on private wells? Check with economic development folks.

4. Are there plans for water supply and/or wastewater treatment improvements within this watershed (impoundments, tanks, etc .)?

5. What are the population predictions for the watershed? Are your cities/counties going to grow in population or decrease? Are there new subdivisions planned?

6. Are there any areas of anticipated development (urban or commercial) that are expected to increase the demand for water?

7. Does anyone have updated spring information?

8. Is there anything we need to know about the parks, scenic areas, etc.?

9. What are the important recreational uses in the area that are dependent on water?

10. Is local precipitation data being recorded on a regular basis?

11. Are there any flooding issues within the watershed?

12. Are there records showing the extent and frequency of former floods?

13. Is there a unified flood warning system?

14. We need accurate Agriculture data for the watershed– does anyone want to volunteer information?

15. Are there any drought issues?

16. Is there a unified drought response plan?

17. Are there any stormwater management plans? Who is doing them, and what do they involve?

18. Are there any existing water quality issues (as it affects quantity) in the watershed?

19. Are there any combined sewer overflow problems and are there any plans to deal with them?

20. What are the main problem streams in the watershed (any specific reasons)?

21. Are there any existing water quantity issues (sufficient supply)?

22. Is there any competition between users?

23. Are there any local agreements concerning water that should be noted?

# Watershed Group Questions V.2

1. What changes do you expect to see in your area in the next five years?

2. What changes would you like to see occur in the next five years? In ten years?

3. In the next ten years how do you expect the local population to change?

4. Are there any new sub-divisions or commercial developments planned? If so, how will water and sewer service be provided?

5. What are the important recreational uses in the area that are dependent on water?

6. Are there records showing the high water marks, or the extent and frequency of former floods?

7. Is agriculture important in your area? What is the predominant agricultural water use in the area (irrigation, livestock, aquaculture, etc.)?

8. What stage are you in meeting the MS4 Permit requirements? What is being done to promote public awareness of storm water issues?

9. Do you have any figures for how many people are dependent on private wells?

10. Are there any local agreements concerning water that should be noted?

11. Are there any existing water quality or quantity issues in the watershed that we have not discussed that deserve more attention?

12. Is there anyone in the group that would be willing to be on a Watershed Support Group for your watershed?

# Water Resources Plan Meeting Questionnaire

Watershed Meeting

| | | |
|---|---|---|
| **Was the meeting facility suitable?** | YES | NO |

Comments:

| | | |
|---|---|---|
| **Did you have problems hearing or viewing the presentation?** | YES | NO |

Comments:

| | | |
|---|---|---|
| **Did you find the overview of the state plan useful?** | YES | NO |

Comments:

| | | |
|---|---|---|
| **Did you find the section on GIS useful?** | YES | NO |

Comments:

| | | |
|---|---|---|
| **Did you find the map section useful?** | YES | NO |

Comments:

| | | |
|---|---|---|
| **Was this meeting valuable to you?** | YES | NO |

Comments:

| | | |
|---|---|---|
| **Will you be able to use information from this meeting in future planning**? | YES | NO |

Comments:

| | | |
|---|---|---|
| **Was there any topic that you feel was missing from the presentation?** | YES | NO |

Comments:

| | | |
|---|---|---|
| **Do you have any suggestions on how to improve future meetings?** | YES | NO |

Comments:

USE BACK IF NECESSARY

# Appendix D

West Virginia Water Law

# WEST VIRGINIA

## WATER LAWS

## WATER REGULATIONS

## AND WATER RIGHTS

WV department of environmental protection – Promoting a healthy environment


By:

West Virginia Department of Environmental Protection

Office of Legal Services


2013

# *Table of Contents*

# A

## West Virginia Ownership Relative to its Border Waters

The waters that border the State of West Virginia vary in terms of which state has "ownership" over them. Pursuant to statutory authority, the term "ownership" in this context means that the State holds the watercourses in public trust for the use and enjoyment of the citizens of the State. West Virginia Code § 22-11-2 holds that "[i]t is the public policy of the State of West Virginia that the water resources of this State with respect to the quantity thereof be available for reasonable use by all of the citizens of this State."

Generally speaking, if there is no authority to the contrary, the State of West Virginia has jurisdiction over watercourses which constitute the boundary of the state. West Virginia Code § 1-1-2 states that "the jurisdiction of [West Virginia] also extends over all the rivers which are boundary lines between this and any other state, to the opposite shore, where there is no statute or compact to the contrary." There does exist, however, various authority that addresses the jurisdiction of the border waters of the State:

**North Branch Potomac River/Potomac River** – The North Branch Potomac River and the Potomac River form the border between West Virginia and Maryland. In *Maryland v. West Virginia*, 217 U.S. 1 (1910), the State of Maryland filed an action against the State of West Virginia to determine the precise boundary line between the two states. By decree issued on May 31, 1910 (217 U.S. 577) the United States Supreme Court determined that the boundary line between West Virginia and Maryland is the low water mark on the south side of the Potomac River.

*Summary*: West Virginia's boundary line extends to the low water mark on the south side of the Potomac River. See *Maryland v. West Virginia*, 217 U.S. 1 (1910).

**Ohio River** – The Ohio River forms the border between West Virginia and Ohio. Prior to West Virginia's formation of a state in 1863, Virginia was the original proprietor of the Ohio River. Section I of Article II of the West Virginia Constitution holds that the State of West Virginia includes "the bed, bank and shores of the Ohio River," and that "all territorial rights and property in, and jurisdiction over, the same, heretofore reserved by, and vested in, the commonwealth of Virginia, are vested in and shall hereafter be exercised by, the State of West Virginia." W.Va. Const. Art. II, § I. Case law has held that the true boundary line between the states is the low water mark on the northwest or Ohio side of the river. See *Ward v. Island Creek Fuel & Transp. Co.*, 261 F. Supp. 810 (1966), *State v. Faudre*, 54 W.Va. 122 (1903), *Handly's Lessee v. Anthony*, 18 U.S. 374 (1820).

*Summary*: West Virginia's jurisdiction of the Ohio River extends to the low water mark of the opposite (western) shore of the Ohio River.

**<u>Big Sandy River</u>** – The Big Sandy River lies between the border of West Virginia and Kentucky. Prior to West Virginia's formation of a state in 1863, the Big Sandy was recognized as the boundary between Virginia (what is now West Virginia) and Kentucky in an Act of the General Assembly of Virginia in 1842. Section I of Article II of the West Virginia Constitution holds that the State of West Virginia "includes...so much of the Big Sandy river as was formerly included in the commonwealth of Virginia." W.Va. Const. Art. II, §I.

*Summary*: No authority has determined precisely where the boundary line between West Virginia and Kentucky lies and it is assumed that both West Virginia and Kentucky share riparian rights with respect to the Big Sandy River.

**<u>Tug Fork River</u>** – The Tug Fork River lies between the border of West Virginia and Kentucky. In 1895, an Act of the West Virginia Legislature defined that the Tug Fork River is the State line and the southwestern boundary of Mingo County. The West Virginia Supreme Court of Appeals has determined that the boundary line "in that locality between the States of West Virginia and Kentucky is as it was between Virginia and Kentucky at the date of the formation of West Virginia…The stream called 'Tug Fork' is here the boundary, and the line between the States is its middle." *Ex parte McNeeley*, 36 W. Va. 84 (1892).

*Summary*: No authority has deviated from the determination by the West Virginia Supreme Court of Appeals that the boundary between West Virginia and Kentucky is the middle of the Tug Fork River and it is assumed that both West Virginia and Kentucky share riparian rights with respect to the Tug Fork River.

# B

## Public Rights in West Virginia Watercourses: A Unique Legacy of Virginia Common Lands and the Jus Publicum of the English Crown

By: Larry W. George

Principal factors determining public and private rights in watercourses:

- Physical Characteristics – Whether the watercourse is navigable-in-fact (non-tidal), floatable, or non-floatable at common law.
- Origin of Title to Riparian Lands – Whether the title to the riparian lands originates from a Colonial patent or a Northern Neck Proprietary grant during the colonial period, a Virginia Land Office patent (1780-1863), a West Virginia land grant (1863 to 1864), or a deed from a West Virginia school land commissioner (1865 to 1912).
- Eastern or Western Waters – Whether riparian lands lie upon the "eastern waters" which drain to the Chesapeake Bay or the "western waters" which drain to the Ohio River.
- 1780 and 1802 Common Lands Acts - Whether a watercourse comprises common lands by reason that it is a "river or creek" excepted by statue from Virginia patents and West Virginia land grants of riparian lands and reserved in public ownership.

Navigable and Floatable Waters:

- Navigable Watercourse – One capable of valuable use by the public on at least a seasonal basis by watercraft historically or customarily used in commercial trade and transport. See *Campbell, Brown & Co. v. Elkins*, 141 W.Va. 801 (1956).
- Floatable Watercourse – One that is passable by "floating logs, rafts, timber, boats,…canoes, push boats, and like craft…" See *State v. Elk Island Boom Co.*, 41 W.Va.796 (1896). Unlike navigable waters, which also encompass those which have been or may be made navigable by reasonable improvement, floatable waters encompass only those subject to such use in their natural condition. See *Gaston v. Mace*, 10 S.E. at 63 (1889).

Benchmarks to Identify Navigable and Floatable Watercourses

- Navigable Watercourses: Any watercourse with an upstream drainage area in excess of one hundred and twenty-five square miles (125 sq. mi.) and an average gradient of less than fifteen feet per mile (15 f.p.m.) may be considered a navigable watercourse. Such a watercourse would be considered navigable even if intermittent segments have a significantly higher gradient or are rendered non-navigable by obstructions. In exceptional circumstances, Corps of Engineers' surveys have found smaller streams and modestly greater gradients to be navigable.

- Floatable Watercourses: Any watercourse with an upstream drainage area in excess of seven square miles (7.0 sq. mi.) and an average gradient of less than thirty-five feet per mile (35 f.p.m.) may be considered a floatable watercourse.

1802 Commons Land Act

- In 1802, the Virginia General Assembly enacted a statute to reserve the "banks, shores and beds of the rivers and creeks in the western parts of the Commonwealth (now West Virginia), which were intended and ought to remain as a common to all the good people thereof." After West Virginia was formed in 1863, the 1868 WV Code did not include the common lands act. However, both the 1863 and 1872 Constitutions of West Virginia provided that all private rights and interests in lands derived under the laws of Virginia were to be determined by such laws. Thus, there is Legislative intent to preserve the common lands and maintain the public uses authorized by the 1802 Commons Land Act.

*Jus Publicum* – Protected Public Uses

- Certain public rights and interests in watercourses are vested as a public trust in the State of West Virginia. In West Virginia, public trust interests in watercourses arise from the *jus publicum*. The sovereign powers of *jus publicum* are vested in the West Virginia Legislature as successor to the English Crown (see *Commonwealth v. City of Newport News*, 164 S.E. 689 (Va. 1932), as West Virginia (nor Virginia) has not adopted the public trust doctrine.
- The concept of *Jus publicum* appeared in the 1671 treatise of English Lord Chief Justice Matthew Hale, *De Juris Maris et Brachiorum Ejusdem* (Concerning the Law of the Sea and its Arms), which has been cited by the West Virginia Supreme Court of Appeals (in *Gaston v. Mace*, 33 W.Va. 14 (1889)) as the most authoritative source of the English common law concerning watercourses and navigation.
- In *Gaston v. Mace*, 33. W.Va. 14 (1889), the West Virginia Supreme Court of Appeals observed that the "rule of the common-law, that riparian proprietors own to the thread of fresh water rivers, has been adopted in this and many other states of the Union.
- West Virginia state law governs public and private rights subject to two doctrines of federal constitutional law:
  (1) The federal navigational servitude imposed by the Commerce Clause – protects navigation on navigable watercourses and regulation of commerce thereon by Congress
  (2) The state sovereign lands doctrine – provides that at independence, as an incident of state sovereignty, the original thirteen states acquired title to non-tidal watercourses and other public rights therein as a public trust

Public Fishing Rights

- Pursuant to West Virginia Code § 20-2-3, the ownership of fish and aquatic life is vested in the State of West Virginia as a public trust for the use, benefit and enjoyment of its citizens. See also *Shobe v. Latimer*, 253 S.E.2d 54 (1979).

# C

## West Virginia Riparian Water Rights

### Riparian Rights

Riparian rights refer to the rights of a landowner whose land abuts a natural watercourse. This is a very complex subject and can be treated only in a general way in this publication. The general principle of law is that all landowners along a watercourse have the same right to the use and enjoyment of its water, provided no one owner substantially climinishes or pollutes the stream, thereby causing hardship to downstream users. A landowner does not own the water in a stream. Instead, he owns the right to use it, subject to the equal rights of other owners along the watercourse.

Ownership of the stream bed depends upon the stream's classification. If the stream is classified as non-navigable, the landowner's property extends to the middle of the streambed, provided the stream is designated as a boundary line in the deed. On a navigable stream, the landowner holds title only to the low water mark, and the rest of the streambed is owned by the West Virginia Public Land Corporation. A navigable stream is defined for ownership purposes as one that may be used by the public for transportation and commerce in its natural condition.

West Virginia has long adhered to the doctrine of riparian rights for the allocation of water to particular uses. This doctrine has been recognized in a number of West Virginia statutes. (W.Va. Code § § 5D-1-5, 8-12-5(33), 17-2A-17, 17-17-17, 20-2-48, 22-ll-24(d), 22-11-27, 22-12-B(b), 31-3-9, 31-156(w), 54-1-10, 54-2-3, 61-3-47 (2003). And West Virginia courts, like courts in nearly all states still adhering to traditional riparian rights, have long applied the reasonable use version of riparian rights. West Virginia, like all states applying traditional riparian rights, does not rely solely on "pure" riparian rights. It has in place any number of regulations directed at particular uses of the waters of the state or of lands the use of which will affect the waters of the state. Still, it remains true that in West Virginia disputes limited to the allocation of water among users is determined by the reasonable use rule and not any other body of law within the state. West Virginia courts have applied the more restrictive natural flow rule only in cases involving flooding or pollution. Given the changing patterns of demand for water in the state -- including the possibility of demands for water by persons located in neighboring states, this body of law cannot stand for long.

### The Reasonable Use Rule

Riparian rights are based on the premise that the right to use water is a natural attribute of land, dependent on the natural availability of water to the land. Indeed, the very word "riparian" derives from the Latin word "ripa" meaning a riverbank. Land abutting or underlying a watercourse is termed "riparian land." Under the reasonable use version of riparian rights, each owner of riparian land is entitled to use water from a contiguous watercourse regardless of the effect on the natural flow of the watercourse so long as each user does not transgress the equal right of other riparians to use the water. While domestic uses are preferred over other uses, the only real restriction is that no use is legal if it "unreasonably harms" another riparian use.

The reasonable use rule thus is a common property system, under which all who own land contiguous to a surface water body are co-owners of the right to use the water. As co-owners, they are left pretty much to their own individual judgment to decide whether, when, and how to use the resource. A court will intervene in these decisions only when a use by one co-owner interferes directly with a use by another co-owner. 106 W.Va. L. Rev. 539 (Spring, 2004).

West Virginia is a common law riparian state which has adopted the "reasonable use" doctrine granting each riparian landowner on a given watercourse an equal and correlative right to a reasonable consumptive use of the natural flow. A riparian may make such consumptive use as does not materially diminish the same rights of the downstream riparian's to a reasonable consumptive use or impair certain public rights. *Supra* note 3. Morris v. Priddy, 383 S.E.2d 770 (W.Va. 1989); Roberts v. Martin, 77 S.E. 535 (W. Va.1913); *Gaston,* 10 S.E. at 22-23; Coalter v. Hunter, 25 Va. 58 (1826); Marlyn E. Lugar, *Water Law in West Virginia,* 66 W.VA. L. REV. 191 (1964).

# D

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**GROUND WATER PROTECTON ACT**

**§ 22-12-1**

**DAMS**

**§61-3-47. Dams or obstructions in watercourses; penalty.**

**NATURAL RESOURCES**

**§20-13-1. Short title.** "West Virginia Stream Partners Program Act."

**§20-13-2.** The purpose of this act is to encourage citizens to work with appropriate state agencies to protect and utilize West Virginia's rivers and streams for public health, recreation, commercial and habitat uses to insure our rivers and streams: (a) Are safe for swimming, fishing and other forms of recreation; (b) can support appropriate public and commercial purposes; and (c) can provide habitat for plant and animal life.

**§20-13-3.** The executive committee will be: The Division of Natural Resources, Department of Environmental Protection, Division of Forestry and the West Virginia State Soil Conservation Agency, they shall jointly administer the program.

**§20-13-4.** Grants are awarded by consensus of the committee, promulgated by the Department of Environmental Protection. Each grant to be matched by the group representatives with cash or in-kind services in at least an amount equal to 20% of the grant. No grant shall exceed the amount of five thousand dollars. See rule for further requirements.

**PUBLIC LAND CORPORATION**

**§5A-11-1.** This rule does not apply to the State of West Virginia's interest in the rivers, streams, creeks or beds thereof and all other public lands managed or acquired by the Division of Natural Resources or the Division of Forestry.

**§5A-11-2.** The Public Land Corporation ("corporation") ex officio members of the board are Executive Director of the Real Estate Division, or designee, chair, Director of Division of Natural Resources or designee, Commissioner of Department of Culture and History or designee and the Secretary of the Department of Administration, or designee.

**§5A-11-3.** This rule give the corporation authority to acquire from any persons or the State Auditor or any local, state or federal agency, by purchase, lease or other agreement, any lands necessary and required for public use by purchase, condemnation, lease or agreement, receive by gifts and devises or exchange, rights-of-way, easements, waters and minerals suitable for public use, and consolidating lands under state or federal government administration.

Disposal Criteria: Authority to sell or exchange public lands if determined the sale or exchange meets certain criteria such as the tract is no longer required for any state purpose.

Authority to purchase, develop, restore and preserve for public use, sites, structures, objects and documents of prehistoric, historical, archaeological, recreational, architectural and cultural significance to the State of West Virginia.

Authority to enter into leases as a lessor for the development and extraction of minerals, including coal, oil, gas, sand or gravel. Reserve title and ownership to the mineral rights in all cases. Convey, assign or allot lands to the title or custody of proper departments or other agencies of state government for administration and control within the functions of departments or other agencies as provided by law.

State Treasury has a special *Public Land Corporation Fund* which shall be paid all proceeds from public land sales and exchanges and rents, royalties and other payments from mineral leases, as long as all royalties and payments derived from rivers, streams or public lands acquired or managed by the Division of Natural Resources.

All proceeds, rents, royalties and other payments from land sales, exchanges and mineral rights leasing for public lands owned, managed or controlled by the Adjutant General's Department will be retained in a fund managed by the Adjutant General.

All state agencies, institutions, divisions and departments shall make an inventory of the public lands of the state. This list of public lands and minerals, including their current use, intended use or best use to which lands and minerals may be put.

The Division of Highways need not provide the inventory of public lands allocated to and used by it. The Division of Natural Resources need not provide the inventory of rivers, streams and public lands acquired or managed by it.

**AGRICULTURE**

**§19-16A-1.** "West Virginia Pesticide Control Act of 1990"

**§19-16A-3. Definitions.** "Environment" includes water, air, land and all plants and man and other animals living therein, and the interrelationships, which exist among these.

Individuals who sell, store, dispose or apply pesticides need to be adequately trained and observe appropriate safety practices.

The commissioner may refuse or cancel the registration of a pesticide if found use of the pesticide demonstrates unreasonable adverse effects on the environment.

**DEPARTMENT OF AGRICULTURE**

**§ 22-12-5(b).** This rule gives Department of Agriculture authority to regulate facilities or activities, with the division of environmental protection, the bureau of public health, and such agencies of the state or any political subdivision as may be designated by the director, as appropriate. Authority to regulate the use or application of pesticides and fertilizers and regulate facilities or activities which may adversely impact groundwater that is not otherwise assigned to the division of environmental protection, the bureau of public health or such other specifically designated agency pursuant to any other provision of this code, the division of environmental protection is hereby authorized to be the groundwater regulatory agency with respect to such unassigned facilities or activities.

**§ 22-12-5(d).** These agencies develop groundwater protection practices to prevent groundwater contamination from facilities and activities within their respective jurisdictions consistent with this article. Such practices shall include, but not be limited to, criteria related to facility design, operational management, closure, remediation and monitoring. Such agencies shall issue such rules, permits, policies, directives or any other appropriate regulatory devices, as necessary.

**§ 22-12-5(e).** These agencies take such action as may be necessary to assure that facilities or activities within their respective jurisdictions maintain and protect groundwater at existing quality, where the existing quality is better than that required to maintain and protect the standards of purity and quality promulgated by the board to support the present and future beneficial uses of the state's groundwater.

**§ 22-12-5(h).** Subsections (e) of this section does not apply to coal extraction and earth disturbing activities directly involved in coal extraction that are subject to either or both article three or eleven of this chapter. Such activities are subject to all other provisions of this article.

**SURFACE COAL MINING AND RECLAMATION ACT**

**Definitions: §22-3-10.** "Replacement of water supply" means, with respect to water supplies, contaminated, diminished or interrupted provision of water supply on both a temporary and permanent basis of equivalent quality and quantity. Replacement includes provision of an equivalent water delivery system and payment of operation and maintenance cost in excess of customary and reasonable delivery cost for the replaced water supplies.

**§22-3-10.** Each reclamation plan submitted as part of a surface mining permit application shall include detailed description of the measures to be taken to assure the protection of the quality of surface and groundwater systems, both on and off site, from adverse effects of the surface mining operation. The rights of present users to the water, the quantity of surface and groundwater systems, both on and off site, from adverse effects of the surface mining operation or to provide alternative sources of water where the protection of quantity cannot be assured.

**§22-3-13.** Any permit issued by department of environmental protection, requires the surface mining operations meet all performance standards and other requirements set forth in legislative rules proposed by the director, including the standard to restore the land affected to a condition supporting the uses which it was capable of supporting prior to any mining, higher or better, as long as it does not pose any hazard to public health or safety or pose any threat of water diminution or pollution.

**§22-3-13a.** At least thirty days prior to commencing blasting, as defined in section twenty-two-a of this article, notifications in writing to all owners and occupants of man-made dwellings or structures that the operator or operator's designee will perform pre-blast surveys.

The Preblast survey includes written documentation relating to the type of water supply, including a description of the type of system and treatment being used, an analysis of untreated water supplies, a water analysis of water supplies other than public utilities and information relating to the quantity and quality of water.

## OIL AND GAS

**§22-6-1. Definitions.** "Waters of this state" has the same meaning as the term "waters" as provided in section three, article eleven of this chapter.

**§22-6-3.** If an inspector finds that an imminent danger to persons exists, or whether an imminent danger that a fresh water source or supply will be contaminated or lost. This is a violation and an order requiring the operator of such well or well site or other oil or gas facility to cease further operations until such imminent danger has been abated.

**§22-6-7.** The director may issue a permit for well work, issue a separate permit, general permit or a permit consolidated with the well work permit for the discharge or disposition of any pollutant or combination of pollutants into waters of this state upon condition that such discharge or disposition meets or will meet all applicable state and federal water quality standards and effluent limitations and all other requirements of the director.

It is unlawful for any person conducting these activities unless that person holds an active water pollution control permit from the director, to allow pollutants produced by or emanating from any point source to discharge of pollutants or the effluent therefrom into the waters or operate any disposal well for the injection or reinjection underground of any pollutant, including, but not limited to, liquids or gasses, or convert any well into such a disposal well or plug or abandon any such disposal well.

**§22-6-21.** No oil or gas well shall be drilled nearer than two hundred feet from an existing water well or dwelling without first obtaining the written consent of the owner of such water well or dwelling.

**§22-6-30.** Within six months after the completion of the drilling process, the operator shall fill all the pits and remove all concrete bases, drilling supplies and drilling equipment. The operator shall grade or terrace and plant, seed or sod the area disturbed. No pit may be used for the ultimate disposal of salt water. Salt water and oil shall be periodically drained or removed, and properly disposed of, from any pit that is retained so the pit is kept reasonably free of salt water and oil.

**§22-6-35.** Any contamination or deprivation of a fresh water source or supply within one thousand feet of the site of drilling for an oil or gas well, there shall be a rebuttable presumption that such drilling, and such oil or gas well, or either, was the proximate cause of the contamination or deprivation of such fresh water source or supply.

## HORIZONTAL WELL ACT

**§22-6A-1. Short Title:** "Horizontal Well Act"

**§22-6A-2.** This rule gives the secretary of department of environmental protection broad authority to condition the issuance of well work permits relating to horizontal well drilling practices.

Horizontal drilling techniques, allow the development of multiple wells from a single surface location, and may involve fracturing processes that use and produce large amounts of water.

Some of these practices require the construction of large impoundments or pits for the storage of water or wastewater. It is necessary to protect the safety of persons, to prevent inadequate or ineffective erosion and sediment control plans, to prevent damage to publicly owned lands or resources, to protect fresh water sources or supplies or to otherwise protect the environment.

**§22-6A-3.** This rule applies to any natural gas well, other than a coal-bed methane well, drilled using a horizontal drilling method**,** which disturbs three acres or more of surface, excluding pipelines, gathering lines and roads, or utilizes more than two hundred ten thousand gallons of water in any thirty day period.

**§22-6A-4. Definitions** "Best management practices" means schedules of activities, prohibitions of practices, maintenance procedures and other management practices established by the department to prevent or reduce pollution of waters of this state. For purposes of this article, best management practices also includes those practices and procedures set out in the Erosion and Sediment Control Manual of the Office of Oil and Gas.

"Flowback Recycle Pit" means a pit used for the retention of flowback and freshwater and into which no other wastes of any kind are placed;

"Freshwater Impoundment" means an impoundment used for the retention of fresh water and into which no wastes of any kind are placed;

"Perennial stream" means a stream or portion of a stream that flows year-round, is considered a permanent stream and for which base flow is maintained by ground-water discharge to the streambed due to the ground-water elevation adjacent to the stream being higher than the elevation of the streambed.

**§22-6A-7.** It is illegal for any person to start any site preparation work without a well work permit.

The well work permit information must supply the type of water source, such as surface or groundwater, the county of each source to be used by the operation for water withdrawals, and the latitude and longitude of each anticipated withdrawal location. The anticipated volume of each water withdrawal. The anticipated months when water withdrawals will be made.

Identification of current and existing water uses, including any public water intakes within one mile downstream of the withdrawal location.

**§22-6A-10.** Notification is to be given to any surface owner or water purveyor to have a water well, spring or water supply source located within one thousand five hundred feet of the center of the well pad which is used to provide water for consumption by humans or domestic animals.

**§22-6A-12.** Wells may not be drilled within two hundred fifty feet measured horizontally from any existing water well or developed spring used for human or domestic animal consumption.

**§22-6A-16.** If well is contaminated payment of all reasonable costs incurred by the real property owner in securing a water supply.

**§22-6A-20.** Certification is required from the Division of Highways pertaining to the state local service roads.

**§22-7-3.** The oil and gas developer shall be obligated to pay the surface owner compensation for any damage to a water supply in use prior to the commencement of the permitted activity.

**PUBLIC SERVICE COMMISSION**

**§24-2-1a.** Gives the commission authorized and empowered permission to enter and inspect any property, premise or place, owned or operated by a railroad.

**§24-2-1b.** Give the commission authority to establish, prescribe and enforce rules providing for the safe transportation of solid waste in the state. The commission shall establish rules for the collection of waste tires by private commercial carriers of solid waste.

**§24-2-1c.** A permit to construct, operate, expand or seeking a major permit modification for a commercial solid waste facility from the division of environmental protection first shall obtain a certificate of need from the public service commission.

**§24-2-1i**. The director of the division of environmental protection shall modify any commercial solid waste facility permit, issued under article five-f, chapter twenty of this code, to conform with the maximum monthly solid waste disposal tonnage and any other terms and conditions set forth in a temporary certificate issued under this section.

**PUBLIC HEALTH.**

**§16-1-1.** The purpose of this policy is to promote the physical and mental health of all of West Virginia Citizens, to prevent disease, injury, and disability whenever possible.

**§16-1-2. Definitions.** "Public water system" means any water supply or system which regularly supplies or offers to supply water for human consumption through pipes or other constructed conveyances, if serving at least an average of twenty-five individuals per day for at least sixty days per year, or which has at least fifteen service connections."

**§16-1-4**. This rule gives Director of Public Health the power to regulate and promote safe drinking water, to regulate land usage endangering the public health, restrict subdivisions or development, to prevent contamination of wellheads and well fields used by public water supplies and to regulate requirement of distribution of bottled drinking water.

**GROUND WATER PROTECTON ACT**

**§22-12-1. Short title.** "Groundwater Protection Act."

**§22-12-2.** This act pertains only to the groundwater of West Virginia. Over fifty percent of West Virginia's overall population, and over ninety percent of the state's rural population, depend on groundwater for drinking water;

The Legislature establishes that it is the public policy of the state of West Virginia to maintain and protect the state's groundwater so as to support the present and future beneficial uses and further to maintain and protect groundwater at existing quality where the existing quality is better than that required to maintain and protect the present and future beneficial uses. Such existing quality shall be maintained and protected unless it is established that (1) the measures necessary to preserve existing quality are not technically feasible or economically practical and (2) a change in groundwater quality is justified based upon economic or societal objectives. Such a change shall maintain and protect groundwater quality so as to support the present and future beneficial uses of such groundwater.

**DAMS**

**§61-3-47. Dams or obstructions in watercourses; penalty.**

No person may fell any timber and permit the same to remain in any navigable or floatable stream of this state when to do so obstructs the passage of boats, rafts, staves, ties or timber of any kind.

Except as may be provided in chapter twenty or twenty-two of this code, no person may construct or maintain any dam or other structure in any stream or watercourse, which in any way prevents or obstructs the free and easy passage of fish up or down such stream or watercourse, without first providing as a part of such dam or other structure a suitable fish ladder, way or flume, so constructed as to allow fish easily to ascend or descend the same; which ladder, way or flume shall be constructed only upon plans, in a manner, and at a place, satisfactory to the division of natural resources: *Provided*, That if the director of the division of natural resources determines that there is no substantial fish life in such stream or watercourse, or that the installation of a fish ladder, way or flume would not facilitate the free and easy passage of fish up or down a stream or watercourse, or that an industrial development project requires the construction of such dam or other structure and the installation of an operational fish ladder, way or flume is impracticable, the director may, in writing, permit the construction or maintenance of a dam or other structure in a stream or watercourse without providing a suitable fish ladder, way or flume; and in all navigable and floatable streams provisions shall be made in such dam or structure for the passage of boats and other crafts, logs and other materials: *Provided, however*, That this section does not relieve such person from liability for damage to any riparian owner on account of the construction or maintenance of such dam.

Any person who violates any of the provisions of this section is guilty of a misdemeanor, and, upon conviction thereof, shall be fined not exceeding one thousand dollars, or imprisoned in the county jail not exceeding one year, or both fined and imprisoned, and, whether a conviction is had under this section or not, such violation is a nuisance, which may be abated at the suit of any citizen or taxpayer, the county commission of the county, or, as to fish ladders, at the suit of the director of the division of natural resources, and, if the same endangers county roads, the county commission may abate such nuisance peaceably without such suit.

# CASE LAW

**1. Ours v. Grace Property**
**186 W.Va. 296 (1991)**

Where ownership of the land underlying a man-made lake is clear and distinct, the owner of a portion of the lake bed has the exclusive control and use of the water above the portion of the lake bed that he owns. Further, the owner has a right to exclude others, including other adjoining owners of the lake bed, by erecting a fence or other barrier to prohibit others from utilizing the water which overlies his property.

Riparian rights do not stem from the ownership of the lake-bed but from shore ownership. Thus, a riparian owner is one who bases his right to use a lake upon the fact that his land abuts upon the lake. Moreover, the general rule is that riparian rights do not ordinarily attach to artificial bodies of water which necessarily includes a man-made lake. In cases where various parts of the soil under a private lake are owned by different persons, and in which it does not appear that ownership was based on riparian rights, it has generally been held that each owner has exclusive rights to the use of the surface of the water over his land, or at least that the owner of a larger portion can exclude from it the owner of a small portion.

**2. Campbell Brown & Co. v. Elkins**
**141 W.Va. 801 (1956)**

In the United States there are three classes of navigable streams: (l) Tidal streams, that are held navigable in law, whether navigable in fact or not; (2) those that, although non-tidal, are yet navigable in fact for 'boats or lighters,' and susceptible of valuable use for commercial purposes; (3) those streams which, though not navigable for boats or lighters, are floatable, or capable of valuable use in bearing logs or the products of mines, forests and tillage of the country they traverse to mills or markets.

As to a stream, which is navigable because it is valuable to the public as a public highway, the fact that it cannot be used at certain seasons of the year will not destroy the right of navigation or make such stream non-navigable. And a stream navigable in the sense that it is or may be used by the public for transportation and commerce is not rendered non-navigable because of the difficulties attending such navigation. *Gaston v. Mace,* 33 W.Va. 14 (1889)

**3. Morris Asscocs. V. Priddy**
**181 W.Va. 588 (1989)**

Generally, under the rule of reasonable use, the landowner, in dealing with surface water, is entitled to take only such steps as are reasonable, in light of all the circumstances of relative advantage to the actor and disadvantage to the adjoining landowners, as well as social utility.

Ordinarily, the determination of such reasonableness is regarded as involving factual issues to be determined by the trier of fact To the extent that *Jordan v. City of Benwood, 42 WVa. 312, 26 S.E. 266 (1896),* differs, it is overruled.

**4. Snyder v. Callaghan**
**168 W.Va. 265 (1981)**

When the State authorizes the introduction of foreign material into the flow of a natural watercourse which passes through or past the land of a lower riparian owner, such state action directly affects the interest of the lower riparian owner in the watercourse and constitutes an infringement of a property interest for purposes of article 3, section 10 of the state constitution.

Parties -- Persons Who May Sue

An association which has suffered no injury itself, but whose members have been injured as a result of the challenged action, may have standing to sue solely as the representative of its members when: (1) its members would have standing to sue in their own right; (2) the interests it seeks to protect are germane to the organization's purpose; and (3) neither the claim asserted nor the relief requested requires the participation of individual members in the lawsuit. Claimed individual holders of riparian interests and organization composed of similarly situated individuals and other interested persons petitioned for writ of mandamus to compel Director of Department of Natural Resources to afford them hearing on certification of upstream construction activity which involved alteration and filling of riverbed.

**5. Gaston v. Mace**
**33 W.Va. 14 (1889)**

The public in this State have a ***right*** to use as highways not only tidal ***rivers,*** in which the tide ebbs and flows, and fresh water ***rivers*** capable of being profitably used to carry on commerce in their natural state without artificial improvement, but also floatable streams, that is, such streams as are capable of being profitably used by the public in their natural state to float logs or timber or the products of mines or tillage to markets or ruills.

To be a floatable stream so as to entitle the public to use it as a public highway, the stream need not be at all times capable of floating logs, but it will suffice, that, when the water is high, it is thus capable for such a length of time as would make it useful and profitable for the public to so use it as a highway to float logs to mill or market

**6. McCausland v. Jarrell**
**136 W.Va. 569 (1951)**

A natural watercourse consists of bed, bank and water, and a stream in which the water usually flows in a certain direction and by a regular channel with banks or sides is a natural watercourse.

The owner of land through which a natural watercourse passes has a *right* of property in such land to have the water of the stream pass to and from his land in its natural flow.

The obstruction or the diversion of a natural watercourse which restricts the natural flow of the water of the stream and causes such water to overflow, accumulate and stand upon the land through which such watercourse passes is an infringement of a property *right* of the landowner and imports damage to such land.

Equity has jurisdiction to vindicate the *right* of a landowner to the natural flow of the water of a natural watercourse to and from his land by restraining the obstruction of the natural flow of the water or its inadequate diversion from its natural course and by requiring the removal of such obstruction or the cause of such diversion.

Though the evidence is conflicting, a finding of fact by a trial chancellor, based upon an inapplicable principle of law, is, for that reason, clearly wrong and will be set aside on appeal.

**7. Union Sand & Gravel Co. v. Northcott**
**102 W.Va. 519 (1926)**

*Owner of Land Bounded by Ohio River,* Not Otherwise Limited by Deed, Has *Rights* and Title of *Riparian* Owner to Low Water Mark (Const. Art. 2, *§* 1). The owner of land bounded by the Ohio *River,* not otherwise limited by the terms of his deed, has all the *rights* and title of a *riparian* owner down to and including low water mark. (p. 520.)

*Holder of Tax Deed to Island in Ohio River* Held to Have, as Against Stranger or Trespasser, All *Rights* of *Riparian* Owner of Land on Mainland (Const. Art. 2, § *!;Acts* 1872-73, c. 134, §§ 1, 3; 2 Vt. St at Large, p. 317). One who holds a tax deed to an island in the Ohio *River* in this state, originating in a proceeding begun in 1878, has, as against a stranger or trespasser, all the *rights* of a *riparian* owner ofland on the mainland bordering on said *river.* (p. 527.)

*Riparian* Owner oflsland May Maintain Trespass Against Person Entering Between High and Low Water Mark and Removing Sand and Gravel. And such a *riparian* owner of an island may maintain trespass against one who without his permission enters upon such island between high and low water mark and removes sand and gravel therefrom, for the value of such material. (p. 529.)

*Trespasser, Entering in Good Faith, Believing He Had* ***Right*** to Take Gravel Between High and Low Water Mark, is Liable for Actual Value Thereof. But if the defendant enters with permission of the federal government, and in good faith, believing he has the ***right*** to take such material at the place or places of entry, he will be liable to the owner only for the actual value thereof at the place from which it was removed. (p. 529.)

*"Low-Water Mark:' of Ohio **River*** is Point to Which Water Recedes at Lowest Stage. Low water mark within the intendment of our law, as related to the Ohio ***River,*** is the point to which the water recedes at its lowest stage. (p. 528.)

*Low Water Mark of Ohio **River*** is Not in Legal Contemplation Changed by Locks and Darns Built to Improve Navigation. And such low water mark will not in contemplation of law be changed by locks and darns built by the state or federal government in the improvement of navigation or in aid of commerce upon said ***river.*** (p. 529.)

**8. Roberts v. Martin**
**72 W.Va. 92 (1913)**

*Natural Water Course--Diversion.* A diversion of a natural watercourse, though without actual damage to a lower riparian owner, is an infringement of a legal right and imports damage. (p. 94).

*Riparian Rights--Nature and Extent.* The right of a riparian proprietor to have the water of the stream pass his land in its natural flow is a right annexed to the soil and exists as parcel of the land. (p. 94).

The right of a riparian owner to the natural flow of the stream is not dependent upon its value to him or the use which he makes of it. (p. 95).

The right of a lower riparian owner to the natural flow of the stream is subject only to a reasonable use of the water by the upper riparian owners as it runs through their lands before reaching his. (p. 95).

No legal right exists in a riparian owner to divert water of the stream for use beyond his riparian land, and any such diversion and use is an infringement of the rights of l0wer riparian proprietors who are thereby deprived of the flow. (p. 96).

If the diversion of water from riparian land for use elsewhere is not so inconsiderable, when the amount diverted is viewed relatively with the stream at its lowest stage as to be excluded under the maxim *de minimis non curat lex*, a lower riparian owner may have redress against the diversion. (p. 98).

*Natural Water Course--Diversion.* A stream begins at its source, when it comes to the surface, and a diversion of it at the spring head is just as much a diversion as if the water had been taken lower dovm. (p. 99).

Equity has jurisdiction to vindicate the right of a riparian owner to the natural flow of the stream by restraining an unlawful diversion of the water from its natural course. (p. 99).

**9. Taylor v. Chesapeake & O.R. Co.**
**84 W.Va. 442 (1919)**

*Defendant not Negligent not Liable for Flood Damages.* In the absence of some initial or intervening act of negligence on his part contributing thereto one is not liable for damages arising from an act of God, such as an unprecedented flood of ***waters*** of great force and volume caused by a cloud burst at the head ***waters*** of a creek or river. (p. 444).

***Riparian*** Owner Has ***Right*** to Unobstructed Flow of Stream. A ***riparian*** proprietor has as a general rule the ***right*** to have the ***waters*** of a stream or ***water*** course pass his land in its natural flow unobstructed and to render anyone violating or interfering with such ***right*** liable to him in damages sustained thereby. (p. 444).

***Riparian*** Owner May Construct Barriers to Keep Flood ***Waters*** in Stream. The only limitation on such ***right*** of a ***riparian*** owner is that any other ***riparian*** owner may erect barriers or dykes on his own land on the banks of such ***water*** course or on the interior of his land for the purpose of confining flood ***waters*** within the natural banks of the stream although such action may result in injury to another ***riparian*** owner. (p. 444).

But such limitation upon the general rule will not justify a ***riparian*** owner or other person in erecting or placing within the channel or banks of such stream any obstruction or barrier which will interfere with the free flow of the ***waters*** therein or cause the same to be backed up and to flood the land or property of a ***riparian*** owner along such stream. (p. 444).

**10. In Re Flood Litig.**
**216 W.Va. 534 (2004)**

"Generally, under the rule of reasonable use, the landowner, in dealing with surface ***water,*** is entitled to take only such steps as are reasonable, in light of all title circumstances of relative advantage to the actor and disadvantage to the adjoining landowners, as well as social utility. Ordinarily, the determination of such reasonableness is regarded as involving factual issues to be determined by the trier of fact" Syllabus Point 2, in part, *Morris Associates, Inc. v. Priddy,* 181 W.Va. 588,383 S.E.2d 770 (1989).

In determining whether a landowner acted reasonably in dealing with surface ***water*** pursuant to the "reasonable use" rule set forth in Syllabus Point 2 of *Morris Associates, Inc. v. Priddy,* 181 W.Va. 588, 383 S.E.2d 770 (1989), a jury generally should consider all relevant circumstances, including such factors as amount of harm caused, foreseeability of harm on the part of the landowner making alteration in the flow of surface ***waters,*** the purpose or motive with which the landowner acted, etc.

"In the matters of negligence, liability attaches to a wrongdoer ... because of a breach of duty which results in an injury to others." Syllabus Point 2, in part, *Sewell v. Gregory,* 179 W.Va. 585, 371 S.E.2d 82 (1988).

"The ultimate test of the existence of a duty to use care is found in the foreseeability that harm may result if it is not exercised. The test is, would the ordinary man [or woman in the defendant's position, knowing what he [or she]knew or should have known, anticipate that harm of the general nature of that suffered was likely to result?" Syllabus Point 3, *Sewell v. Gregory,* 179 W.Va. 585, 371 S.E.2d 82 (1988).

"The right of a ***riparian*** proprietor to have the ***water*** of the stream pass his [or her]land in its natural flow is a right annexed to the soil and exists as parcel of the land." Syllabus Point 2, *Roberts v. Martin,* 72 W.Va. 92, 77 S.E. 535 (1913).

"A diversion of a natural ***water*** course, though without actual damage to a lower ***riparian*** owner, is an infringement of a legal right and imports damage." Syllabus Point 1, *Roberts v. Martin,* 72 W.Va. 92, 77 S.E. 535 (1913).

"The right of a ***riparian*** owner to the natural flow of the stream is not dependent upon its value to him [or her] or the use which he [or she] makes of it." Syllabus Point 3, *Roberts v. Martin,* 72 W.Va. 92, 77 S.E. 535 (1913).

"The obstruction or the diversion of a natural watercourse which restricts the natural flow of the ***water*** of the stream and causes such ***water*** to overflow, accumulate and stand upon the land through which such watercourse passes is an infringement of a property right of the landowner and imports damage to such land." Syllabus Point 3, *McCausland v. Jarrell,* 136
W.Va. 569, 68 S.E.2d 729 (1951).

Compliance of a landowner in the extraction and removal of natural resources on his or her property with the appropriate state and federal regulations may be evidence in any cause of action against the landowner for negligence or unreasonable use of the landowner's land if the injury complained of was the sort the regulations were intended to prevent. Such compliance, however, does not give rise to a presumption that the landowner acted reasonably or without negligence or liability to others in his or her extraction and removal activities.

Where a rainfall event of an unusual and unforeseeable nature combines with a defendant's actionable conduct to cause flood damage, and where it is shown that a discrete portion of the damage complained of was unforeseeable and solely the result of such event and in no way fairly attributable to the defendant's conduct, the defendant is liable only for the damages that are fairly attributable to the defendant's conduct. However, in such a case, a defendant has the burden to show by clear and convincing evidence the character and measure of damages that are not the defendant's responsibility; and if the defendant cannot do so, then the defendant bears the entire liability. To the extent that our prior cases such as *State ex ref. Summers v. Sims,* 142 W.Va. 640, 97 S.E.2d 295 (1957); *Riddle v. Baltimore & O. R. Co.,*137 W.Va. 733, 73 S.E.2d 793 (1952), and others similarly situated held differently, they are hereby modified.

**11. International Shoe Co. v. Heatwole**
**126 W.Va. 888; 30 S.E.2d 537 (1944)**

A private individual has no right of action for a public nuisance or wrong unless he has suffered some special and peculiar injury, differing, not simply in degree, but in character, from that affecting the general public.

# Appendix E

HUC-10 and 12 Watershed Main Stem Streams

# HUC Watershed Main Stem Streams

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| **Big Sandy** | | | | | |
| | Whites Creek-Big Sandy River | 146 | Bear Creek-Big Sandy River | 39 | Wayne |
| | Whites Creek-Big Sandy River | 146 | Chadwick Creek-Big Sandy River | 26 | Wayne |
| | Whites Creek-Big Sandy River | 146 | Durbin Creek-Big Sandy River | 17 | Wayne |
| | Whites Creek-Big Sandy River | 146 | Hurricane Creek-Big Sandy River | 27 | Wayne |
| | Whites Creek-Big Sandy River | 146 | Tabor Creek-Big Sandy River | 20 | Wayne |
| | Whites Creek-Big Sandy River | 146 | Whites Creek | 16 | Wayne |
| **Cacapon** | | | | | |
| | Cacapon River | 297 | Bloomery Run-Cacapon River | 37 | Hampshire |
| | Cacapon River | 297 | Capon Springs Run-Cacapon River | 30 | Hardy |
| | Cacapon River | 297 | Connor Hollow-Cacapon River | 33 | Morgan |
| | Cacapon River | 297 | Critton Run-Cacapon River | 28 | Morgan |
| | Cacapon River | 297 | Dillons Run | 20 | Hampshire |
| | Cacapon River | 297 | Mill Branch-Cacapon River | 57 | Hampshire |
| | Cacapon River | 297 | Trout Run | 47 | Hardy |
| | Cacapon River | 297 | Waites Run-Cacapon River | 45 | Hardy |
| | Little Cacapon River | 109 | Crooked Run-Little Cacapon River | 19 | Hampshire |
| | Little Cacapon River | 109 | Dug Hill Run-Little Cacapon River | 23 | Hampshire |
| | Little Cacapon River | 109 | North Fork-Little Cacapon River | 25 | Hampshire |
| | Little Cacapon River | 109 | Shawan Run-Little Cacapon River | 25 | Hampshire |
| | Little Cacapon River | 109 | Three Churches Run-Little Cacapon River | 22 | Hampshire |
| | Long Hollow Run-Potomac River | 92 | Purslane Run-Potomac River | 25 | Morgan |
| | Long Hollow Run-Potomac River | 92 | Rockwell Run-Potomac River | 42 | Morgan |
| | Long Hollow Run-Potomac River | 92 | Willett Run-Potomac River | 26 | Morgan |
| | Lost River | 178 | Baker Run | 26 | Hardy |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Lost River | 178 | Cullers Run-Lost River | 23 | Hardy |
| | Lost River | 178 | Kimsey Run-Lost River | 57 | Hardy |
| | Lost River | 178 | Three Springs Run-Lost River | 28 | Hardy |
| | Lost River | 178 | Upper Cove Run-Lost River | 45 | Hardy |
| | North River | 206 | Crooked Run-North River | 29 | Hampshire |
| | North River | 206 | Hiett Run-North River | 22 | Hampshire |
| | North River | 206 | Meadow Run-North River | 58 | Hardy |
| | North River | 206 | Pine Draft Run-North River | 23 | Hampshire |
| | North River | 206 | Sperry Run-North River | 39 | Hardy |
| | North River | 206 | Tear Coat Creek | 36 | Hampshire |
| **Cheat** | | | | | |
| | Big Sandy Creek | 208 | Beaver Creek-Little Sandy Creek | 53 | Preston |
| | Big Sandy Creek | 208 | Fike Run-Little Sandy Creek | 28 | Preston |
| | Big Sandy Creek | 208 | Lower Big Sandy Creek | 40 | Preston |
| | Big Sandy Creek | 208 | Middle Big Sandy Creek | 32 | Preston |
| | Big Sandy Creek | 208 | Upper Big Sandy Creek | 54 | Preston |
| | Blackwater River | 139 | Lower Blackwater River | 38 | Grant |
| | Blackwater River | 139 | Middle Blackwater River | 47 | Grant |
| | Blackwater River | 139 | Upper Blackwater River | 55 | Grant |
| | Dry Fork | 297 | Big Run-Dry Fork | 20 | Randolph |
| | Dry Fork | 297 | Dry Fork-Black Fork | 31 | Tucker |
| | Dry Fork | 297 | Gandy Creek-Dry Fork | 55 | Randolph |
| | Dry Fork | 297 | Horsecamp Run-Dry Fork | 40 | Randolph |
| | Dry Fork | 297 | Laurel Fork | 60 | Randolph |
| | Dry Fork | 297 | Otter Creek | 29 | Randolph |
| | Dry Fork | 297 | Red Creek | 61 | Randolph |
| | Glady Fork | 64 | Headwaters Glady Fork | 37 | Randolph |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Glady Fork | 64 | Outlet Glady Fork | 27 | Randolph |
| | Lower Cheat River | 278 | Bull Run-Cheat River | 25 | Preston |
| | Lower Cheat River | 278 | Cheat Lake-Cheat River | 61 | Preston |
| | Lower Cheat River | 278 | Greens Run-Cheat River | 33 | Preston |
| | Lower Cheat River | 278 | Muddy Creek | 34 | Preston |
| | Lower Cheat River | 278 | Pringle Run-Cheat River | 44 | Preston |
| | Lower Cheat River | 278 | Roaring Creek-Cheat River | 47 | Preston |
| | Lower Cheat River | 278 | Saltlick Creek | 35 | Preston |
| | Shavers Fork | 215 | First Fork-Shavers Fork | 56 | Randolph |
| | Shavers Fork | 215 | Haddix Run-Shavers Fork | 56 | Randolph |
| | Shavers Fork | 215 | Red Run-Shavers Fork | 58 | Randolph |
| | Shavers Fork | 215 | Taylor Run-Shavers Fork | 44 | Randolph |
| | Upper Cheat River | 221 | Buffalo Creek-Cheat River | 35 | Tucker |
| | Upper Cheat River | 221 | Clover Run | 30 | Randolph |
| | Upper Cheat River | 221 | Horseshoe Run | 55 | Tucker |
| | Upper Cheat River | 221 | Licking Creek-Cheat River | 48 | Barbour |
| | Upper Cheat River | 221 | Minear Run-Cheat River | 33 | Tucker |
| | Upper Cheat River | 221 | Wolf Creek | 20 | Preston |
| **Coal** | | | | | |
| | Clear Fork | 63 | Headwaters Clear Fork | 36 | Fayette |
| | Clear Fork | 63 | Outlet Clear Fork | 27 | Fayette |
| | Coal River | 282 | Brier Creek | 16 | Boone |
| | Coal River | 282 | Browns Creek-Coal River | 22 | Putnam |
| | Coal River | 282 | Drawdy Creek-Big Coal River | 47 | Boone |
| | Coal River | 282 | Fork Creek-Big Coal River | 34 | Boone |
| | Coal River | 282 | Joes Creek-Big Coal River | 54 | Boone |
| | Coal River | 282 | Laurel Creek | 49 | Boone |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Coal River | 282 | Smith Creek-Coal River | 40 | Kanawha |
| | Coal River | 282 | White Oak Creek | 19 | Boone |
| | Little Coal River | 119 | Big Horse Creek | 29 | Boone |
| | Little Coal River | 119 | Lower Little Coal River | 24 | Boone |
| | Little Coal River | 119 | Upper Little Coal River | 66 | Boone |
| | Marsh Fork | 163 | Lower Marsh Fork | 39 | Boone |
| | Marsh Fork | 163 | Middle Marsh Fork | 42 | Boone |
| | Marsh Fork | 163 | Stephens Lake | 25 | Raleigh |
| | Marsh Fork | 163 | Upper Marsh Fork | 57 | Raleigh |
| | Pond Fork | 138 | Lower Pond Fork | 35 | Boone |
| | Pond Fork | 138 | Middle Pond Fork | 29 | Boone |
| | Pond Fork | 138 | Upper Pond Fork | 31 | Boone |
| | Pond Fork | 138 | West Fork | 43 | Boone |
| | Spruce Fork | 126 | Headwaters Spruce Fork | 51 | Boone |
| | Spruce Fork | 126 | Outlet Spruce Fork | 44 | Boone |
| | Spruce Fork | 126 | Spruce Laurel Fork | 32 | Boone |
| **Potomac Direct Drains** | | | | | |
| | Back Creek | 274 | Babbs Run | 27 | Berkeley |
| | Back Creek | 274 | Brush Creek-Back Creek | 29 | Berkeley |
| | Back Creek | 274 | Elk Branch-Back Creek | 35 | Berkeley |
| | Back Creek | 274 | Isaacs Creek-Back Creek | 32 | Hampshire |
| | Back Creek | 274 | Mine Spring Run-Back Creek | 39 | Hampshire |
| | Back Creek | 274 | Outlet Back Creek | 32 | Berkeley |
| | Back Creek | 274 | Tilhance Creek | 20 | Berkeley |
| | Back Creek | 274 | Warm Springs Hollow-Back Creek | 17 | Berkeley |
| | Little Tonoloway Creek-Potomac River | 112 | Cherry Run-Potomac River | 28 | Berkeley |
| | Little Tonoloway Creek-Potomac River | 112 | Ditch Run-Potomac River | 23 | Morgan |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Little Tonoloway Creek-Potomac River | 112 | Sir Johns Run-Potomac River | 21 | Morgan |
| | Little Tonoloway Creek-Potomac River | 112 | Warm Spring Run | 15 | Morgan |
| | Opequon Creek | 344 | Evans Run-Opequon Creek | 34 | Berkeley |
| | Opequon Creek | 344 | Hoke Run-Opequon Creek | 36 | Berkeley |
| | Opequon Creek | 344 | Middle Creek-Opequon Creek | 41 | Berkeley |
| | Opequon Creek | 344 | Mill Creek | 33 | Berkeley |
| | Opequon Creek | 344 | Turkey Run-Opequon Creek | 56 | Berkeley |
| | Opequon Creek | 344 | Tuscarora Creek | 26 | Berkeley |
| | Rocky Marsh Run-Potomac River | 216 | Camp Spring Run-Potomac River | 48 | Berkeley |
| | Rocky Marsh Run-Potomac River | 216 | Elks Run | 19 | Jefferson |
| | Rocky Marsh Run-Potomac River | 216 | Harlan Run | 17 | Berkeley |
| | Rocky Marsh Run-Potomac River | 216 | Harpers Ferry-Potomac River | 21 | Jefferson |
| | Rocky Marsh Run-Potomac River | 216 | Rattlesnake Run-Potomac River | 56 | Berkeley |
| | Rocky Marsh Run-Potomac River | 216 | Rockymarsh Run | 16 | Berkeley |
| | Sleepy Creek | 145 | Lower Sleepy Creek | 20 | Berkeley |
| | Sleepy Creek | 145 | Meadow Branch | 20 | Berkeley |
| | Sleepy Creek | 145 | Middle Fork Sleepy Creek | 35 | Berkeley |
| | Sleepy Creek | 145 | Middle Sleepy Creek | 28 | Berkeley |
| | Sleepy Creek | 145 | Upper Sleepy Creek | 42 | Morgan |
| **Elk** | | | | | |
| | Big Sandy Creek | 134 | Lefthand Creek | 30 | Kanawha |
| | Big Sandy Creek | 134 | Lefthand Run | 16 | Roane |
| | Big Sandy Creek | 134 | Lower Big Sandy Creek | 31 | Clay |
| | Big Sandy Creek | 134 | Middle Big Sandy Creek | 19 | Clay |
| | Big Sandy Creek | 134 | Right Fork Big Sandy Creek | 19 | Clay |
| | Big Sandy Creek | 134 | Upper Big Sandy Creek | 19 | Calhoun |
| | Birch River | 142 | Little Birch River | 40 | Nicholas |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Birch River | 142 | Lower Birch River | 25 | Nicholas |
| | Birch River | 142 | Middle Birch River | 29 | Nicholas |
| | Birch River | 142 | Upper Birch River | 48 | Nicholas |
| | Blue Creek | 80 | Headwaters Blue Creek | 50 | Clay |
| | Blue Creek | 80 | Outlet Blue Creek | 30 | Kanawha |
| | Buffalo Creek | 113 | Headwaters Buffalo Creek | 39 | Nicholas |
| | Buffalo Creek | 113 | Lilly Fork | 29 | Nicholas |
| | Buffalo Creek | 113 | Outlet Buffalo Creek | 45 | Nicholas |
| | Holly River | 148 | Headwaters Holly River | 55 | Randolph |
| | Holly River | 148 | Headwaters Right Fork Holly River | 42 | Webster |
| | Holly River | 148 | Outlet Holly River | 30 | Webster |
| | Holly River | 148 | Outlet Right Fork Holly River | 21 | Webster |
| | Laurel Creek | 67 | Headwaters Laurel Creek | 30 | Webster |
| | Laurel Creek | 67 | Outlet Laurel Creek | 37 | Webster |
| | Lower Elk River | 328 | Coopers Creek-Elk River | 33 | Kanawha |
| | Lower Elk River | 328 | Falling Rock Creek | 25 | Clay |
| | Lower Elk River | 328 | Laurel Creek | 19 | Clay |
| | Lower Elk River | 328 | Leatherwood Creek-Elk River | 48 | Nicholas |
| | Lower Elk River | 328 | Little Sandy Creek | 51 | Kanawha |
| | Lower Elk River | 328 | Mill Creek-Elk River | 34 | Kanawha |
| | Lower Elk River | 328 | Morris Creek-Elk River | 39 | Clay |
| | Lower Elk River | 328 | Porter Creek-Elk River | 34 | Clay |
| | Lower Elk River | 328 | Sycamore Creek-Elk River | 45 | Nicholas |
| | Middle Elk River | 280 | Big Otter Creek-Elk River | 59 | Nicholas |
| | Middle Elk River | 280 | Big Run-Elk River | 28 | Webster |
| | Middle Elk River | 280 | Duck Creek-Elk River | 33 | Clay |
| | Middle Elk River | 280 | Laurel Run-Elk River | 24 | Clay |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Middle Elk River | 280 | Little Otter Creek-Elk River | 54 | Braxton |
| | Middle Elk River | 280 | Lower Sutton Lake-Elk River | 35 | Braxton |
| | Middle Elk River | 280 | Strange Creek | 28 | Nicholas |
| | Middle Elk River | 280 | Upper Sutton Lake-Elk River | 19 | Webster |
| | Upper Elk River | 241 | Abb Run-Elk River | 32 | Randolph |
| | Upper Elk River | 241 | Back Fork Elk River | 47 | Randolph |
| | Upper Elk River | 241 | Bergoo Creek-Elk River | 52 | Randolph |
| | Upper Elk River | 241 | Dry Fork-Elk River | 33 | Randolph |
| | Upper Elk River | 241 | Old Field Fork | 54 | Pocahontas |
| | Upper Elk River | 241 | Sugar Creek | 23 | Randolph |
| **Gauley** | | | | | |
| | Cranberry River | 97 | Headwaters Cranberry River | 47 | Webster |
| | Cranberry River | 97 | Outlet Cranberry River | 50 | Nicholas |
| | Headwaters Gauley River | 135 | Big Laurel Creek-Gauley River | 57 | Nicholas |
| | Headwaters Gauley River | 135 | Hughes Run-Gauley River | 36 | Randolph |
| | Headwaters Gauley River | 135 | Turkey Creek-Gauley River | 42 | Webster |
| | Hominy Creek | 103 | Headwaters Hominy Creek | 53 | Nicholas |
| | Hominy Creek | 103 | Outlet Hominy Creek | 50 | Nicholas |
| | Laurel Creek-Cherry River | 166 | Cherry River | 38 | Nicholas |
| | Laurel Creek-Cherry River | 166 | Laurel Creek | 42 | Nicholas |
| | Laurel Creek-Cherry River | 166 | North Fork Cherry River | 37 | Nicholas |
| | Laurel Creek-Cherry River | 166 | South Fork Cherry River | 48 | Nicholas |
| | Meadow River | 365 | Anglins Creek | 33 | Nicholas |
| | Meadow River | 365 | Big Clear Creek | 36 | Greenbrier |
| | Meadow River | 365 | Brackens Creek-Meadow River | 33 | Nicholas |
| | Meadow River | 365 | Glade Creek-Meadow River | 43 | Nicholas |
| | Meadow River | 365 | Little Clear Creek | 33 | Greenbrier |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Meadow River | 365 | Meadow Creek-Meadow River | 51 | Nicholas |
| | Meadow River | 365 | Mill Creek-Meadow River | 40 | Greenbrier |
| | Meadow River | 365 | Otter Creek-Meadow River | 56 | Fayette |
| | Meadow River | 365 | Sewell Creek | 40 | Fayette |
| | Outlet Gauley River | 339 | Big Beaver Creek | 39 | Nicholas |
| | Outlet Gauley River | 339 | Headwaters Muddlety Creek | 36 | Nicholas |
| | Outlet Gauley River | 339 | Headwaters Peters Creek | 30 | Nicholas |
| | Outlet Gauley River | 339 | Laurel Creek-Gauley River | 41 | Nicholas |
| | Outlet Gauley River | 339 | Outlet Muddlety Creek | 31 | Nicholas |
| | Outlet Gauley River | 339 | Outlet Peters Creek | 23 | Nicholas |
| | Outlet Gauley River | 339 | Panther Creek-Gauley River | 47 | Nicholas |
| | Outlet Gauley River | 339 | Rich Creek-Gauley River | 41 | Nicholas |
| | Outlet Gauley River | 339 | Summersville Lake-Gauley River | 52 | Nicholas |
| | Twentymile Creek | 86 | Headwaters Twentymile Creek | 33 | Nicholas |
| | Twentymile Creek | 86 | Outlet Twentymile Creek | 54 | Nicholas |
| | Williams River | 129 | Lower Williams River | 25 | Webster |
| | Williams River | 129 | Middle Fork Williams River | 26 | Webster |
| | Williams River | 129 | Middle Williams River | 38 | Randolph |
| | Williams River | 129 | Upper Williams River | 40 | Pocahontas |
| **Greenbrier** | | | | | |
| | Anthony Creek | 148 | Lower Anthony Creek | 48 | Greenbrier |
| | Anthony Creek | 148 | Meadow Creek | 24 | Greenbrier |
| | Anthony Creek | 148 | Middle Anthony Creek | 21 | Greenbrier |
| | Anthony Creek | 148 | North Fork Anthony Creek | 22 | Greenbrier |
| | Anthony Creek | 148 | Upper Anthony Creek | 33 | Greenbrier |
| | Deer Creek-Greenbrier River | 247 | Brush Run-Greenbrier River | 48 | Pocahontas |
| | Deer Creek-Greenbrier River | 247 | Headwaters Deer Creek | 31 | Pocahontas |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Deer Creek-Greenbrier River | 247 | Headwaters East Fork Greenbrier River | 39 | Randolph |
| | Deer Creek-Greenbrier River | 247 | Little River | 20 | Randolph |
| | Deer Creek-Greenbrier River | 247 | Outlet Deer Creek | 36 | Pocahontas |
| | Deer Creek-Greenbrier River | 247 | Outlet East Fork Greenbrier River | 30 | Pocahontas |
| | Deer Creek-Greenbrier River | 247 | West Fork Greenbrier River | 44 | Randolph |
| | Howard Creek | 91 | Dry Creek | 23 | Greenbrier |
| | Howard Creek | 91 | Headwaters Howard Creek | 27 | Greenbrier |
| | Howard Creek | 91 | Outlet Howard Creek | 42 | Greenbrier |
| | Knapp Creek | 110 | Douthat Creek | 30 | Greenbrier |
| | Knapp Creek | 110 | Headwaters Knapp Creek | 48 | Pocahontas |
| | Knapp Creek | 110 | Outlet Knapp Creek | 32 | Pocahontas |
| | Second Creek | 117 | Lower Second Creek | 43 | Greenbrier |
| | Second Creek | 117 | Middle Second Creek | 54 | Greenbrier |
| | Second Creek | 117 | Upper Second Creek | 19 | Monroe |
| | Sinking Creek-Muddy Creek | 155 | Kitchen Creek | 25 | Summers |
| | Sinking Creek-Muddy Creek | 155 | Mill Creek | 18 | Greenbrier |
| | Sinking Creek-Muddy Creek | 155 | Muddy Creek | 55 | Summers |
| | Sinking Creek-Muddy Creek | 155 | Sinking Creek | 58 | Greenbrier |
| | Sitlington Creek-Greenbrier River | 338 | Clover Creek-Greenbrier River | 39 | Pocahontas |
| | Sitlington Creek-Greenbrier River | 338 | Locust Creek-Greenbrier River | 57 | Greenbrier |
| | Sitlington Creek-Greenbrier River | 338 | Sitlington Creek | 50 | Pocahontas |
| | Sitlington Creek-Greenbrier River | 338 | Slabcamp Run-Greenbrier River | 41 | Greenbrier |
| | Sitlington Creek-Greenbrier River | 338 | Stamping Creek-Greenbrier River | 56 | Pocahontas |
| | Sitlington Creek-Greenbrier River | 338 | Stony Creek | 23 | Pocahontas |
| | Sitlington Creek-Greenbrier River | 338 | Swago Creek-Greenbrier River | 25 | Pocahontas |
| | Sitlington Creek-Greenbrier River | 338 | Thorny Creek-Greenbrier River | 47 | Pocahontas |
| | Spring Creek | 121 | Headwaters Spring Creek | 35 | Greenbrier |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Spring Creek | 121 | Outlet Spring Creek | 86 | Greenbrier |
| | Wolf Creek-Greenbrier River | 318 | Big Creek-Greenbrier River | 46 | Summers |
| | Wolf Creek-Greenbrier River | 318 | Boulder Run-Greenbrier River | 30 | Greenbrier |
| | Wolf Creek-Greenbrier River | 318 | Griffith Creek-Greenbrier River | 23 | Summers |
| | Wolf Creek-Greenbrier River | 318 | Hungard Creek-Greenbrier River | 34 | Summers |
| | Wolf Creek-Greenbrier River | 318 | Laurel Run-Greenbrier River | 34 | Greenbrier |
| | Wolf Creek-Greenbrier River | 318 | Milligan Creek-Greenbrier River | 95 | Greenbrier |
| | Wolf Creek-Greenbrier River | 318 | Stony Creek-Greenbrier River | 17 | Summers |
| | Wolf Creek-Greenbrier River | 318 | Wolf Creek | 38 | Greenbrier |
| **Little Kanawha** | | | | | |
| | Cedar Creek | 81 | Headwaters Cedar Creek | 48 | Gilmer |
| | Cedar Creek | 81 | Outlet Cedar Creek | 34 | Gilmer |
| | Goose Creek-Hughes River | 76 | Headwaters Goose Creek | 23 | Ritchie |
| | Goose Creek-Hughes River | 76 | Hughes River | 19 | Ritchie |
| | Goose Creek-Hughes River | 76 | Outlet Goose Creek | 34 | Ritchie |
| | Leading Creek | 146 | Cove Creek | 32 | Lewis |
| | Leading Creek | 146 | Fink Creek | 43 | Lewis |
| | Leading Creek | 146 | Headwaters Leading Creek | 30 | Lewis |
| | Leading Creek | 146 | Horn Creek | 20 | Ritchie |
| | Leading Creek | 146 | Outlet Leading Creek | 21 | Gilmer |
| | Left Fork Reedy Creek-Reedy Creek | 133 | Left Fork Reedy Creek | 62 | Jackson |
| | Left Fork Reedy Creek-Reedy Creek | 133 | Reedy Creek | 29 | Roane |
| | Left Fork Reedy Creek-Reedy Creek | 133 | Right Reedy Creek | 43 | Jackson |
| | Lower Little Kanawha River | 207 | Neal Run-Little Kanawha River | 44 | Wood |
| | Lower Little Kanawha River | 207 | Slate Creek | 21 | Wood |
| | Lower Little Kanawha River | 207 | Stillwell Creek | 24 | Wood |
| | Lower Little Kanawha River | 207 | Tygart Creek | 51 | Wood |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Lower Little Kanawha River | 207 | Walker Creek | 32 | Ritchie |
| | Lower Little Kanawha River | 207 | Worthington Creek | 35 | Wood |
| | Middle Little Kanawha River | 300 | Cole Run-Leading Creek | 17 | Ritchie |
| | Middle Little Kanawha River | 300 | Laurel Creek-Little Kanawha River | 27 | Calhoun |
| | Middle Little Kanawha River | 300 | Lee Creek-Little Kanawha River | 48 | Wirt |
| | Middle Little Kanawha River | 300 | Pine Creek-Little Kanawha River | 39 | Calhoun |
| | Middle Little Kanawha River | 300 | Sinking Creek-Little Kanawha River | 34 | Gilmer |
| | Middle Little Kanawha River | 300 | Standingstone Creek | 21 | Ritchie |
| | Middle Little Kanawha River | 300 | Straight Creek-Little Kanawha River | 43 | Ritchie |
| | Middle Little Kanawha River | 300 | Tanner Creek | 37 | Ritchie |
| | Middle Little Kanawha River | 300 | Tucker Creek | 19 | Wood |
| | Middle Little Kanawha River | 300 | Yellow Creek | 15 | Ritchie |
| | North Fork Hughes River | 202 | Addis Run-North Fork Hughes River | 24 | Ritchie |
| | North Fork Hughes River | 202 | Bonds Creek | 44 | Ritchie |
| | North Fork Hughes River | 202 | Bunnell Run-North Fork Hughes River | 29 | Ritchie |
| | North Fork Hughes River | 202 | Cabin Run-North Fork Hughes River | 40 | Ritchie |
| | North Fork Hughes River | 202 | Devilhole Creek-North Fork Hughes River | 23 | Ritchie |
| | North Fork Hughes River | 202 | Gillespie Run-North Fork Hughes River | 17 | Ritchie |
| | North Fork Hughes River | 202 | Stewart Run-North Fork Hughes River | 27 | Ritchie |
| | Right Fork Spring Creek-Spring Creek | 90 | Right Fork Spring Creek | 39 | Roane |
| | Right Fork Spring Creek-Spring Creek | 90 | Spring Creek | 50 | Roane |
| | Right Fork Steer Creek-Steer Creek | 184 | Crooked Fork | 16 | Gilmer |
| | Right Fork Steer Creek-Steer Creek | 184 | Headwaters Right Fork Steer Creek | 31 | Braxton |
| | Right Fork Steer Creek-Steer Creek | 184 | Left Fork Steer Creek | 50 | Gilmer |
| | Right Fork Steer Creek-Steer Creek | 184 | Outlet Right Fork Steer Creek | 40 | Calhoun |
| | Right Fork Steer Creek-Steer Creek | 184 | Steer Creek | 47 | Calhoun |
| | Sand Fork | 80 | Headwaters Sand Fork | 39 | Lewis |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Sand Fork | 80 | Indian Fork | 24 | Lewis |
| | Sand Fork | 80 | Outlet Sand Fork | 17 | Lewis |
| | South Fork Hughes River | 250 | Bone Creek | 19 | Ritchie |
| | South Fork Hughes River | 250 | Grass Run-South Fork Hughes River | 34 | Ritchie |
| | South Fork Hughes River | 250 | Indian Creek | 34 | Ritchie |
| | South Fork Hughes River | 250 | Leatherbark Creek | 18 | Ritchie |
| | South Fork Hughes River | 250 | Macfarlan Creek-South Fork Hughes River | 44 | Ritchie |
| | South Fork Hughes River | 250 | Middle Fork | 23 | Ritchie |
| | South Fork Hughes River | 250 | Slab Creek-South Fork Hughes River | 26 | Ritchie |
| | South Fork Hughes River | 250 | Spruce Creek | 24 | Ritchie |
| | South Fork Hughes River | 250 | White Oak Creek-South Fork Hughes River | 28 | Ritchie |
| | Upper Little Kanawha River | 312 | Burnsville Lake-Little Kanawha River | 36 | Lewis |
| | Upper Little Kanawha River | 312 | Copen Run-Little Kanawha River | 34 | Gilmer |
| | Upper Little Kanawha River | 312 | Falls Run-Little Kanawha River | 33 | Lewis |
| | Upper Little Kanawha River | 312 | Glady Creek-Little Kanawha River | 61 | Lewis |
| | Upper Little Kanawha River | 312 | Oil Creek | 32 | Lewis |
| | Upper Little Kanawha River | 312 | Right Fork Little Kanawha River | 38 | Lewis |
| | Upper Little Kanawha River | 312 | Saltlick Creek | 49 | Braxton |
| | Upper Little Kanawha River | 312 | Stewart Creek-Little Kanawha River | 31 | Gilmer |
| | West Fork Little Kanawha River | 246 | Beech Fork | 25 | Calhoun |
| | West Fork Little Kanawha River | 246 | Headwaters Henry Fork | 24 | Calhoun |
| | West Fork Little Kanawha River | 246 | Left Fork West Fork Little Kanawha River | 29 | Calhoun |
| | West Fork Little Kanawha River | 246 | Lower West Fork Little Kanawha River | 42 | Calhoun |
| | West Fork Little Kanawha River | 246 | Middle West Fork Little Kanawha River | 46 | Calhoun |
| | West Fork Little Kanawha River | 246 | Outlet Henry Fork | 43 | Calhoun |
| | West Fork Little Kanawha River | 246 | Upper West Fork Little Kanawha River | 39 | Calhoun |
| **Middle Ohio North** | | | | | |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Fishing Creek | 218 | Headwaters South Fork Fishing Creek | 40 | Marion |
| | Fishing Creek | 218 | Little Fishing Creek | 41 | Wetzel |
| | Fishing Creek | 218 | Lower Fishing Creek | 31 | Tyler |
| | Fishing Creek | 218 | North Fork Fishing Creek | 42 | Marion |
| | Fishing Creek | 218 | Outlet South Fork Fishing Creek | 31 | Tyler |
| | Fishing Creek | 218 | Upper Fishing Creek | 32 | Tyler |
| | French Creek-Ohio River | 318 | Bull Creek-Ohio River | 43 | Ritchie |
| | French Creek-Ohio River | 318 | Cow Creek-Ohio River | 48 | Ritchie |
| | French Creek-Ohio River | 318 | French Creek | 27 | Ritchie |
| | French Creek-Ohio River | 318 | Haynes Run-Ohio River | 30 | Marshall |
| | French Creek-Ohio River | 318 | Leith Run-Ohio River | 27 | Pleasants |
| | French Creek-Ohio River | 318 | Mill Creek-Ohio River | 43 | Pleasants |
| | French Creek-Ohio River | 318 | Patton Run-Ohio River | 32 | Tyler |
| | French Creek-Ohio River | 318 | Proctor Creek | 22 | Marshall |
| | French Creek-Ohio River | 318 | Stillhouse Run-Ohio River | 19 | Marshall |
| | Headwaters Middle Island Creek | 197 | Arnold Creek | 35 | Ritchie |
| | Headwaters Middle Island Creek | 197 | Buckeye Creek | 39 | Doddridge |
| | Headwaters Middle Island Creek | 197 | Conaway Run-Middle Island Creek | 30 | Ritchie |
| | Headwaters Middle Island Creek | 197 | Meathouse Fork | 49 | Lewis |
| | Headwaters Middle Island Creek | 197 | Nutter Fork-Middle Island Creek | 29 | Doddridge |
| | Headwaters Middle Island Creek | 197 | Toms Fork | 16 | Doddridge |
| | McElroy Creek | 106 | Flint Run | 26 | Tyler |
| | McElroy Creek | 106 | Headwaters McElroy Creek | 57 | Tyler |
| | McElroy Creek | 106 | Outlet McElroy Creek | 24 | Tyler |
| | Outlet Middle Island Creek | 261 | Buffalo Run-Middle Island Creek | 29 | Tyler |
| | Outlet Middle Island Creek | 261 | Elk Fork | 21 | Tyler |
| | Outlet Middle Island Creek | 261 | Gorrell Run-Middle Island Creek | 25 | Tyler |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Outlet Middle Island Creek | 261 | Indian Creek | 32 | Tyler |
| | Outlet Middle Island Creek | 261 | McKim Creek | 37 | Ritchie |
| | Outlet Middle Island Creek | 261 | Point Pleasant Creek | 39 | Tyler |
| | Outlet Middle Island Creek | 261 | Sancho Creek | 22 | Ritchie |
| | Outlet Middle Island Creek | 261 | Sugar Creek | 22 | Pleasants |
| | Outlet Middle Island Creek | 261 | Willow Island Creek-Middle Island Creek | 33 | Pleasants |
| **Lower Guyandotte** | | | | | |
| | Big Harts Creek-Guyandotte River | 284 | Big Creek | 29 | Boone |
| | Big Harts Creek-Guyandotte River | 284 | Big Harts Creek | 45 | Logan |
| | Big Harts Creek-Guyandotte River | 284 | Big Ugly Creek | 37 | Boone |
| | Big Harts Creek-Guyandotte River | 284 | Crawley Creek-Guyandotte River | 56 | Logan |
| | Big Harts Creek-Guyandotte River | 284 | Fourmile Creek | 23 | Wayne |
| | Big Harts Creek-Guyandotte River | 284 | Fourteenmile Creek-Guyandotte River | 53 | Wayne |
| | Big Harts Creek-Guyandotte River | 284 | Tenmile Creek-Guyandotte River | 41 | Wayne |
| | Heath Creek-Guyandotte River | 96 | Davis Creek-Guyandotte River | 24 | Cabell |
| | Heath Creek-Guyandotte River | 96 | Madison Creek-Guyandotte River | 32 | Lincoln |
| | Heath Creek-Guyandotte River | 96 | Smith Creek-Guyandotte River | 39 | Wayne |
| | Mud River | 280 | Ballard Fork-Mud River | 35 | Boone |
| | Mud River | 280 | Big Cabell Creek-Mud River | 34 | Cabell |
| | Mud River | 280 | Big Creek-Mud River | 45 | Lincoln |
| | Mud River | 280 | Buffalo Creek-Mud River | 16 | Lincoln |
| | Mud River | 280 | Charley Creek-Mud River | 28 | Putnam |
| | Mud River | 280 | Left Fork Mud River | 16 | Boone |
| | Mud River | 280 | Merrick Creek-Mud River | 17 | Cabell |
| | Mud River | 280 | Middle Fork Mud River | 51 | Putnam |
| | Mud River | 280 | Mill Creek-Mud River | 36 | Putnam |
| | Trace Fork | 80 | Headwaters Trace Fork | 46 | Putnam |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Trace Fork | 80 | Outlet Trace Fork | 34 | Putnam |
| **Lower Kanawha** | | | | | |
| | Eighteenmile Creek | 77 | Headwaters Eighteenmile Creek | 35 | Jackson |
| | Eighteenmile Creek | 77 | Outlet Eighteenmile Creek | 42 | Putnam |
| | Headwaters Pocatalico River | 228 | Big Lick Run-Pocatalico River | 41 | Roane |
| | Headwaters Pocatalico River | 228 | Flat Fork | 30 | Roane |
| | Headwaters Pocatalico River | 228 | Green Creek-Pocatalico River | 39 | Jackson |
| | Headwaters Pocatalico River | 228 | Johnson Creek-Pocatalico River | 25 | Roane |
| | Headwaters Pocatalico River | 228 | Middle Fork | 29 | Jackson |
| | Headwaters Pocatalico River | 228 | Pocatalico Creek | 35 | Jackson |
| | Headwaters Pocatalico River | 228 | Rock Creek-Pocatalico River | 28 | Jackson |
| | Hurricane Creek-Kanawha River | 278 | Buffalo Creek-Kanawha River | 47 | Putnam |
| | Hurricane Creek-Kanawha River | 278 | Davis Creek | 47 | Kanawha |
| | Hurricane Creek-Kanawha River | 278 | Five and Twentymile Creek | 18 | Putnam |
| | Hurricane Creek-Kanawha River | 278 | Hurricane Creek | 51 | Putnam |
| | Hurricane Creek-Kanawha River | 278 | Poplar Fork | 25 | Putnam |
| | Hurricane Creek-Kanawha River | 278 | Scary Creek-Kanawha River | 32 | Putnam |
| | Hurricane Creek-Kanawha River | 278 | Twomile Creek | 24 | Kanawha |
| | Hurricane Creek-Kanawha River | 278 | Tyler Creek-Kanawha River | 33 | Kanawha |
| | Outlet Pocatalico River | 128 | Frog Creek-Pocatalico River | 33 | Putnam |
| | Outlet Pocatalico River | 128 | Heizer Creek | 25 | Putnam |
| | Outlet Pocatalico River | 128 | Kelly Creek-Pocatalico River | 27 | Putnam |
| | Outlet Pocatalico River | 128 | Rocky Fork | 19 | Putnam |
| | Outlet Pocatalico River | 128 | Tupper Creek | 24 | Kanawha |
| | Sixteenmile Creek-Kanawha River | 135 | Fivemile Creek-Kanawha River | 40 | Mason |
| | Sixteenmile Creek-Kanawha River | 135 | Little Sixteenmile Creek-Kanawha River | 34 | Putnam |
| | Sixteenmile Creek-Kanawha River | 135 | Sixteenmile Creek | 20 | Putnam |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Sixteenmile Creek-Kanawha River | 135 | Tenmile Creek-Kanawha River | 41 | Mason |
| | Thirteenmile Creek | 78 | Headwaters Thirteenmile Creek | 39 | Jackson |
| | Thirteenmile Creek | 78 | Outlet Thirteenmile Creek | 38 | Jackson |
| **Dunkard** | | | | | |
| | Dunkard Creek | 233 | Days Run | 15 | Monongalia |
| | Dunkard Creek | 233 | Hoovers Run-Dunkard Creek | 14 | Monongalia |
| | Dunkard Creek | 233 | Jakes Run-Dunkard Creek | 45 | Monongalia |
| | Dunkard Creek | 233 | Meadow Run-Dunkard Creek | 41 | Monongalia |
| | Dunkard Creek | 233 | Miracle Run | 23 | Marion |
| | Dunkard Creek | 233 | Pennsylvania Fork-Dunkard Creek | 20 | Monongalia |
| | Dunkard Creek | 233 | Rudolph Run-Dunkard Creek | 31 | Monongalia |
| | Dunkard Creek | 233 | West Virginia Fork | 27 | Marion |
| **Lower New** | | | | | |
| | Glade Creek-New River | 269 | Chestnut Knob Fork-Laurel Creek | 27 | Fayette |
| | Glade Creek-New River | 269 | Farleys Creek-New River | 50 | Fayette |
| | Glade Creek-New River | 269 | Headwaters Glade Creek | 26 | Mercer |
| | Glade Creek-New River | 269 | Lick Creek | 39 | Summers |
| | Glade Creek-New River | 269 | Madam Creek-New River | 42 | Raleigh |
| | Glade Creek-New River | 269 | Meadow Creek | 29 | Fayette |
| | Glade Creek-New River | 269 | Mudlick Branch-Laurel Creek | 18 | Summers |
| | Glade Creek-New River | 269 | Outlet Glade Creek | 37 | Raleigh |
| | Manns Creek-New River | 286 | Arbuckle Creek-New River | 58 | Fayette |
| | Manns Creek-New River | 286 | Dunloup Creek | 48 | Fayette |
| | Manns Creek-New River | 286 | Laurel Creek-New River | 37 | Fayette |
| | Manns Creek-New River | 286 | Manns Creek | 58 | Fayette |
| | Manns Creek-New River | 286 | Mill Creek-New River | 38 | Fayette |
| | Manns Creek-New River | 286 | Wolf Creek-New River | 46 | Fayette |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Piney Creek | 136 | Beaver Creek | 39 | Raleigh |
| | Piney Creek | 136 | Headwaters Piney Creek | 53 | Mercer |
| | Piney Creek | 136 | Outlet Piney Creek | 44 | Fayette |
| **Upper New** | | | | | |
| | Bluestone Lake-New River | 108 | Adair Run-Bluestone Lake | 24 | Mercer |
| | Bluestone Lake-New River | 108 | Lick Creek-Bluestone Lake | 48 | Mercer |
| | Bluestone Lake-New River | 108 | Toms Run-Bluestone Lake | 35 | Summers |
| | Bluestone River | 387 | Blacklick Creek-Bluestone River | 37 | Mercer |
| | Bluestone River | 387 | Brush Fork-Bluestone River | 56 | Mercer |
| | Bluestone River | 387 | Camp Creek | 40 | Mercer |
| | Bluestone River | 387 | Laurel Fork-Bluestone River | 52 | Mercer |
| | Bluestone River | 387 | Little Bluestone River-Bluestone River | 62 | Raleigh |
| | Bluestone River | 387 | Mountain Creek-Bluestone River | 49 | Mercer |
| | Bluestone River | 387 | Rich Creek | 23 | Mercer |
| | Bluestone River | 387 | Widemouth Creek-Bluestone River | 51 | Mercer |
| | Brush Creek | 74 | Headwaters Brush Creek | 33 | Mercer |
| | Brush Creek | 74 | Outlet Brush Creek | 41 | Mercer |
| | East River-New River | 169 | Clendennin Creek-Bluestone Lake | 39 | Mercer |
| | East River-New River | 169 | East River | 59 | Mercer |
| | East River-New River | 169 | Headwaters East River | 17 | Mercer |
| | East River-New River | 169 | Rich Creek | 53 | Monroe |
| | Indian Creek | 193 | Burnside Branch | 34 | Monroe |
| | Indian Creek | 193 | Lower Indian Creek | 41 | Summers |
| | Indian Creek | 193 | Middle Indian Creek | 54 | Monroe |
| | Indian Creek | 193 | Rock Camp Creek | 24 | Monroe |
| | Indian Creek | 193 | Upper Indian Creek | 40 | Monroe |
| | Sinking Creek-New River | 198 | Stony Creek | 49 | Monroe |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| **North Branch Potomac** | | | | | |
| | New Creek-North Branch Potomac Rive | 138 | Limestone Run-North Branch Potomac River | 41 | Mineral |
| | New Creek-North Branch Potomac Rive | 138 | Mill Run-North Branch Potomac River | 44 | Mineral |
| | New Creek-North Branch Potomac Rive | 138 | New Creek | 54 | Mineral |
| | Patterson Creek | 282 | Beaver Run-Patterson Creek | 43 | Mineral |
| | Patterson Creek | 282 | Cabin Run | 23 | Mineral |
| | Patterson Creek | 282 | Horseshoe Creek-Patterson Creek | 40 | Mineral |
| | Patterson Creek | 282 | Keller Run-Patterson Creek | 24 | Mineral |
| | Patterson Creek | 282 | Middle Fork Patterson Creek-Patterson Creek | 33 | Grant |
| | Patterson Creek | 282 | Mikes Run | 19 | Mineral |
| | Patterson Creek | 282 | Mill Creek-Patterson Creek | 33 | Mineral |
| | Patterson Creek | 282 | North Fork Patterson Creek | 30 | Grant |
| | Patterson Creek | 282 | Rosser Run-Patterson Creek | 37 | Mineral |
| | Stony River-North Branch Potomac Rive | 292 | Abram Creek | 44 | Mineral |
| | Stony River-North Branch Potomac Rive | 292 | Bloomington Lake-North Branch Potomac River | 34 | Mineral |
| | Stony River-North Branch Potomac Rive | 292 | Buffalo Creek-North Branch Potomac River | 44 | Mineral |
| | Stony River-North Branch Potomac Rive | 292 | Lostland Run-North Branch Potomac River | 42 | Mineral |
| | Stony River-North Branch Potomac Rive | 292 | Mount Storm Lake-Stony River | 59 | Mineral |
| | Stony River-North Branch Potomac Rive | 292 | Piney Swamp Run-North Branch Potomac River | 28 | Mineral |
| | Stony River-North Branch Potomac Rive | 292 | Shields Run-North Branch Potomac River | 41 | Grant |
| | Trading Run-North Branch Potomac Riv | 94 | Collier Run-North Branch Potomac River | 31 | Mineral |
| | Trading Run-North Branch Potomac Riv | 94 | Green Spring Run-North Branch Potomac River | 41 | Mineral |
| **Shenandoah Hardy** | | | | | |
| | Shoemaker River-North Fork Shenando | 208 | Capon Run-North Fork Shenandoah River | 49 | Hardy |
| | Shoemaker River-North Fork Shenando | 208 | Crab Run | 29 | Hardy |
| | Shoemaker River-North Fork Shenando | 208 | German River | 31 | Pendleton |
| | Shoemaker River-North Fork Shenando | 208 | Runion Creek-North Fork Shenandoah River | 32 | Hardy |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| **Lower Ohio** | | | | | |
| | Crab Creek-Ohio River | 79 | Crab Creek | 22 | Mason |
| | Crab Creek-Ohio River | 79 | Long Run-Ohio River | 26 | Mason |
| | Indian Guyan Creek-Ohio River | 299 | Eighteenmile Creek | 30 | Putnam |
| | Indian Guyan Creek-Ohio River | 299 | Flatfoot Creek-Ohio River | 23 | Mason |
| | Indian Guyan Creek-Ohio River | 299 | Guyan Creek | 48 | Putnam |
| | Indian Guyan Creek-Ohio River | 299 | Paddy Creek-Ohio River | 70 | Mason |
| | Indian Guyan Creek-Ohio River | 299 | Sixteenmile Creek | 35 | Mason |
| | Symmes Creek-Ohio River | 180 | Buffalo Creek-Ohio River | 19 | Wayne |
| | Symmes Creek-Ohio River | 180 | Fourpole Creek | 23 | Wayne |
| **Shenandoah Jefferson** | | | | | |
| | Bullskin Run-Shenandoah River | 86 | Bullskin Run | 22 | Jefferson |
| | Bullskin Run-Shenandoah River | 86 | Evitts Run | 20 | Jefferson |
| | Bullskin Run-Shenandoah River | 86 | Flowing Springs Run-Shenandoah River | 30 | Jefferson |
| | Bullskin Run-Shenandoah River | 86 | Furnace Run-Shenandoah River | 15 | Jefferson |
| | Long Marsh Run-Shenandoah River | 101 | Dog Run-Shenandoah River | 55 | Jefferson |
| | Long Marsh Run-Shenandoah River | 101 | Long Marsh Run | 20 | Jefferson |
| **South Branch Potomac** | | | | | |
| | Lower South Branch Potomac River | 343 | Abernathy Run-South Branch Potomac River | 28 | Mineral |
| | Lower South Branch Potomac River | 343 | Anderson Run | 40 | Grant |
| | Lower South Branch Potomac River | 343 | Fort Run-South Branch Potomac River | 40 | Hardy |
| | Lower South Branch Potomac River | 343 | Fox Run-South Branch Potomac River | 53 | Mineral |
| | Lower South Branch Potomac River | 343 | Hutton Run-South Branch Potomac River | 51 | Grant |
| | Lower South Branch Potomac River | 343 | McDowell Run-South Branch Potomac River | 23 | Hampshire |
| | Lower South Branch Potomac River | 343 | Mill Creek | 49 | Mineral |
| | Lower South Branch Potomac River | 343 | Sawmill Run-South Branch Potomac River | 34 | Hardy |
| | Lower South Branch Potomac River | 343 | Stony Run-South Branch Potomac River | 24 | Hardy |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Lunice Creek | 89 | Headwaters Lunice Creek | 54 | Grant |
| | Lunice Creek | 89 | Outlet Lunice Creek | 35 | Grant |
| | North Fork South Branch Potomac River | 317 | Big Run | 29 | Randolph |
| | North Fork South Branch Potomac River | 317 | Headwaters Seneca Creek | 39 | Randolph |
| | North Fork South Branch Potomac River | 317 | Jordan Run-North Fork South Branch Potomac River | 47 | Randolph |
| | North Fork South Branch Potomac River | 317 | Laurel Fork-North Fork South Branch Potomac River | 63 | Pendleton |
| | North Fork South Branch Potomac River | 317 | Mill Creek-North Fork South Branch Potomac River | 45 | Pendleton |
| | North Fork South Branch Potomac River | 317 | Outlet Seneca Creek | 29 | Randolph |
| | North Fork South Branch Potomac River | 317 | Red Lick Run-North Fork South Branch Potomac River | 32 | Pendleton |
| | North Fork South Branch Potomac River | 317 | Zeke Run-North Fork South Branch Potomac River | 32 | Randolph |
| | South Fork South Branch Potomac River | 287 | Brushy Fork-South Fork South Branch Potomac River | 48 | Pendleton |
| | South Fork South Branch Potomac River | 287 | Hawes Run-South Fork South Branch Potomac River | 33 | Pendleton |
| | South Fork South Branch Potomac River | 287 | Kettle Creek-South Fork South Branch Potomac River | 33 | Grant |
| | South Fork South Branch Potomac River | 287 | Little Fork-South Fork South Branch Potomac River | 27 | Pendleton |
| | South Fork South Branch Potomac River | 287 | Miller Run-South Fork South Branch Potomac River | 28 | Pendleton |
| | South Fork South Branch Potomac River | 287 | Rohrbaugh Run-South Fork South Branch Potomac Ri | 30 | Grant |
| | South Fork South Branch Potomac River | 287 | Rough Run-South Fork South Branch Potomac River | 27 | Pendleton |
| | South Fork South Branch Potomac River | 287 | Stony Run-South Fork South Branch Potomac River | 32 | Hardy |
| | South Fork South Branch Potomac River | 287 | Stump Run-South Fork South Branch Potomac River | 30 | Grant |
| | South Mill Creek-Mill Creek | 104 | Johnson Run-Mill Creek | 57 | Grant |
| | South Mill Creek-Mill Creek | 104 | South Mill Creek | 47 | Grant |
| | Upper South Branch Potomac River | 340 | Briggs Run-South Branch Potomac River | 31 | Grant |
| | Upper South Branch Potomac River | 340 | East Dry Run-South Branch Potomac River | 44 | Pendleton |
| | Upper South Branch Potomac River | 340 | Frank Run-South Branch Potomac River | 30 | Pendleton |
| | Upper South Branch Potomac River | 340 | Hayes Gap Run-South Branch Potomac River | 35 | Pendleton |
| | Upper South Branch Potomac River | 340 | Hoglan Run-South Branch Potomac River | 22 | Grant |
| | Upper South Branch Potomac River | 340 | Mill Run-South Branch Potomac River | 36 | Grant |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Upper South Branch Potomac River | 340 | Reeds Creek | 20 | Pendleton |
| | Upper South Branch Potomac River | 340 | Smith Creek-South Branch Potomac River | 43 | Pendleton |
| | Upper South Branch Potomac River | 340 | Strait Creek | 27 | Pendleton |
| | Upper South Branch Potomac River | 340 | Whitethorn Creek-Thorn Creek | 51 | Pendleton |
| **Tug** | | | | | |
| | Dry Fork | 230 | Big Creek | 34 | McDowell |
| | Dry Fork | 230 | Jacobs Fork | 35 | McDowell |
| | Dry Fork | 230 | Lower Dry Fork | 51 | McDowell |
| | Dry Fork | 230 | Middle Dry Fork | 52 | McDowell |
| | Dry Fork | 230 | Upper Dry Fork | 58 | McDowell |
| | Elkhorn Creek-Tug Fork | 329 | Clear Fork | 25 | McDowell |
| | Elkhorn Creek-Tug Fork | 329 | Headwaters Elkhorn Creek | 40 | Mercer |
| | Elkhorn Creek-Tug Fork | 329 | Horse Creek-Tug Fork | 38 | McDowell |
| | Elkhorn Creek-Tug Fork | 329 | Outlet Elkhorn Creek | 33 | McDowell |
| | Elkhorn Creek-Tug Fork | 329 | Panther Creek | 45 | McDowell |
| | Elkhorn Creek-Tug Fork | 329 | Sandlick Creek-Tug Fork | 43 | McDowell |
| | Elkhorn Creek-Tug Fork | 329 | South Fork Tug Fork-Tug Fork | 46 | McDowell |
| | Elkhorn Creek-Tug Fork | 329 | Spice Creek-Tug Fork | 59 | McDowell |
| | Knox Creek-Tug Fork | 376 | Beech Creek-Tug Fork | 27 | Mingo |
| | Knox Creek-Tug Fork | 376 | Ben Creek | 23 | Logan |
| | Knox Creek-Tug Fork | 376 | Blackberry Creek-Tug Fork | 39 | Mingo |
| | Knox Creek-Tug Fork | 376 | Bull Creek-Tug Fork | 23 | McDowell |
| | Knox Creek-Tug Fork | 376 | Left Fork-Knox Creek | 41 | McDowell |
| | Knox Creek-Tug Fork | 376 | Long Branch-Tug Fork | 36 | McDowell |
| | Knox Creek-Tug Fork | 376 | Mate Creek | 16 | Mingo |
| | Knox Creek-Tug Fork | 376 | Right Fork-Knox Creek | 23 | McDowell |
| | Knox Creek-Tug Fork | 376 | Sycamore Creek-Tug Fork | 23 | Mingo |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Knox Creek-Tug Fork | 376 | Upper Elk Creek-Knox Creek | 31 | McDowell |
| | Pigeon Creek | 142 | Headwaters Pigeon Creek | 58 | Logan |
| | Pigeon Creek | 142 | Laurel Fork | 33 | Logan |
| | Pigeon Creek | 142 | Outlet Pigeon Creek | 51 | Logan |
| | Rockcastle Creek-Tug Fork | 280 | Bull Creek-Tug Fork | 48 | Wayne |
| | Rockcastle Creek-Tug Fork | 280 | Jennie Creek-Tug Fork | 36 | Wayne |
| | Rockcastle Creek-Tug Fork | 280 | Lost Creek-Tug Fork | 27 | Wayne |
| | Rockcastle Creek-Tug Fork | 280 | Marrowbone Creek | 23 | Wayne |
| | Rockcastle Creek-Tug Fork | 280 | Mill Creek | 25 | Wayne |
| | Wolf Creek-Tug Fork | 199 | Miller Creek-Tug Fork | 56 | Mingo |
| **Twelvepole** | | | | | |
| | East Fork Twelvepole Creek | 172 | Kiah Creek | 31 | Wayne |
| | East Fork Twelvepole Creek | 172 | Lower East Fork Twelvepole Creek | 39 | Wayne |
| | East Fork Twelvepole Creek | 172 | Middle East Fork Twelvepole Creek | 48 | Wayne |
| | East Fork Twelvepole Creek | 172 | Upper East Fork Twelvepole Creek | 54 | Wayne |
| | Twelvepole Creek | 156 | Headwaters Beech Fork | 42 | Wayne |
| | Twelvepole Creek | 156 | Lower Twelvepole Creek | 40 | Wayne |
| | Twelvepole Creek | 156 | Millers Fork | 20 | Wayne |
| | Twelvepole Creek | 156 | Outlet Beech Fork | 22 | Wayne |
| | Twelvepole Creek | 156 | Upper Twelvepole Creek | 32 | Wayne |
| | West Fork Twelvepole Creek | 115 | Lower West Fork Twelvepole Creek | 37 | Wayne |
| | West Fork Twelvepole Creek | 115 | Middle West Fork Twelvepole Creek | 32 | Wayne |
| | West Fork Twelvepole Creek | 115 | Upper West Fork Twelvepole Creek | 45 | Wayne |
| **Tygart Valley** | | | | | |
| | Buckhannon River | 309 | Fink Run-Buckhannon River | 39 | Lewis |
| | Buckhannon River | 309 | French Creek | 49 | Lewis |
| | Buckhannon River | 309 | Left Fork Buckhannon River | 37 | Randolph |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Buckhannon River | 309 | Pecks Run-Buckhannon River | 40 | Barbour |
| | Buckhannon River | 309 | Right Fork Buckhannon River | 53 | Randolph |
| | Buckhannon River | 309 | Sand Run | 30 | Upshur |
| | Buckhannon River | 309 | Tenmile Creek-Buckhannon River | 61 | Upshur |
| | Lower Tygart Valley River | 279 | Guyses Run-Tygart Valley River | 19 | Marion |
| | Lower Tygart Valley River | 279 | Hackers Creek-Tygart Valley River | 33 | Barbour |
| | Lower Tygart Valley River | 279 | Laurel Creek | 23 | Barbour |
| | Lower Tygart Valley River | 279 | Little Laurel Run-Tygart Valley River | 20 | Barbour |
| | Lower Tygart Valley River | 279 | Lost Run-Tygart Valley River | 30 | Marion |
| | Lower Tygart Valley River | 279 | Sugar Creek | 31 | Randolph |
| | Lower Tygart Valley River | 279 | Teter Creek | 53 | Randolph |
| | Lower Tygart Valley River | 279 | Tygart Lake-Tygart Valley River | 33 | Barbour |
| | Lower Tygart Valley River | 279 | Wickwire Run-Tygart Valley River | 37 | Taylor |
| | Middle Fork River | 151 | Lower Middle Fork River | 41 | Randolph |
| | Middle Fork River | 151 | Middle Middle Fork River | 41 | Randolph |
| | Middle Fork River | 151 | Right Fork Middle Fork River | 30 | Randolph |
| | Middle Fork River | 151 | Upper Middle Fork River | 38 | Randolph |
| | Middle Tygart Valley River | 291 | Beaver Creek-Tygart Valley River | 35 | Randolph |
| | Middle Tygart Valley River | 291 | Chenoweth Creek | 21 | Randolph |
| | Middle Tygart Valley River | 291 | Files Creek | 21 | Randolph |
| | Middle Tygart Valley River | 291 | Laurel Run-Tygart Valley River | 28 | Barbour |
| | Middle Tygart Valley River | 291 | Leading Creek | 60 | Randolph |
| | Middle Tygart Valley River | 291 | Mill Creek-Tygart Valley River | 55 | Randolph |
| | Middle Tygart Valley River | 291 | Roaring Creek | 29 | Randolph |
| | Middle Tygart Valley River | 291 | Shavers Run-Tygart Valley River | 43 | Randolph |
| | Sandy Creek | 89 | Left Fork-Sandy Creek | 51 | Barbour |
| | Sandy Creek | 89 | Little Sandy Creek | 39 | Taylor |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Three Fork Creek | 101 | Headwaters Three Fork Creek | 59 | Taylor |
| | Three Fork Creek | 101 | Outlet Three Fork Creek | 42 | Taylor |
| | Upper Tygart Valley River | 154 | Becky Creek-Tygart Valley River | 45 | Randolph |
| | Upper Tygart Valley River | 154 | Elkwater Fork-Tygart Valley River | 43 | Randolph |
| | Upper Tygart Valley River | 154 | Mill Creek | 23 | Randolph |
| | Upper Tygart Valley River | 154 | Ralston Run-Tygart Valley River | 44 | Randolph |
| **Upper Guyandotte** | | | | | |
| | Buffalo Creek-Guyandotte River | 336 | Big Cub Creek-Guyandotte River | 48 | Logan |
| | Buffalo Creek-Guyandotte River | 336 | Buffalo Creek | 46 | Boone |
| | Buffalo Creek-Guyandotte River | 336 | Dingess Run-Guyandotte River | 32 | Logan |
| | Buffalo Creek-Guyandotte River | 336 | Elk Creek-Guyandotte River | 44 | Logan |
| | Buffalo Creek-Guyandotte River | 336 | Gilbert Creek | 29 | McDowell |
| | Buffalo Creek-Guyandotte River | 336 | Huff Creek | 52 | Boone |
| | Buffalo Creek-Guyandotte River | 336 | Little Huff Creek | 41 | McDowell |
| | Buffalo Creek-Guyandotte River | 336 | Rum Creek-Guyandotte River | 44 | Logan |
| | Clear Fork | 129 | Headwaters Clear Fork | 37 | Boone |
| | Clear Fork | 129 | Laurel Fork | 56 | Raleigh |
| | Clear Fork | 129 | Outlet Clear Fork | 35 | Wyoming |
| | Copperas Mine Fork-Island Creek | 105 | Copperas Mine Fork | 45 | Logan |
| | Copperas Mine Fork-Island Creek | 105 | Island Creek | 60 | Logan |
| | Pinnacle Creek-Guyandotte River | 238 | Barkers Creek | 37 | Mercer |
| | Pinnacle Creek-Guyandotte River | 238 | Cabin Creek-Guyandotte River | 35 | Wyoming |
| | Pinnacle Creek-Guyandotte River | 238 | Indian Creek | 43 | McDowell |
| | Pinnacle Creek-Guyandotte River | 238 | Pinnacle Creek | 57 | Mercer |
| | Pinnacle Creek-Guyandotte River | 238 | Rockcastle Creek | 20 | Wyoming |
| | Pinnacle Creek-Guyandotte River | 238 | Turkey Creek-Guyandotte River | 46 | Wyoming |
| | Tommy Creek-Guyandotte River | 131 | Devils Fork-Guyandotte River | 41 | Mercer |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Tommy Creek-Guyandotte River | 131 | Slab Fork | 35 | Raleigh |
| | Tommy Creek-Guyandotte River | 131 | Tommy Creek | 55 | Mercer |
| **James** | | | | | |
| | Dunlap Creek | 168 | Cove Run-Dunlap Creek | 47 | Greenbrier |
| | Dunlap Creek | 168 | Johnsons Creek-Ogle Creek | 39 | Greenbrier |
| | Dunlap Creek | 168 | Sweet Springs Creek-Cove Creek | 42 | Greenbrier |
| | Potts Creek | 174 | Mill Branch-Potts Creek | 59 | Monroe |
| | Potts Creek | 174 | South Fork Potts Creek-North Fork Potts Creek | 20 | Monroe |
| | Potts Creek | 174 | Trout Branch-Potts Creek | 26 | Monroe |
| | Upper Cowpasture River | 186 | Daves Run-Bullpasture River | 62 | Pendleton |
| **Upper Kanawha** | | | | | |
| | Cabin Creek | 73 | Headwaters Cabin Creek | 35 | Fayette |
| | Cabin Creek | 73 | Outlet Cabin Creek | 37 | Boone |
| | Campbells Creek-Kanawha River | 147 | Campbells Creek | 39 | Kanawha |
| | Campbells Creek-Kanawha River | 147 | Fields Creek-Kanawha River | 34 | Boone |
| | Campbells Creek-Kanawha River | 147 | Lens Creek | 20 | Boone |
| | Campbells Creek-Kanawha River | 147 | Rush Creek-Kanawha River | 33 | Kanawha |
| | Campbells Creek-Kanawha River | 147 | Witcher Creek | 21 | Kanawha |
| | Loop Creek-Kanawha River | 177 | Armstrong Creek | 23 | Fayette |
| | Loop Creek-Kanawha River | 177 | Boomer Branch-Kanawha River | 21 | Fayette |
| | Loop Creek-Kanawha River | 177 | Hughes Creek-Kanawha River | 40 | Fayette |
| | Loop Creek-Kanawha River | 177 | Kellys Creek | 25 | Kanawha |
| | Loop Creek-Kanawha River | 177 | Loop Creek | 50 | Fayette |
| | Loop Creek-Kanawha River | 177 | Smithers Creek | 18 | Fayette |
| | Paint Creek | 123 | Fourmile Fork-Paint Creek | 19 | Kanawha |
| | Paint Creek | 123 | Long Branch-Paint Creek | 35 | Fayette |
| | Paint Creek | 123 | Packs Branch-Paint Creek | 45 | Fayette |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Paint Creek | 123 | Plum Orchard Lake-Paint Creek | 23 | Fayette |
| **Monongahela** | | | | | |
| | Buffalo Creek | 125 | Headwaters Buffalo Creek | 41 | Marion |
| | Buffalo Creek | 125 | Outlet Buffalo Creek | 54 | Marion |
| | Buffalo Creek | 125 | Pyles Fork | 30 | Marion |
| | Deckers Creek | 63 | Headwaters Deckers Creek | 30 | Preston |
| | Deckers Creek | 63 | Outlet Deckers Creek | 33 | Preston |
| | Upper Monongahela River | 275 | Booths Creek | 22 | Monongalia |
| | Upper Monongahela River | 275 | Cobun Creek-Monongahela River | 34 | Monongalia |
| | Upper Monongahela River | 275 | Indian Creek | 21 | Marion |
| | Upper Monongahela River | 275 | Little Creek-Monongahela River | 27 | Marion |
| | Upper Monongahela River | 275 | Paw Paw Creek | 42 | Marion |
| | Upper Monongahela River | 275 | Prickett Creek | 24 | Marion |
| | Upper Monongahela River | 275 | Scotts Run-Monongahela River | 35 | Monongalia |
| | Upper Monongahela River | 275 | West Run-Monongahela River | 36 | Monongalia |
| | Upper Monongahela River | 275 | Whiteday Creek | 33 | Marion |
| **Upper Ohio North** | | | | | |
| | Cross Creek | 80 | South Fork Cross Creek-Cross Creek | 63 | Brooke |
| | Kings Creek-Ohio River | 295 | Carpenter Run-Ohio River | 36 | Hancock |
| | Kings Creek-Ohio River | 295 | Hardin Run-Ohio River | 42 | Hancock |
| | Kings Creek-Ohio River | 295 | Harmon Creek | 38 | Hancock |
| | Kings Creek-Ohio River | 295 | Kings Creek | 50 | Hancock |
| | Kings Creek-Ohio River | 295 | Mill CreeK | 15 | Hancock |
| | Kings Creek-Ohio River | 295 | Tomlinson Run | 28 | Hancock |
| | Kings Creek-Ohio River | 295 | Wills Creek-Ohio River | 37 | Hancock |
| **Middle Ohio South** | | | | | |
| | Left Fork Sandy Creek-Sandy Creek | 124 | Headwaters Left Fork Sandy Creek | 35 | Jackson |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Left Fork Sandy Creek-Sandy Creek | 124 | Outlet Left Fork Sandy Creek | 22 | Jackson |
| | Left Fork Sandy Creek-Sandy Creek | 124 | Right Fork Sandy Creek | 26 | Jackson |
| | Left Fork Sandy Creek-Sandy Creek | 124 | Sandy Creek | 41 | Jackson |
| | Little Hocking River-Ohio River | 202 | Big Run | 20 | Wood |
| | Little Hocking River-Ohio River | 202 | Mile Run-Ohio River | 40 | Wood |
| | Little Hocking River-Ohio River | 202 | Sandy Creek-Ohio River | 40 | Wood |
| | Little Sandy Creek-Ohio River | 189 | Broad Run-Ohio River | 51 | Mason |
| | Little Sandy Creek-Ohio River | 189 | Groundhog Creek-Ohio River | 38 | Jackson |
| | Little Sandy Creek-Ohio River | 189 | Little Sandy Creek | 18 | Jackson |
| | Little Sandy Creek-Ohio River | 189 | Oldtown Creek-Ohio River | 30 | Jackson |
| | Little Sandy Creek-Ohio River | 189 | West Creek-Ohio River | 53 | Jackson |
| | Mill Creek | 235 | Elk Fork | 27 | Jackson |
| | Mill Creek | 235 | Grasslick Creek | 27 | Jackson |
| | Mill Creek | 235 | Little Mill Creek | 42 | Jackson |
| | Mill Creek | 235 | Lower Mill Creek | 29 | Jackson |
| | Mill Creek | 235 | Middle Mill Creek | 18 | Jackson |
| | Mill Creek | 235 | Parchment Creek | 37 | Jackson |
| | Mill Creek | 235 | Tug Fork | 30 | Jackson |
| | Mill Creek | 235 | Upper Mill Creek | 24 | Jackson |
| | Oldtown Creek-Ohio River | 164 | Crooked Creek-Ohio River | 45 | Mason |
| | Oldtown Creek-Ohio River | 164 | Oldtown Creek | 43 | Mason |
| | Pond Creek-Ohio River | 131 | Forked Run-Ohio River | 36 | Jackson |
| | Pond Creek-Ohio River | 131 | Lee Creek | 34 | Wood |
| | Pond Creek-Ohio River | 131 | Pond Creek | 43 | Jackson |
| | Pond Creek-Ohio River | 131 | South Fork Lee Creek | 18 | Wood |
| **Upper Ohio South** | | | | | |
| | Buffalo Creek | 163 | Buffalo Creek-Ohio River | 18 | Brooke |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Buffalo Creek | 163 | Castleman Run | 17 | Brooke |
| | Buffalo Creek | 163 | Sugarcamp Run-Buffalo Creek | 38 | Brooke |
| | Dunkard Fork | 77 | Outlet Dunkard Fork | 22 | Marshall |
| | Dunkard Fork | 77 | South Fork Dunkard Fork | 27 | Marshall |
| | Fish Creek | 161 | Lower Fish Creek | 23 | Marshall |
| | Fish Creek | 161 | Lynn Camp Run | 19 | Marshall |
| | Fish Creek | 161 | Middle Fish Creek | 39 | Marshall |
| | Fish Creek | 161 | Pennsylvania Fork Fish Creek | 52 | Marshall |
| | Fish Creek | 161 | Upper Fish Creek | 28 | Marshall |
| | Middle Grave Creek-Grave Creek | 75 | Grave Creek | 45 | Marshall |
| | Middle Grave Creek-Grave Creek | 75 | Middle Grave Creek | 29 | Marshall |
| | Robinson Fork-Enlow Fork | 75 | Enlow Fork | 32 | Marshall |
| | Short Creek-Ohio River | 198 | Big Run-Ohio River | 11 | Marshall |
| | Short Creek-Ohio River | 198 | Boggs Run-Ohio River | 17 | Ohio |
| | Short Creek-Ohio River | 198 | Glenns Run-Ohio River | 31 | Brooke |
| | Short Creek-Ohio River | 198 | Pipe Creek-Ohio River | 35 | Marshall |
| | Short Creek-Ohio River | 198 | Salt Run-Ohio River | 29 | Brooke |
| | Short Creek-Ohio River | 198 | Short Creek | 24 | Brooke |
| | Short Creek-Ohio River | 198 | Wegee Creek-Ohio River | 38 | Marshall |
| | West Virginia Fork Fish Creek | 89 | Long Drain | 19 | Marion |
| | West Virginia Fork Fish Creek | 89 | Lower West Virginia Fork Fish Creek | 32 | Marshall |
| | West Virginia Fork Fish Creek | 89 | Middle West Virginia Fork Fish Creek | 20 | Marshall |
| | West Virgnia Fork Fish Creek | 89 | Upper West Virginia Fork Fish Creek | 18 | Marion |
| | Wheeling Creek | 145 | Grandstaff Run-Wheeling Creek | 27 | Ohio |
| | Wheeling Creek | 145 | Little Wheeling Creek | 28 | Ohio |
| | Wheeling Creek | 145 | Long Run-Wheeling Creek | 16 | Ohio |
| | Wheeling Creek | 145 | Middle Wheeling Creek | 34 | Ohio |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| | Wheeling Creek | 145 | Upper Wheeling Creek | 40 | Ohio |
| **West Fork** | | | | | |
| | Elk Creek | 121 | Brushy Fork | 21 | Barbour |
| | Elk Creek | 121 | Gnatty Creek | 34 | Barbour |
| | Elk Creek | 121 | Headwaters Elk Creek | 36 | Barbour |
| | Elk Creek | 121 | Outlet Elk Creek | 29 | Harrison |
| | Lower West Fork River | 177 | Bingamon Creek | 46 | Marion |
| | Lower West Fork River | 177 | Booths Creek | 44 | Marion |
| | Lower West Fork River | 177 | Coons Run-West Fork River | 31 | Marion |
| | Lower West Fork River | 177 | Limestone Run-West Fork River | 56 | Marion |
| | Middle West Fork River | 211 | Freemans Creek | 31 | Lewis |
| | Middle West Fork River | 211 | Hackers Creek | 57 | Lewis |
| | Middle West Fork River | 211 | Isaacs Creek-West Fork River | 47 | Lewis |
| | Middle West Fork River | 211 | Kincheloe Creek | 21 | Lewis |
| | Middle West Fork River | 211 | Lost Creek | 20 | Lewis |
| | Middle West Fork River | 211 | Sycamore Creek-West Fork River | 35 | Harrison |
| | Simpson Creek | 73 | Headwaters Simpson Creek | 50 | Barbour |
| | Simpson Creek | 73 | Outlet Simpson Creek | 23 | Harrison |
| | Tenmile Creek | 125 | Headwaters Tenmile Creek | 40 | Doddridge |
| | Tenmile Creek | 125 | Little Tenmile Creek | 28 | Marion |
| | Tenmile Creek | 125 | Outlet Tenmile Creek | 40 | Doddridge |
| | Tenmile Creek | 125 | Salem Fork | 16 | Doddridge |
| | Upper West Fork River | 174 | Polk Creek-West Fork River | 33 | Lewis |
| | Upper West Fork River | 174 | Right Fork-West Fork River | 29 | Lewis |
| | Upper West Fork River | 174 | Sand Fork-West Fork River | 40 | Lewis |
| | Upper West Fork River | 174 | Skin Creek | 33 | Lewis |
| | Upper West Fork River | 174 | Stonecoal Creek | 40 | Lewis |

| HUC 8 Name | HUC 10 Name | HUC 10 sq mi | HUC 12 Name | HUC 12 sq mi | County |
|---|---|---|---|---|---|
| **Youghiogheny** | | | | | |
| | Headwaters Youghiogheny River | 185 | Herrington Run-Youghiogheny River | 33 | Preston |
| | Headwaters Youghiogheny River | 185 | Maple Run-Youghiogeny River | 22 | Preston |
| | Headwaters Youghiogheny River | 185 | Muddy Creek | 18 | Preston |
| | Headwaters Youghiogheny River | 185 | Rhine Creek-Youghiogheny River | 21 | Preston |
| | Headwaters Youghiogheny River | 185 | Snowy Creek | 34 | Preston |
| | Upper Youghiogheny River | 185 | Buffalo Run | 20 | Preston |
| | Upper Youghiogheny River | 185 | Salt Block Run-Youghiogheny River | 48 | Preston |

# Appendix F

Active West Virginia Stream Gages – March 2013

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in mi² | Type of data collected | | | | | | | | | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | GH | Q | SV | Pr | WT | sK | pH | DO | Turb | |
| 01595300 | ABRAM CREEK AT OAKMONT, WV | 39.36676569 | -79.17892449 | 42.6 | x | x | | | | | | | | New station, previously unpublished in the WDR. |
| 01604500 | PATTERSON CREEK NEAR HEADSVILLE, WV | 39.44314946 | -78.8219649 | 221 | x | x | | | | | | | | Since 1963, the flow from 115 mi² upstream from the station is partially controlled, but not diverted, by several floodwater detention reservoirs with the total combined detention capacity of 19,887 acre-ft. |
| 01605500 | SOUTH BRANCH POTOMAC RIVER AT FRANKLIN, WV | 38.63567247 | -79.3378199 | 179 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 01606000 | N F SOUTH BRANCH POTOMAC RIVER AT CABINS, WV | 38.9845546 | -79.2336508 | 310 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 01606500 | SOUTH BRANCH POTOMAC RIVER NEAR PETERSBURG, WV | 38.99122107 | -79.17587059 | 651 | x | x | | x | | | | | | No remarks were made on regulation or diversion. |
| 01607500 | S F SOUTH BRANCH POTOMAC RIVER AT BRANDYWINE, WV | 38.63150665 | -79.2436497 | 103 | x | x | | | | | | | | Beginning in 1973, the flow from 41.3 mi² upstream from station has been partially controlled, but not diverted, by several floodwater-detention reservoirs with a total combined detention capacity of 8,882 acre-ft. |
| 01608000 | S F SOUTH BRANCH POTOMAC RIVER NR MOOREFIELD, WV | 39.0123313 | -78.9561387 | 277 | x | x | | | | | | | | Beginning in 1973, the flow from 92.7 mi² upstream from station has been partially controlled, but not diverted, by several floodwater-detention reservoirs with a total combined detention capacity of 19,870 acre-ft. |
| 01608500 | SOUTH BRANCH POTOMAC RIVER NEAR SPRINGFIELD, WV | 39.44703879 | -78.6541817 | 1461 | x | x | | | x | x | x | x | x | No remarks were made on regulation or diversion. |
| 01610400 | WAITES RUN NEAR WARDENSVILLE, WV | 39.0427222 | -78.5983333 | 12.6 | x | x | | | x | | | | | No remarks were made on regulation or diversion. |
| 01611500 | CACAPON RIVER NEAR GREAT CACAPON, WV | 39.5823158 | -78.3097312 | 675 | x | x | | | x | x | x | x | | No remarks were made on regulation or diversion. |
| 01613030 | WARM SPRINGS RUN NEAR BERKELEY SPRINGS, WV | 39.6405833 | -78.2189444 | 6.76 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 01614000 | BACK CREEK NEAR JONES SPRINGS, WV | 39.51204187 | -78.0372224 | 235 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 01616400 | MILL CREEK AT | 39.334625 | -78.0534361 | 18.4 | x | x | | | | | | | | New station, previously unpublished in the |

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in mi² | Type of data collected | | | | | | | | | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | GH | Q | SV | Pr | WT | sK | pH | DO | Turb | |
| | BUNKER HILL, WV | | | | | | | | | | | | | WDR. |
| 01616500 | OPEQUON CREEK NEAR MARTINSBURG, WV | 39.42371047 | -77.9386084 | 273 | x | x | | | | | | | | Some diurnal fluctuation at low flow caused by upstream mills in Virginia and since July 18, 1988, by wastewater treatment plant, 1,000 ft upstream from Opequon Creek near Berryville, Va (01615000); drainage area 57.4 mi². |
| 01617000 | TUSCARORA CREEK ABOVE MARTINSBURG, WV | 39.46954296 | -77.9713871 | 11.3 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 01618100 | ROCKYMARSH RUN AT SCRABBLE, WV | 39.4830833 | -77.8318333 | 15.9 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 01636464 | BULLSKIN RUN BELOW KABLETOWN, WV | 39.2115833 | -77.8348611 | 21.8 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 01636500 | SHENANDOAH RIVER AT MILLVILLE, WV | 39.28204576 | -77.7891606 | 3041 | x | x | | | | | | | | Some regulation by upstream hydroelectric plants, including that of Potomac Light and Power Company, 0.5 mi upstream from station. |
| 03050000 | TYGART VALLEY RIVER NEAR DAILEY, WV | 38.809275 | -79.8817342 | 185 | x | x | | x | | | | | | No remarks were made on regulation or diversion. |
| 03051000 | TYGART VALLEY RIVER AT BELINGTON, WV | 39.0292694 | -79.93590799 | 406 | x | x | | x | | | | | | No remarks were made on regulation or diversion. |
| 03052000 | MIDDLE FORK RIVER AT AUDRA, WV | 39.03954454 | -80.0681352 | 148 | x | x | | x | | | | | | No remarks were made on regulation or diversion. |
| 03052120 | BUCKHANNON RIVER AT ALTON, WV | 38.82010299 | -80.2150795 | 94.7 | x | x | | x | | | | | | New station, previously unpublished in the WDR. |
| 03052500 | SAND RUN NEAR BUCKHANNON, WV | 38.96398938 | -80.1525806 | 14.3 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03053500 | BUCKHANNON RIVER AT HALL, WV | 39.05121 | -80.1145254 | 277 | x | x | | | | | | | | Some regulation at low flow from mine pumpage above station. |
| 03054500 | TYGART VALLEY RIVER AT PHILIPPI, WV | 39.15037545 | -80.038691 | 914 | x | x | | x | x | | | | | No remarks were made on regulation or diversion. |
| 03056000 | TYGART VALLEY R AT TYGART DAM NR GRAFTON, WV[1] | 39.31981459 | -80.0250779 | 1182 | x | x | | | x | x | x | x | | Flow regulated by Tygart Dam. |
| 03056250 | THREE FORK CREEK NR GRAFTON, WV | 39.33648107 | -79.9934094 | 96.8 | x | x | | x | | | | | | No remarks were made on regulation or diversion. |
| 03057000 | TYGART VALLEY RIVER AT COLFAX, | 39.4350866 | -80.1325789 | 1363 | x | x | | | x | x | x | | | Flow regulated by Tygart Dam. |

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in $mi^2$ | Type of data collected | | | | | | | | | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | GH | Q | SV | Pr | WT | sK | pH | DO | Turb | |
| | WV | | | | | | | | | | | | | |
| 03058000 | WEST FORK R BL STONEWALL JACKSON DAM NR WESTON, WV | 39.00452778 | -80.4733611 | 101 | x | x | | | x | x | x | x | | Flow regulated since January 1990 by Stonewall Jackson Dam. |
| 03058975 | WEST FORK RIVER NEAR MOUNT CLARE, WV | 39.23870156 | -80.3589793 | 368 | x | x | | x | | | | | | Flow partially regulated since 1973 by Stonecoal Reservoir, and regulated since January 1990 by Stonewall Jackson Dam. |
| 03061000 | WEST FORK RIVER AT ENTERPRISE, WV | 39.42230818 | -80.2759187 | 759 | x | x | | x | x | x | x | x | | Flow partially regulated since 1973 by Stonecoal Reservoir, and regulated since January 1990 by Stonewall Jackson Dam. |
| 03061500 | BUFFALO CREEK AT BARRACKVILLE, WV | 39.50397288 | -80.1720235 | 116 | x | x | | x | | | | | | Flow from 5.20 $mi^2$ is partially controlled, but not diverted, by three floodwater-detention reservoirs. Some additional regulation at low flow from mine pumpage above station. |
| 03062500 | DECKERS CREEK AT MORGANTOWN, WV | 39.62924826 | -79.9525633 | 63.2 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03065000 | DRY FORK AT HENDRICKS, WV | 39.07232928 | -79.6228373 | 349 | x | x | | x | | | | | | No remarks were made on regulation or diversion. |
| 03065400 | BLACKWATER RIVER NEAR DAVIS, WV | 39.14010775 | -79.4197715 | 54.7 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03066000 | BLACKWATER RIVER AT DAVIS, WV | 39.1270524 | -79.4683852 | 85.9 | x | x | | x | | | | | | No remarks were made on regulation or diversion. |
| 03067510 | SHAVERS FORK NR CHEAT BRIDGE, WV | 38.6170576 | -79.8697849 | 60.2 | x | x | | x | x | x | x | x | x | No remarks were made on regulation or diversion. |
| 03068800 | SHAVERS FORK BELOW BOWDEN, WV | 38.91316335 | -79.770342 | 151 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03069500 | CHEAT RIVER NEAR PARSONS, WV | 39.1228835 | -79.68117409 | 722 | x | x | | x | x | | | | | No remarks were made on regulation or diversion. |
| 03070260 | CHEAT RIVER AT ALBRIGHT, WV | 39.4948104 | -79.6444969 | 1044 | x | x | | x | x | | | | | No remarks were made on regulation or diversion. |
| 03070500 | BIG SANDY CREEK AT ROCKVILLE, WV | 39.62175 | -79.7045556 | 200 | x | x | | x | | | | | | No remarks were made on regulation or diversion. |
| 03110830 | KINGS CREEK AT WEIRTON, WV | 40.4356229 | -80.5925723 | 48.9 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03111955 | WHEELING CREEK NEAR MAJORSVILLE, WV | 39.9533333 | -80.54 | 152 | x | x | | | | | | | | New station, previously unpublished in the WDR. |

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in $mi^2$ | Type of data collected | | | | | | | | | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | GH | Q | SV | Pr | WT | sK | pH | DO | Turb | |
| 03112000 | WHEELING CREEK AT ELM GROVE, WV | 40.0445177 | -80.6609116 | 281 | x | x | | x | | | | | | The flow from 205 $mi^2$ upstream from station is partially controlled, but not diverted, by seven floodwater detention reservoirs with a total combined detention capacity of 24,148 acre-ft. Cummulative detention as construction progressed 1975 to 1995. |
| 03114500 | MIDDLE ISLAND CREEK AT LITTLE, WV | 39.4750762 | -80.9970537 | 458 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03151400 | LITTLE KANAWHA RIVER NR WILDCAT, WV | 38.7434337 | -80.5253667 | 112 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03155000 | LITTLE KANAWHA RIVER AT PALESTINE, WV | 39.0589686 | -81.38956408 | 1516 | x | x | | | | | | | | Prior to 1968, flow partially regulated by old dams 3, 4, and 5 that leak at variable rates. Flow partially regulated since 1968 by five floodwater-detention reservoirs affecting 49.5 $mi^2$. Flow regulated since March 1979 by Burnsville Reservoir at mile 124.2. |
| 03155220 | SOUTH FORK HUGHES RIVER BELOW MACFARLAN, WV | 39.07896905 | -81.2123373 | 229 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03177120 | EAST RIVER AT WILLOWTON, WV | 37.3485 | -80.8860833 | 73 | x | x | | | | | | | | New station, previously unpublished in the WDR. |
| 03177480 | INDIAN CREEK AT RED SULPHUR SPRINGS, WV | 37.52925 | -80.7701944 | 160 | x | x | | | | | | | | New station, previously unpublished in the WDR. |
| 03179000 | BLUESTONE RIVER NEAR PIPESTEM, WV | 37.54400779 | -81.0103678 | 395 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03180500 | GREENBRIER RIVER AT DURBIN, WV | 38.54372659 | -79.833115 | 133 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03182500 | GREENBRIER RIVER AT BUCKEYE, WV | 38.18595326 | -80.1306225 | 540 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03183500 | GREENBRIER RIVER AT ALDERSON, WV | 37.7242874 | -80.641468 | 1364 | x | x | | | x | x | x | x | | No remarks were made on regulation or diversion. |
| 03184000 | GREENBRIER RIVER AT HILLDALE, WV | 37.64012018 | -80.805083 | 1619 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03185000 | PINEY CREEK AT RALEIGH, WV | 37.7606708 | -81.1623212 | 52.7 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03185400 | NEW RIVER AT THURMOND, WV | 37.95511285 | -81.07648838 | 6687 | x | x | | | | | | | | Flow regulated since May 1939 by Claytor Lake, and since August 1949 by Bluestone Lake. |
| 03186500 | WILLIAMS RIVER AT | 38.37899915 | -80.4839737 | 128 | x | x | | | | | | | | No remarks were made on regulation or |

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in mi$^2$ | Type of data collected GH | Q | SV | Pr | WT | sK | pH | DO | Turb | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DYER, WV | | | | | | | | | | | | | diversion. |
| 03187500 | CRANBERRY RIVER NEAR RICHWOOD, WV | 38.2953903 | -80.5264749 | 80.4 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03188900 | LAUREL CREEK NEAR FENWICK, WV | 38.1636111 | -80.5880556 | 32.7 | x | x | | | | | | | | New station, previously unpublished in the WDR. |
| 03189100 | GAULEY RIVER NEAR CRAIGSVILLE, WV | 38.29094494 | -80.6409242 | 529 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03190000 | MEADOW RIVER AT NALLEN, WV | 38.1126125 | -80.8762069 | 287 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03190400 | MEADOW RIVER NEAR MT. LOOKOUT, WV | 38.18983209 | -80.94676579 | 365 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03191500 | PETERS CREEK NEAR LOCKWOOD, WV | 38.26260716 | -81.0231582 | 40.2 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03192000 | GAULEY RIVER ABOVE BELVA, WV | 38.2334395 | -81.1809415 | 1317 | x | x | | | | | | | | Flow regulated since May 1965 by Summersville Dam. |
| 03193000 | KANAWHA RIVER AT KANAWHA FALLS, WV | 38.1381632 | -81.2142745 | 8371 | x | x | | | | | | | | Flow regulated since 1939 by Claytor Dam, since 1949 by Bluestone Dam, and since 1965 by Summersville Dam. |
| 03194700 | ELK RIVER BELOW WEBSTER SPRINGS, WV | 38.59732627 | -80.4903644 | 266 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03196500 | BIRCH RIVER AT HEROLD, WV | 38.5748233 | -80.8009334 | 124 | x | x | | | | | | | | New station, previously unpublished in the WDR. |
| 03197000 | ELK RIVER AT QUEEN SHOALS, WV | 38.47093228 | -81.2840057 | 1145 | x | x | | | | | | | | Flow regulated since October 1960 by Sutton Lake. Flows were affected by dam construction during the 1959-60 water years and were not used for any statistical calculations. |
| 03198000 | KANAWHA RIVER AT CHARLESTON, WV | 38.37148448 | -81.7020701 | 10448 | x | x | x | | | | | | | Flow regulated since May 1939 by increasing number of reservoirs upstream from station. |
| 03198350 | CLEAR FORK AT WHITESVILLE, WV | 37.9662186 | -81.524278 | 62.8 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03198500 | BIG COAL RIVER AT ASHFORD, WV | 38.1798222 | -81.7115106 | 391 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03200500 | COAL RIVER AT TORNADO, WV | 38.33898309 | -81.841518 | 862 | x | x | | | x | x | | | | No remarks were made on regulation or diversion. |
| 03201405 | HURRICANE CREEK AT HURRICANE, WV | 38.4453673 | -82.0068032 | 26.8 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03202400 | GUYANDOTTE RIVER NEAR BAILEYSVILLE, WV | 37.60400034 | -81.6451096 | 306 | x | x | | | | | | | | No remarks were made on regulation or diversion. |

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in $mi^2$ | Type of data collected | | | | | | | | | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | GH | Q | SV | Pr | WT | sK | pH | DO | Turb | |
| 03202750 | CLEAR FORK AT CLEAR FORK, WV | 37.62316608 | -81.7073342 | 126 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03203600 | GUYANDOTTE RIVER AT LOGAN, WV | 37.84232616 | -81.9759574 | 833 | x | x | | | | | | | | Flow regulated since February 1980 by R. D. Bailey Lake at mile 112. Unregulated statistics of monthly mean data and summary statistics for water years 1963-1979 are also published. |
| 03206600 | EAST FORK TWELVEPOLE CREEK NEAR DUNLOW, WV | 38.01731624 | -82.29597689 | 38.5 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03212750 | TUG FORK DOWNSTREAM OF ELKHORN CREEK AT WELCH, WV | 37.44122439 | -81.5998295 | 174 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03212980 | DRY FORK AT BEARTOWN, WV | 37.39538968 | -81.8026142 | 209 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03213500 | PANTHER CREEK NEAR PANTHER, WV | 37.44555556 | -81.8711111 | 31 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03213700 | TUG FORK AT WILLIAMSON, WV | 37.67315699 | -82.2801408 | 936 | x | x | | | | | | | | No remarks were made on regulation or diversion. |
| 03214500 | TUG FORK AT KERMIT, WV | 37.83731869 | -82.4087578 | 1280 | x | x | | | x | x | | | | No remarks were made on regulation or diversion. |
| 01599200 | LINTON CREEK NEAR LAUREL DALE, WV | 39.26944444 | -79.13138889 | 5.02 | x | | | | | | | | | Stage-only or reservoir gage. |
| 01605002 | PAINTER RUN NEAR FORT ASHBY, WV | 39.4856472 | -78.7600181 | 1.76 | x | | | | | | | | | Stage-only or reservoir gage. |
| 01606900 | SOUTH MILL CREEK NEAR MOZER, WV | 38.8548343 | -79.16309189 | 10 | x | | | | | | | | | Stage-only or reservoir gage. |
| 01607300 | BRUSHY FORK NEAR SUGAR GROVE, WV | 38.46638889 | -79.31888889 | 15.2 | x | | | | | | | | | Stage-only or reservoir gage. |
| 01610195 | PARKER HOLLOW RUN AT NEEDMORE, WV | 39.04277778 | -78.7977778 | 6.7 | x | | | | | | | | | Stage-only or reservoir gage. |
| 01613020 | UNNAMED TRIB TO WARM SPR RUN NR BERKELEY SPR, WV | 39.6058333 | -78.2291667 | 0.45 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03049930 | ELKWATER FORK NEAR SPANGLER, WV | 38.5983333 | -80.0611111 | 8.4 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03050350 | TYGART VALLEY R BELOW INLET WORKS, ELKINS, WV | 38.91501944 | -79.8749194 | nd | x | | | | | | | | | Stage-only or reservoir gage. |
| 03050450 | TYGART VALLEY R ABOVE OUTLET | 38.9212583 | -79.86838889 | nd | x | | | | | | | | | Stage-only or reservoir gage. |

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in mi² | Type of data collected GH | Q | SV | Pr | WT | sK | pH | DO | Turb | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WORKS, ELKINS, WV | | | | | | | | | | | | | |
| 03050460 | TYGART VALLEY R BELOW OUTLET WORKS, ELKINS, WV | 38.92106944 | -79.8695 | nd | x | | | | | | | | | Stage-only or reservoir gage. |
| 03050500 | TYGART VALLEY RIVER NEAR ELKINS, WV | 38.92371705 | -79.8789587 | 271 | x | | | x | | | | | | Slight regulation at times by flood-diversion dam upstream from station. |
| 03052450 | BUCKHANNON R AT BUCKHANNON, WV | 39.0053762 | -80.20924949 | 217 | x | | | x | | | | | | No remarks were made on regulation or diversion. |
| 03055500 | TYGART LAKE NR GRAFTON, WV | 39.3128703 | -80.0336896 | 1182 | x | | | x | | | | | | Stage-only or reservoir gage. |
| 03057300 | WEST FORK RIVER AT WALKERSVILLE, WV | 38.86870938 | -80.4578658 | 28.8 | x | | | x | x | | | | | Records affected by unquantified backwater from Stonewall Jackson Lake. |
| 03057900 | STONEWALL JACKSON LAKE NEAR WESTON, WV | 39.0036111 | -80.4742222 | 101 | x | | | x | | | | | | Stage-only or reservoir gage. |
| 03058020 | WEST FORK RIVER AT WESTON, WV | 39.02930556 | -80.47375 | 122 | x | | | x | | | | | | Flow regulated since January 1990 by Stonewall Jackson Dam. |
| 03058500 | WEST FORK RIVER AT BUTCHERVILLE, WV | 39.09064846 | -80.4675915 | 181 | x | | | | | | | | | Flow partially regulated since 1973 by Stonecoal Reservoir, and regulated since January 1990 by Stonewall Jackson Dam. |
| 03061430 | WHETSTONE RUN NEAR MANNINGTON, WV | 39.51758396 | -80.37119738 | 1.98 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03062224 | MONONGAHELA R AT OPEKISKA LOCK & DAM (UPPER), WV | 39.563972 | -80.05118159 | 2523 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03062225 | MONONGAHELA R AT OPEKISKA LOCK & DAM (LOWER), WV | 39.56452757 | -80.05062599 | 2523 | x | | | x | | | | | | Stage-only or reservoir gage. |
| 03062245 | MONONGAHELA R AT HILDEBRAND LOCK & DAM (UPPER), WV | 39.58174955 | -80.0095122 | 2539 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03062250 | MONONGAHELA R AT HILDEBRAND LOCK & DAM (LOWER), WV | 39.5828606 | -80.0100678 | 2538 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03062445 | MONONGAHELA R AT MORGANTOWN LOCK & DAM | 39.6198041 | -79.9695089 | 2579 | x | | | | | | | | | Stage-only or reservoir gage. |

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in mi$^2$ | Type of data collected | | | | | | | | | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | GH | Q | SV | Pr | WT | sK | pH | DO | Turb | |
| | (UPPER), WV | | | | | | | | | | | | | |
| 03062450 | MONONGAHELA R AT MORGANTOWN LOCK & DAM (LOWER), WV | 39.62008188 | -79.9689533 | 2579 | x | | | x | x | | | | | Stage-only or reservoir gage. |
| 03071590 | CHEAT LAKE NEAR STEWARTSTOWN, WV | 39.72007846 | -79.8556116 | 1411 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03071600 | CHEAT RIVER AT LAKE LYNN, PA | 39.72091177 | -79.8553338 | 1411 | x | | | x | | | | | | This stage-only station is completely regulated by Cheat Lake Dam. |
| 03110685 | OHIO R AT NEW CUMBERLAND LOCK & DAM (UPPER), OH | 40.5283988 | -80.62673998 | 23820 | x | | | | x | | | | | Stage-only or reservoir gage. |
| 03110690 | OHIO R AT NEW CUMBERLAND LOCK & DAM (LOWER), OH | 40.52812107 | -80.6256288 | 23820 | x | | | x | | | | | | Stage-only or reservoir gage. |
| 03111515 | OHIO R AT PIKE ISLAND DAM NR WHEELING (UPPER), WV | 40.15284939 | -80.6998021 | 24600 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03111520 | OHIO R AT PIKE ISLAND LOCK & DAM (LOWER), WV | 40.14979387 | -80.70146889 | 24600 | x | | | x | x | | | | | Stage-only or reservoir gage. |
| 03111950 | DUNKARD FORK NEAR MAJORSVILLE, WV | 39.95285399 | -80.5256277 | 77.2 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03112500 | OHIO RIVER AT WHEELING, WV | 40.0572949 | -80.7284154 | 25030 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03114275 | OHIO RIVER AT HANNIBAL LOCK AND DAM (UPPER), OH | 39.66757665 | -80.86593189 | 25930 | x | | | | x | | | | | Stage-only or reservoir gage. |
| 03114280 | OHIO RIVER AT HANNIBAL LOCK AND DAM (LOWER), OH | 39.66729887 | -80.8659319 | 25930 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03150700 | OHIO RIVER AT MARIETTA, OH | 39.4095187 | -81.45762149 | 35590 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03151000 | OHIO RIVER AT PARKERSBURG, WV | 39.2681306 | -81.5637358 | 35650 | x | | | | | | | | | Stage-only or reservoir gage. |

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in mi$^2$ | Type of data collected: GH | Q | SV | Pr | WT | sK | pH | DO | Turb | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 03151550 | SALTLICK CREEK NEAR FLATWOODS, WV | 38.73194444 | -80.5952778 | 9.75 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03151600 | LITTLE KANAWHA RIVER AT BURNSVILLE, WV | 38.8650952 | -80.6762077 | 248 | x | | | | | | | | | Flow partially regulated by five flood-water detention reservoirs affecting 49.5 mi² and regulated since March 1979 by Burnsville Reservoir at mile 124.2. |
| 03152000 | LITTLE KANAWHA RIVER AT GLENVILLE, WV | 38.9329722 | -80.8382222 | 387 | x | | | | | | | | | Flow partially regulated by five flood-water detention reservoirs affecting 49.5 mi² and regulated since March 1979 by Burnsville Reservoir at mile 124.2. |
| 03153500 | LITTLE KANAWHA RIVER AT GRANTSVILLE, WV | 38.92203068 | -81.0976124 | 913 | x | | | | | | | | | Flow partially regulated by five flood-water detention reservoirs affecting 49.5 mi² and regulated since March 1979 by Burnsville Reservoir at mile 124.2. |
| 03154000 | WEST FORK LITTLE KANAWHA RIVER AT ROCKSDALE, WV | 38.84425369 | -81.2226168 | 205 | x | | | | | | | | | No remarks were made on regulation or diversion. |
| 03155405 | NORTH FORK HUGHES RIVER NEAR CAIRO, WV | 39.21896789 | -81.0998337 | 92 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03159750 | TUG FORK AT STATTS MILLS, WV | 38.7436111 | -81.6255556 | 52.3 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03178150 | MIDDLE FORK BRUSH CREEK AT EDISON, WV | 37.3062288 | -81.1648167 | 2.05 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03182050 | MARLIN RUN AT MARLINTON, WV | 38.22012028 | -80.0808982 | 1.02 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03182888 | DRY CREEK AT TUCKAHOE, WV | 37.7412334 | -80.2781241 | 13.5 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03184500 | NEW RIVER AT HINTON, WV | 37.6703969 | -80.8925874 | 6256 | x | | | | | | | | | Flow regulated since May 1939 by Claytor Lake, and since August 1949 by Bluestone Lake. |
| 03187000 | GAULEY RIVER AT CAMDEN ON GAULEY, WV | 38.36594285 | -80.6009232 | 236 | x | | | | | | | | | No remarks were made on regulation or diversion. |
| 03189600 | GAULEY RIVER BELOW SUMMERSVILLE DAM, WV | 38.2151103 | -80.8881536 | 806 | x | | | | | | | | | Flow regulated since May 1965 by Summersville Lake. |
| 03195500 | ELK RIVER AT SUTTON, WV | 38.66315555 | -80.7095413 | 542 | x | | | | | | | | | Flow regulated since October 1960 by Sutton Lake. |
| 03196600 | ELK RIVER NEAR | 38.59232159 | -80.8845474 | 751 | x | | | | | | | | | Flow regulated since October 1960 by Sutton |

| Station number | Station name | Latitude, in DD | Longitude, in DD | Drainage area, in $mi^2$ | Type of data collected | | | | | | | | | WDR remarks on regulation and diversion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | GH | Q | SV | Pr | WT | sK | pH | DO | Turb | |
| | FRAMETOWN, WV | | | | | | | | | | | | | Lake. |
| 03196800 | ELK RIVER AT CLAY, WV | 38.46065656 | -81.0876087 | 992 | x | | | | | | | | | Flow regulated since October 1960 by Sutton Lake. |
| 03197910 | UNNAMED TRIB TO ELK TWOMILE CR NR CHARLESTON, WV | 38.36088889 | -81.5128611 | 0.65 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03197990 | KANAWHA R AT CHARLESTON, WV AUXILIARY (UPPER) | 38.3612076 | -81.6623467 | 10419 | x | | | | | | | | | This is an auxilliary gage for station 03198000 Kanawha River at Charleston. |
| 03201500 | OHIO RIVER AT POINT PLEASANT, WV | 38.84396959 | -82.139589 | 52740 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03203000 | GUYANDOTTE RIVER AT MAN, WV | 37.740385 | -81.8767857 | 758 | x | | | | | | | | | Flow regulated since February, 1980 by R.D. Bailey Dam at mile 112. |
| 03204000 | GUYANDOTTE RIVER AT BRANCHLAND, WV | 38.22092326 | -82.2026417 | 1224 | x | | | | | | | | | Flow regulated since February, 1980 by R.D. Bailey Dam at mile 112. |
| 03204250 | MUD RIVER AT PALERMO, WV | 38.165 | -82.0586111 | 51.3 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03206000 | OHIO RIVER AT HUNTINGTON, WV | 38.41341549 | -82.500434 | 55850 | x | | | | | | | | | Stage-only or reservoir gage. |
| 03207020 | TWELVEPOLE CREEK BELOW WAYNE, WV | 38.24897409 | -82.4343191 | 300 | x | | | | | | | | | Flow regulated since March 1972 by East Lynn Dam. |
| 38064908-1083301 | NEW RIVER BELOW HAWKS NEST DAM, WV | 38.11372008 | -81.14232689 | 6909 | x | | | | | | | | | Stage-only or reservoir gage. |

[1] Total partial pressure of dissolved gases is also measured continuously at this station.

[DD, decimal degrees; mi2, square miles; GH, gage height; Q, streamflow; SV, stream velocity;Pr, precipitation; WT, water temperature; sK, specific conductance; DO, dissolved oxygen concentration; Turb, turbidity; WDR, determined]

# Appendix G

## Evaluation of USGS Geophysical Well Logging

***Evaluation of Geophysical Log data collected April 20-24, 2009 in Mineral, Harrison, Hardy, and Berkeley Counties, West Virginia***

The reference measuring point for all geophysical logs is land surface. Depth of boreholes, casing lengths, and water-levels at the time of logging are given in feet below land-surface (ft bls), except for borehole Har-0165 that was measured from top of casing.

**Min-0173**

The caliper log shows that the total depth of the borehole is 240 ft bls and is cased to 18 ft bls with 6-in.-diameter steel casing. The static water level at the time of logging was 22.37 ft bls. The caliper log shows no major fractures and only a few smaller fractures throughout the borehole. Under nonpumping conditions the heatpulse flowmeter measured no vertical borehole at 42, 75, 85, 115, 143, 165, and 206 ft bls table 2. The natural-gamma log shows a slight change in gamma counts at 18 ft bls, (casing bottom) and a decrease in counts at 61 ft bls that is consistent with a thin sandstone unit; no other important changes in gamma counts over the length of the borehole, just normal variation in what appears to be a single competent lithologic unit. The single-point-resistance log shows a minor change in lithology at 61 ft bls which is indicative of a thin sandstone unit. The fluid-temperature log shows a consistent geothermal gradient with a slight change at approximately 150 ft bls that correlates to a series of small fractures shown on the caliper and the acoustic televiewer (ATV) log. The ATV log shows numerous bedding planes and several fractures or bedding plane separations. The fluid-resistivity log shows only minor variations throughout the borehole. The water producing zone for this borehole appears to be a series of fractures located near 150 ft bls. The borehole deviates from vertical approximately 24.5 feet to the SSW.

***Table 1: Summary of heatpulse-flowmeter measurements for borehole Min-0173*** *(*ft bls, feet below land surface; gal/min, gallon per minute)

| Depth (ft bls) | Flow rate under ambient conditions (gal/min) |
|---|---|
| 42 | No flow |
| 75 | No flow |
| 85 | No flow |
| 115 | No flow |
| 143 | No flow |
| 165 | No flow |
| 206 | No flow |

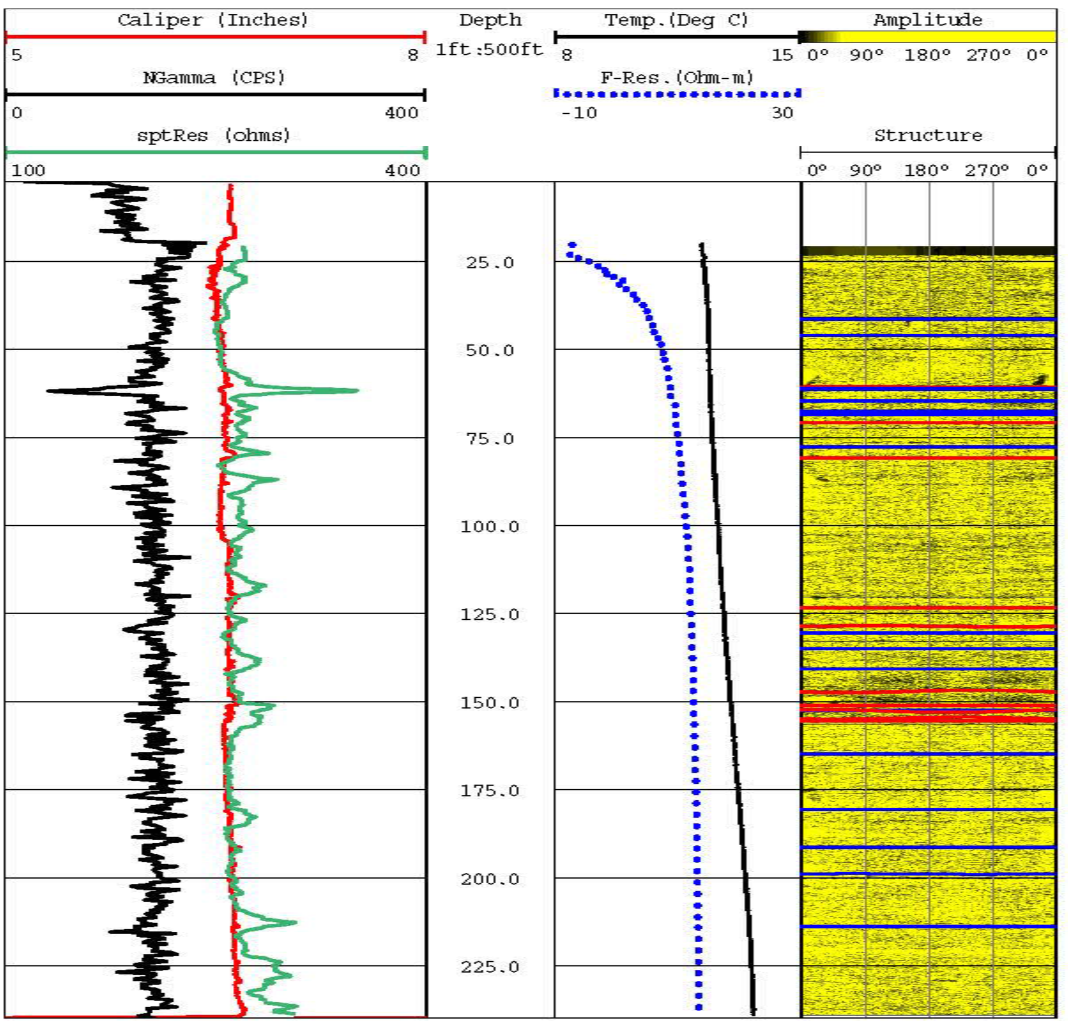


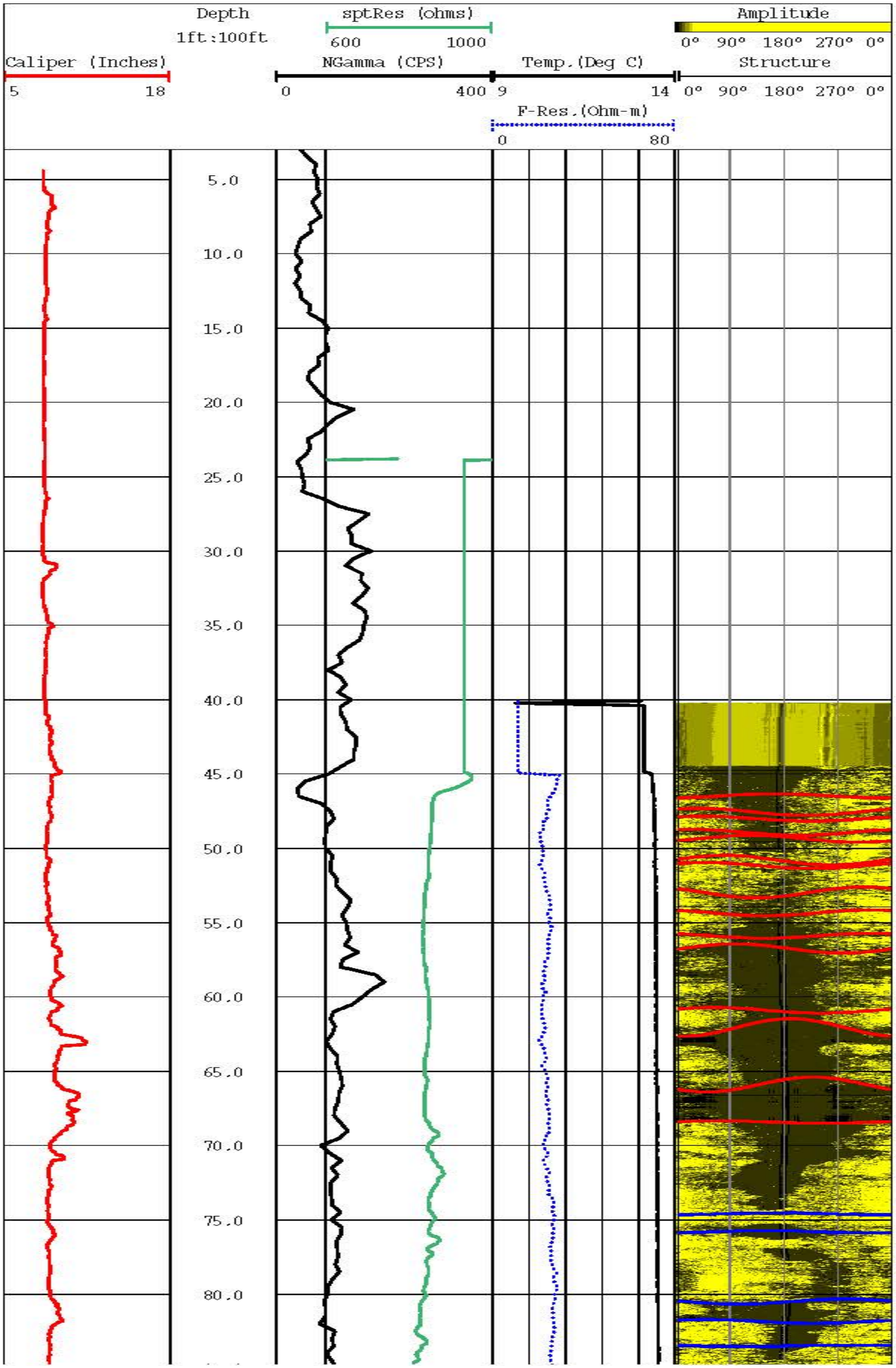

***Figure 1: Mineral County #0173 geophysical well log.***

**Har-0165**

The caliper log shows that the total depth of the borehole is 111 ft bls. The static water level at the time of logging was 44.64 feet from top of casing (ft toc). The caliper log shows major fractures at 63, 66-71 and 92-98 ft toc and numerous smaller fractures throughout the borehole. Under nonpumping conditions the heatpulse flowmeter measured no vertical borehole at 50, 74, 86, and 100 ft toc table 3. Under pumping conditions the heatpulse flowmeter measured upward borehole flow at 57, 66, 74, and 86 ft toc and no flow at 100 ft toc. Under pumping conditions the greatest quantity of water is produced from the small fractures located at 76 and/or 80-82 ft toc and only a minor quantity is produced from the large fracture at 92-98 ft toc. The natural-gamma log shows only small changes in gamma counts over the length of the borehole, suggesting the lithology is the same type rock unit with only minor variations. The single-point-resistance log shows minor changes in lithology at 70- 85 ft toc which corresponds to the main water producing zone in the borehole. The fluid-temperature log shows only a slight geothermal gradient that is typical for a shallow borehole. The ATV log shows numerous bedding planes and several fractures and/or bedding plane separations. The fluid-resistivity log shows minor variations throughout the borehole which is sometimes indicative of lateral flow through the borehole from numerous zones through the formation. The main water producing zone for this borehole is the fractures located 76 and/or 80-82 ft toc. The borehole deviates from vertical approximately 0.5 feet to the East.

**Table 2: Summary of heatpulse-flowmeter measurements for borehole Har-0165** (ft bls, feet below land surface; gal/min, gallon per minute)

| Depth (ft bls) | Flow rate under nonpumping conditions (gal/min) | Flow direction under nonpumping conditions (gal/min) |
|---|---|---|
| 50 | No flow | Not determined |
| 57 | No flow | 0.2 up (turbulence) |
| 66 | No flow | .3 up |
| 74 | No flow | .6 up |
| 86 | No flow | .1 up |
| 100 | No flow | No flow |



Depth
1ft:100ft
sptRes (ohms)
600
1000
Amplitude
0° 90° 180° 270° 0°
Caliper (Inches)
5
18
NGamma (CPS)
0
400
Temp.(Deg C)
9
14
Structure
0° 90° 180° 270° 0°
F-Res.(Ohm-m)
0
80
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0

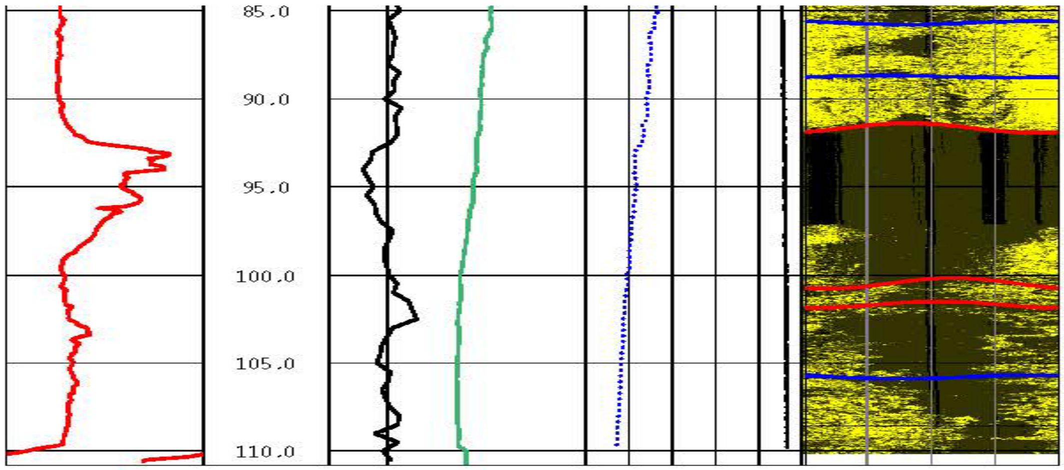



***Figure 2: Harrison County #0165 geophysical well log.***

**<u>Hrd-0301</u>**

The caliper log shows that the total depth of the borehole is 161 ft bls and is cased to 58 ft bls with 6-in.-diameter steel casing. The static water level at the time of logging was 15.50 ft bls. The caliper log shows major fractures at 68, 72, and 80 ft bls and numerous smaller fractures throughout the borehole. Under nonpumping conditions the heatpulse flowmeter measured no vertical borehole at 69, 76, 85, 95, 110, 130, and 146 ft bls table 4. Under pumping conditions the heatpulse flowmeter measured upward borehole flow at 69, 76, 85, 95, 110, 130, and 146 ft bls. Under pumping conditions the greatest quantity of water is produced from the fracture located at 80 ft bls and minor quantities are produced from the fractures at 90, 98-102, 118, 138-143, and 154 ft bls. The natural-gamma log shows only small changes in gamma counts over the length of the borehole, suggesting the lithology is the same type rock unit with minor variations. Also, the natural-gamma log shows a shift at the transition from bottom of casing to open borehole where the counts become less muted. The single-point-resistance log shows a change in lithology at 90 ft bls which corresponds to a decrease shown on the natural-gamma log that may indicate a thin sandstone unit. The fluid-temperature log shows only a slight geothermal gradient that is typical for a shallow borehole. The ATV log shows bedding planes and numerous fractures and/or bedding plane separations. The fluid-resistivity log shows minor variations throughout the borehole which is sometimes indicative of lateral flow from numerous zones through the formation. The main water producing zone for this borehole is the fractures located at 80 ft bls. The borehole deviates from vertical approximately 1.7 feet to the NNE.

**Table 3: Summary of heatpulse-flowmeter measurements for borehole Hrd-0301** (ft bls, feet below land surface; gal/min, gallon per minute)

| Depth (ft bls) | Flow rate under nonpumping conditions (gal/min) | Flow direction under nonpumping conditions (gal/min) |
|---|---|---|
| 69 | No flow | not determined |
| 76 | No flow | 0.5 up |
| 85 | No flow | .5 up |
| 95 | No flow | .13 up |
| 110 | .No flow | .11 up |
| 130 | No flow | .08 up |
| 146 | No flow | .05 up |

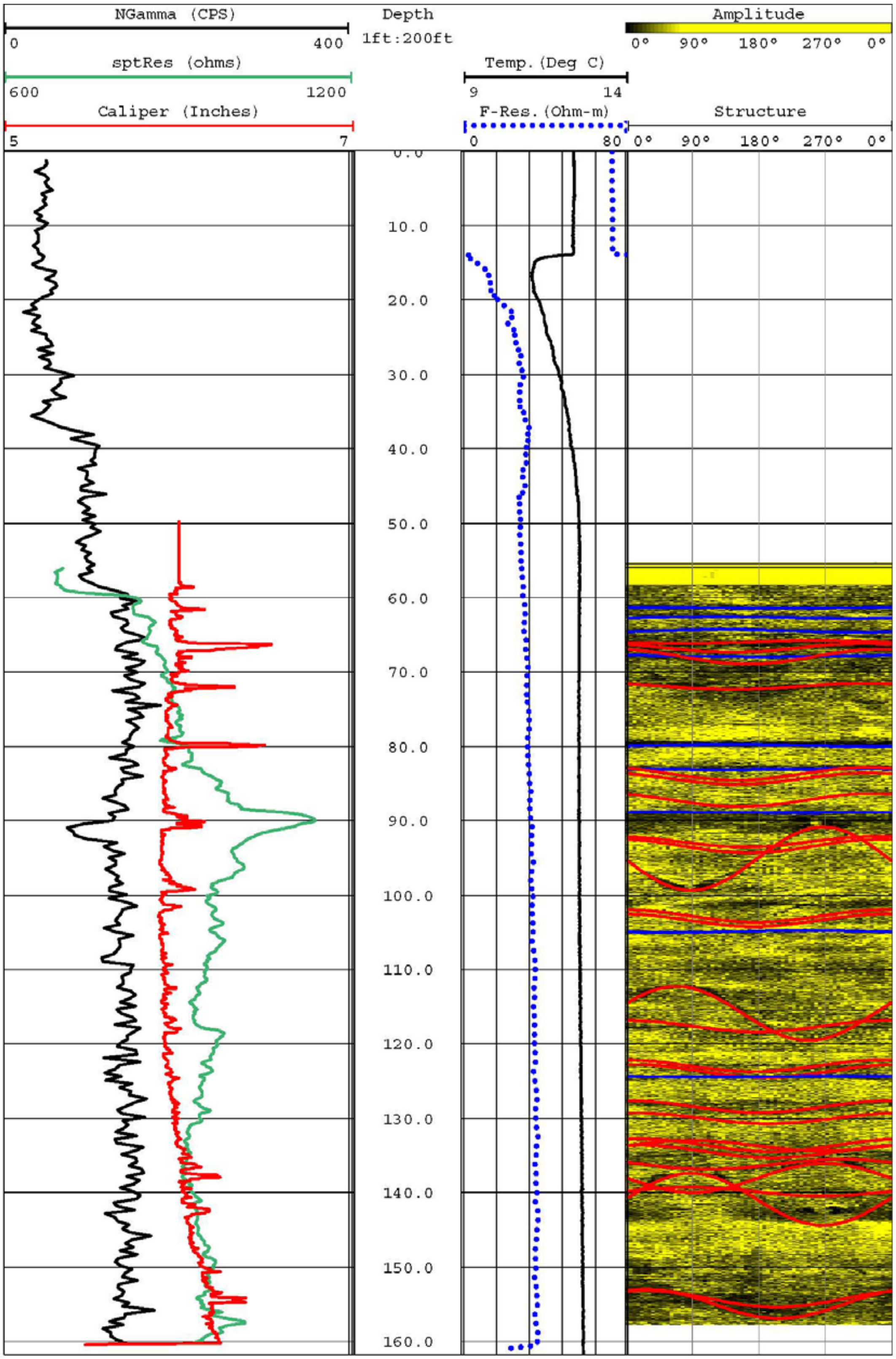


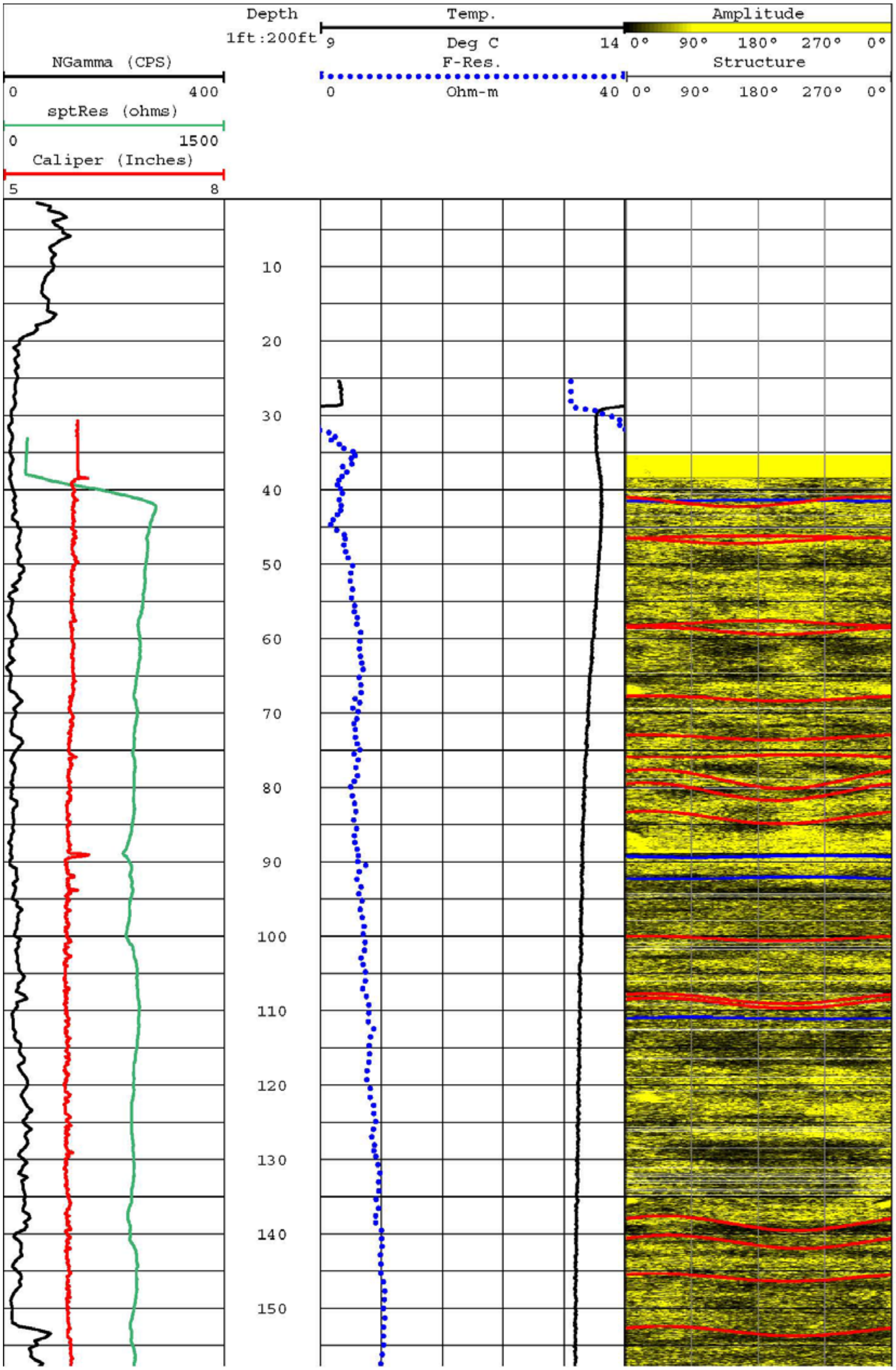

***Figure 3: Hardy County #0301 geophysical well log.***

**Ber-0840**

The caliper log shows that the total depth of the borehole is 301 ft bls and is cased to 38 ft bls with 6-in.-diameter steel casing. The static water level at the time of logging was 28.68 ft bls. The caliper log shows small fractures at 89 and 230 ft bls and numerous small fractures throughout the borehole. Under nonpumping conditions the heatpulse flowmeter measured slight upward borehole at 82 ft bls and no borehole flow at 52, 62, 96, 112, 160, 194, 250, and 288 ft bls table 5. Under pumping conditions the heatpulse flowmeter measured upward borehole flow at 70, 82, 96, 112, and 160 ft bls and no flow at 194 ft bls. Under pumping conditions water is produced from fractures located at 76, 137, and 176-178 ft bls. The natural-gamma log shows a shale unit at 152-160 ft bls and then only small changes in gamma counts over the length of the borehole. The consistency of the gamma log suggests the lithology is the same type rock unit with minor variations. Also, the natural-gamma log shows a shift at approximately 18 ft bls that is caused by the bottom of surface casing and grout seal of an 8-in-diameter over-casing. The single-point-resistance log shows numerous changes over the length of the borehole that may be related to changes in grain size or fractures. The fluid-temperature log shows only a slight inverse geothermal gradient that is somewhat inconsistent for a deeper borehole of low production capabilities. The fluid-resistivity log shows minor variations throughout the borehole. The ATV log shows bedding planes and numerous fractures and/or bedding plane separations. The main water producing zone for this borehole is the fractures located at 89 ft bls. The borehole deviates from vertical approximately 26 feet to the SSW.

**Table 4: Summary of heatpulse-flowmeter measurements for borehole Ber-0840** (ft bls, feet below land surface; gal/min, gallon per minute)

| Depth (ft bls) | Flow rate under nonpumping conditions (gal/min) | Flow direction under nonpumping conditions (gal/min) |
|---|---|---|
| 52 | No flow | Not determined |
| 62 | No flow | Not determined |
| 70 | Not determined | 0.10 up |
| 82 | 0.03 up | .05 up |
| 96 | No flow | .03 up |
| 112 | No flow | .06 up |
| 160 | No flow | .04 up |
| 194 | No flow | No flow |
| 250 | No flow | Not determined |
| 288 | No flow | Not determined |



Depth
1ft:200ft
Temp.
9
Deg C
14
F-Res.
0
Ohm-m
40
Amplitude
0° 90° 180° 270° 0°
Structure
0° 90° 180° 270° 0°
NGamma (CPS)
0
400
sptRes (ohms)
0
1500
Caliper (Inches)
5
8
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

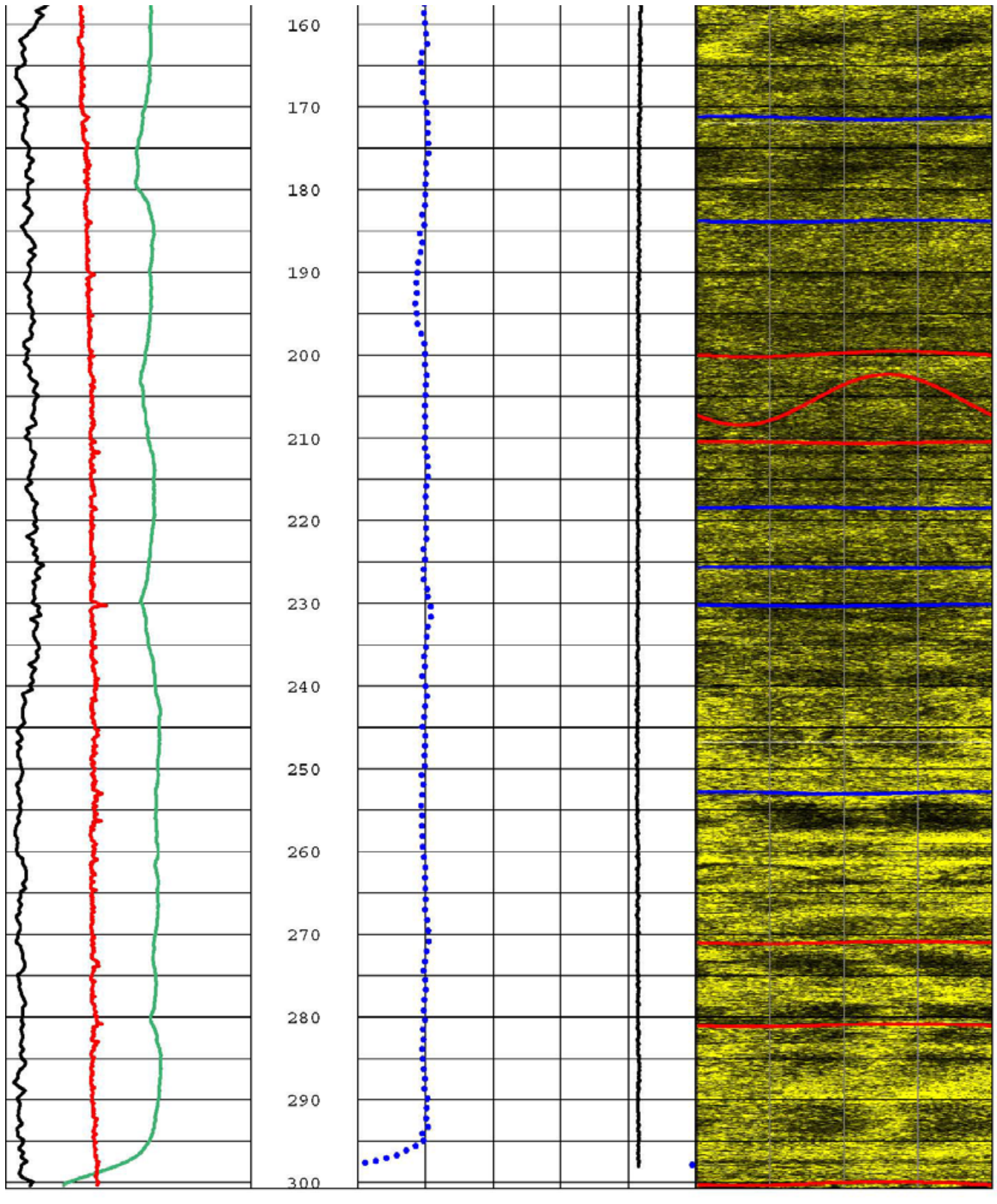



*Figure 4: Berkley County #0840 geophysical well log.*

***Evaluation of Geophysical Log data collected May - October, 2010 in Wyoming, Webster, Wayne, Pocahontas, Monongalia, Kanawha, Berkeley, and Barbour Counties, West Virginia***

**WYO-0148**

The caliper log shows that the total depth of the borehole is 67 ft bls and is cased to 24 ft bls with 6-in.-diameter steel casing. The static water level at the time of logging was 24.83 ft bls. The caliper log shows major fractures at 35 and 54 ft blus and several smaller fractures throughout the borehole. The natural-gamma log shows a decrease in gamma counts at 35 ft bls (coal), and a increase in counts between 40 and 48 ft bls that is consistent with a siltstone unit; below 48 ft bls no other important changes in gamma counts over the length of the borehole, just normal variation in what appears to be predominantly sandstone. The single-point-resistance log shows a minor change in lithology at 61 ft bls which is indicative of a thin sandstone unit. The fluid-temperature log is generally flat with a small inflection centered on the fracture that correlates to a series of fractures shown on the caliper and the acoustic televiewer (ATV) log at 35 ft bls. The ATV log shows bedding planes (blue) and several fractures (red) or bedding plane separations. A total of 9 fractures were mapped. Most fractures were striking NW and SE with gentle dips (fig. 2).The water producing zone for this borehole appears to be a series of fractures located near 35 ft bls. The borehole deviates from vertical approximately 0.17 feet to the SSE.

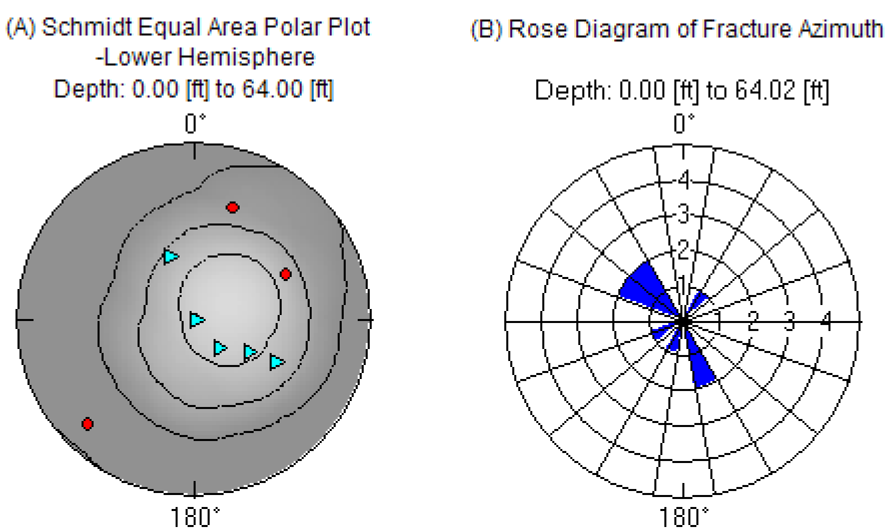



**Figure 5: Summary of fracture measurements for borehole Wyo-0148. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.**

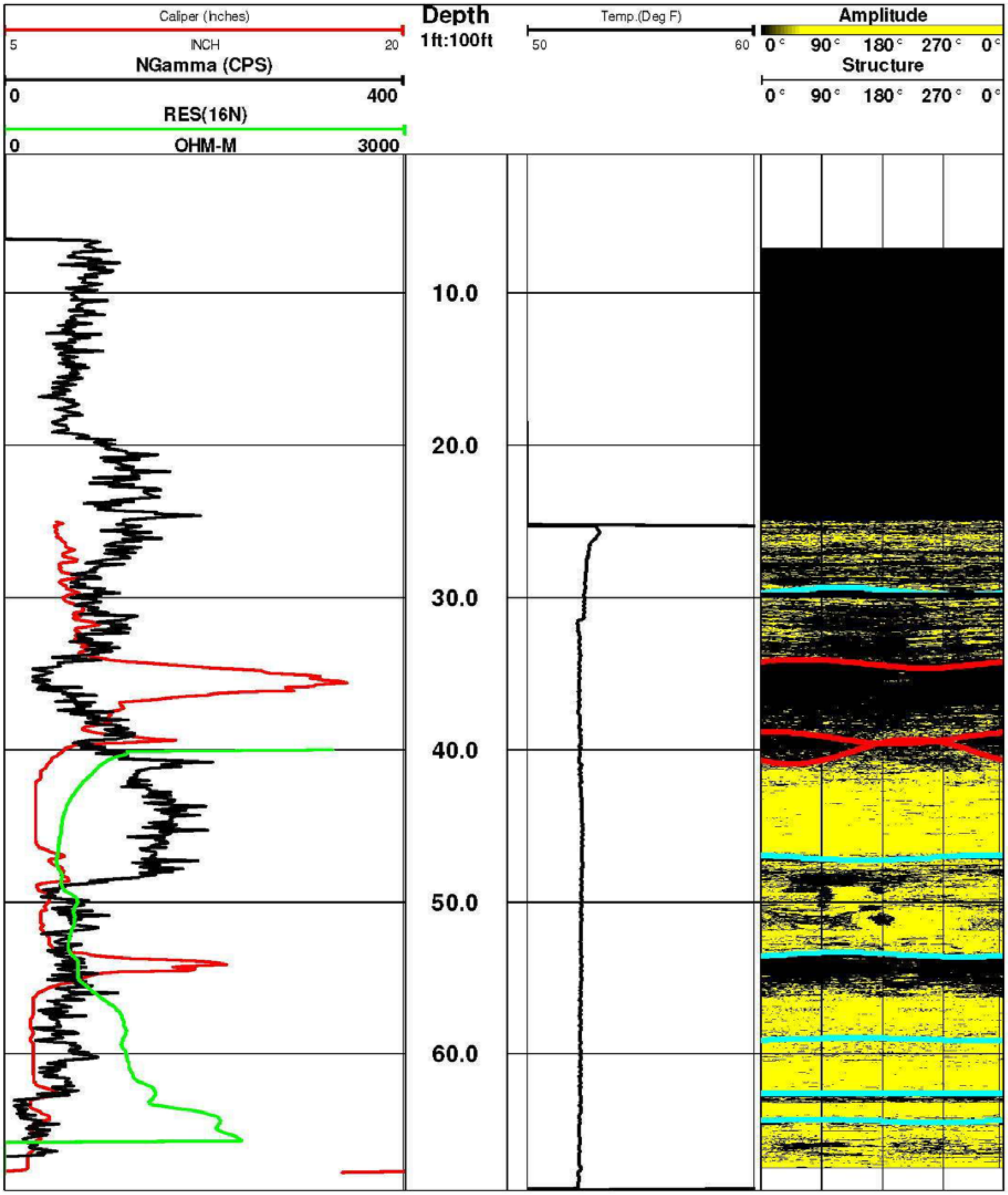



*Figure 6: Wyoming County #0148 geophysical well log.*

**Web-0167**

The caliper log shows that the total depth of the borehole is 80 ft bls and is cased to 24 ft bls. The static water level at the time of logging was 22.94 feet from top of casing (ft toc). The caliper log shows major fractures at 36, 47, and and several smaller fractures at 69-74 ft bls. The natural-gamma log shows a large change in gamma counts a 68-71 and 72-74 ft bls with and intervening low gamma count interval from 71-72. The lithology changes from sandstone with thin siltstone interbeds ( 24-68 ft bls) to siltstone at 68 ft bls with a thin sandstone interbedded at 71-72. The resistivity log shows a similar change in lithology at 65 ft bls. The ATV log shows numerous bedding planes (blue) and several fractures (red) and/or bedding plane separations. A total of 11 fractures striking NE and NW with gentle dips were mapped in the borehole (fig. 2). The borehole deviates from vertical approximately 0.20 feet to the ENE.

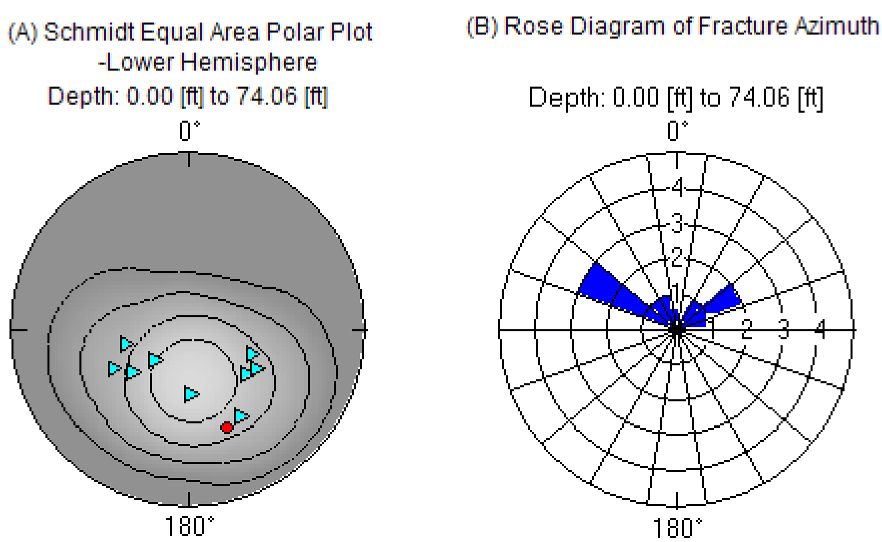



**Figure 7: Summary of fracture measurements for borehole Web-0167. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.**

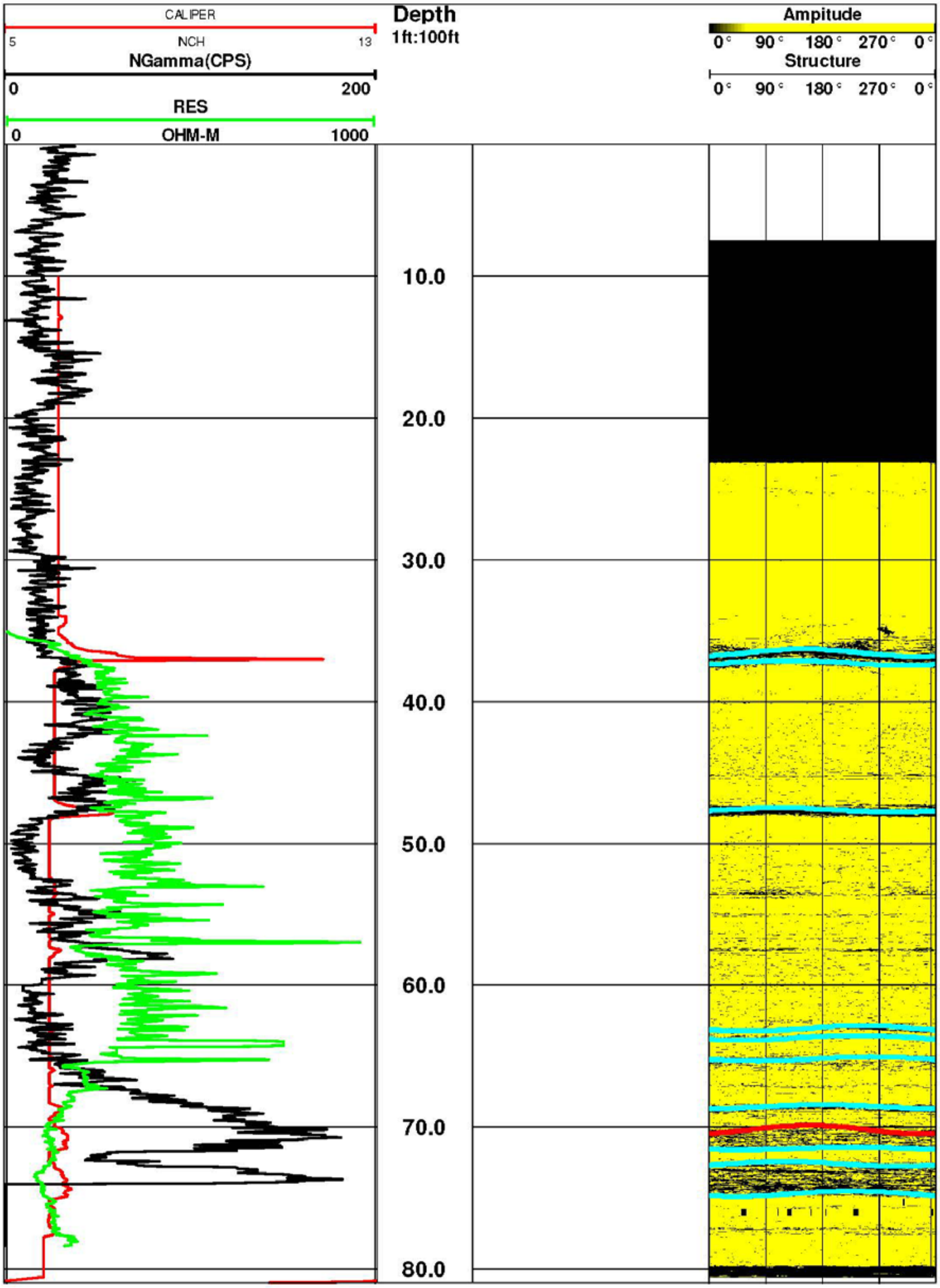



*Figure 9: Webster County #0167 geophysical well log.*

**Way-0144**

The total depth of the borehole is 106 ft bls and is cased to 20 ft bls with 6-in.-diameter steel casing. The static water level at the time of logging was 33.19 ft bls. The natural-gamma log shows multiple shifts throughout the borehole that indicate interbedded sandstones, siltstones, shales, and coal with layers ranging from 6-10 ft thick. The resistivity log shows similar changes in lithology to those indicated in the natural-gamma log. The fluid-temperature log shows only a slight deflection in the geothermal gradient at about 51 ft bls that is coincident with a coal layer. At depths greater than 51 ft bls, the fluid temperature log is flat and indicates no flow within the borehole at those depths.

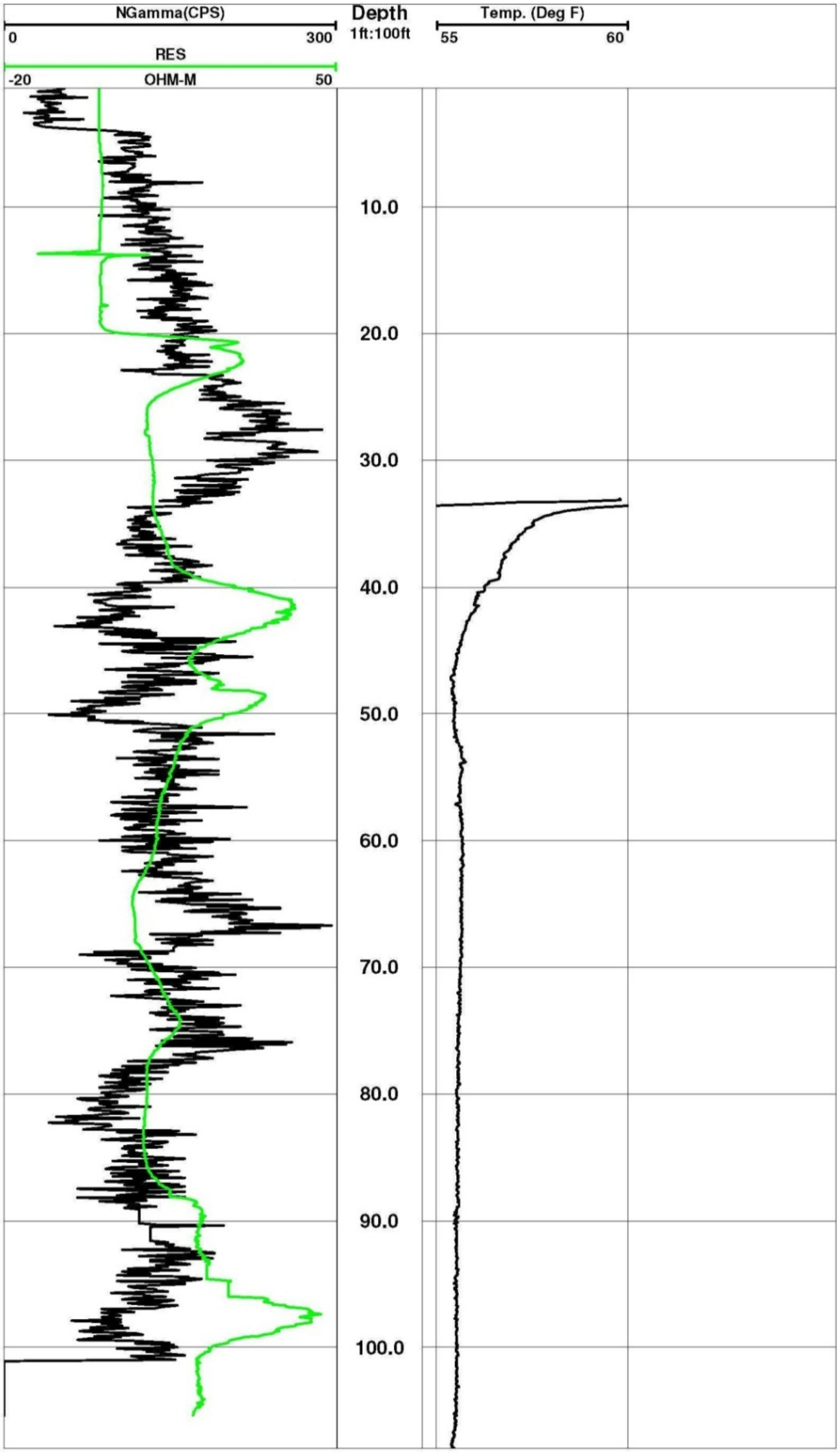



***Figure 10: Wayne County #0144 geophysical well log.***

**Poc-0256**

The caliper log shows that the total depth of the borehole is 84 ft bls and is cased to 48 ft bls with 6-in.-diameter steel casing. The static water level at the time of logging was 68.50 ft bls. The caliper log shows only one large fracture at 70 ft bls. The natural-gamma log shows a small shift at 70 ft bls and then only small changes in gamma counts over the length of the borehole. The consistency of the gamma log suggests the lithology is the same type rock unit with minor variations. The resistivity log shows numerous changes over the length of the borehole that may be related to changes in grain size or fractures. At 70 ft bls the resistivity log shows a large shift that suggests the fracture at that depth is consistent with a lithologic contact. The fluid-temperature log shows only a slight inverse geothermal gradient that is somewhat inconsistent for a deeper borehole of low production capabilities. The ATV log shows bedding planes (blue) and numerous fractures (red) and/or bedding plane separations. A total of 3 fractures gently dipping fractures were mapped in the borehole (fig. 3). The borehole deviates from vertical approximately 1.1 feet to the WSW.

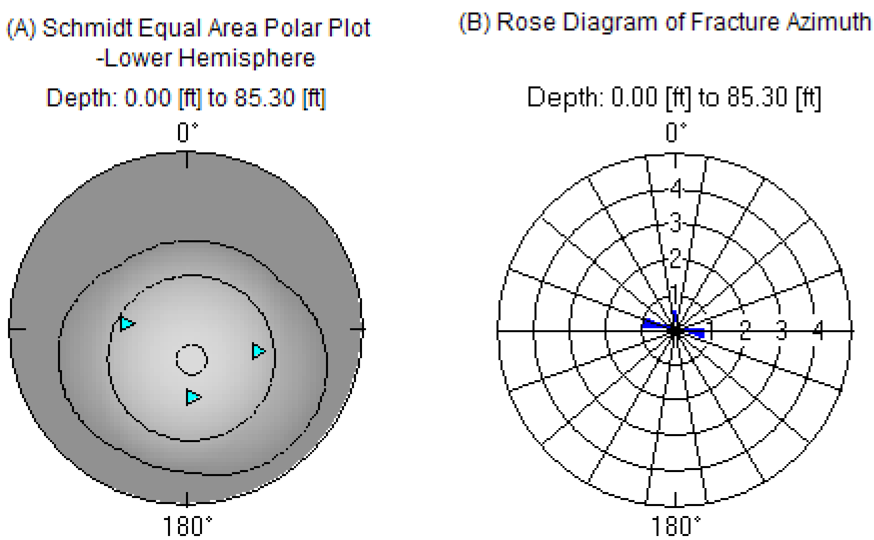



**Figure 11: Summary of fracture measurements for borehole Poc-0256. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.**

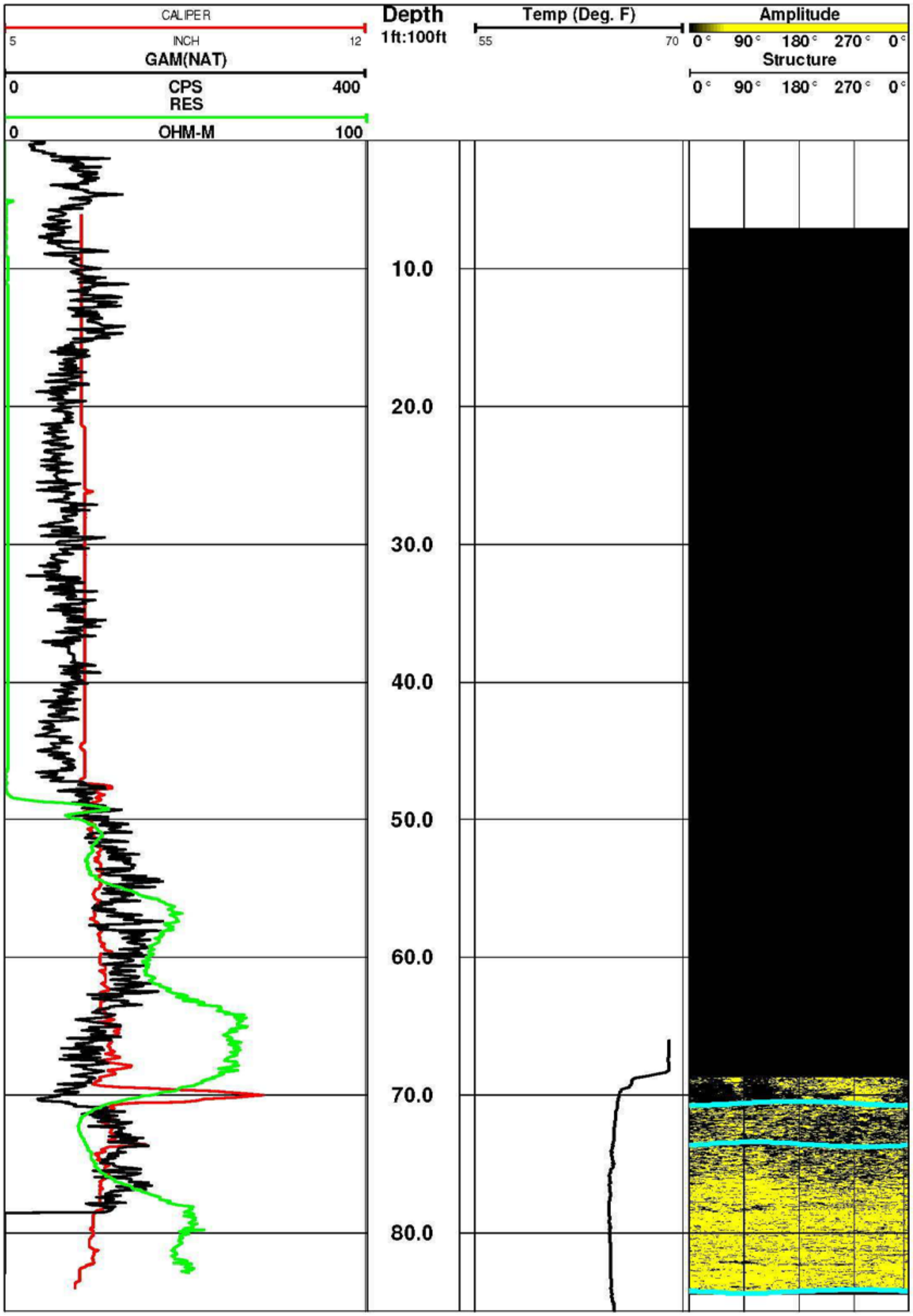



*Figure 12: Pocahontas County #0256 geophysical well log.*

**MNG-0585**

The caliper log shows that the total depth of the borehole is 218 ft bls and is cased to 26 ft bls with 6-in.-diameter steel casing. The static water level at the time of logging was 27.14 ft bls. The caliper log shows notable fractures at 27-31, 44-62, 88, 131, 159, and 167-169 ft bls and numerous smaller fractures throughout the borehole. Under nonpumping conditions the heatpulse flowmeter measured no borehole flow below 90 ft bls. Water enters the borehole at 51, 53, and 90 ft bls at a respective rate of 0.1, 0.3, and 0.1 gpm (Table 1). All of the water exits the borehole at the 27-13 ft bls fracture zone. The natural-gamma log shows a siltstone unit at 44-62 and 131-210 ft bls. The remaining portions of the borehole are comprised of sandstone units. The resistivity log shows small resistance peaks at major fracture zones at 62, 129, and 168 ft bls that is in proximity to fractures on the caliper and ATV logs and suggest water producing zones. The fluid-temperature log shows a slight inverse geothermal. The ATV log shows bedding planes (blue) and numerous fractures (red) and/or bedding plane separations (fig. 4). There were 33 fractures mapped in the borehole with most fractures oriented orthogonal to bedding. The main water producing zone for this borehole is the fracture located at 44 ft bls. The borehole deviates from vertical approximately 1.9feet to the SSE.

**Table 5: Summary of heatpulse-flowmeter measurements for borehole Mng-0585** (ft bls, feet below land surface; gal/min, gallon per minute)

| Depth (ft bls) | Flow rate under nonpumping conditions (gal/min) |
|---|---|
| 27-31 | 0.5 out |
| 51 | 0.1 up |
| 53 | 0.3 up |
| 90 | 0.1 up |
| 131 | No flow |
| 159 | No flow |
| 167-169 | No flow |

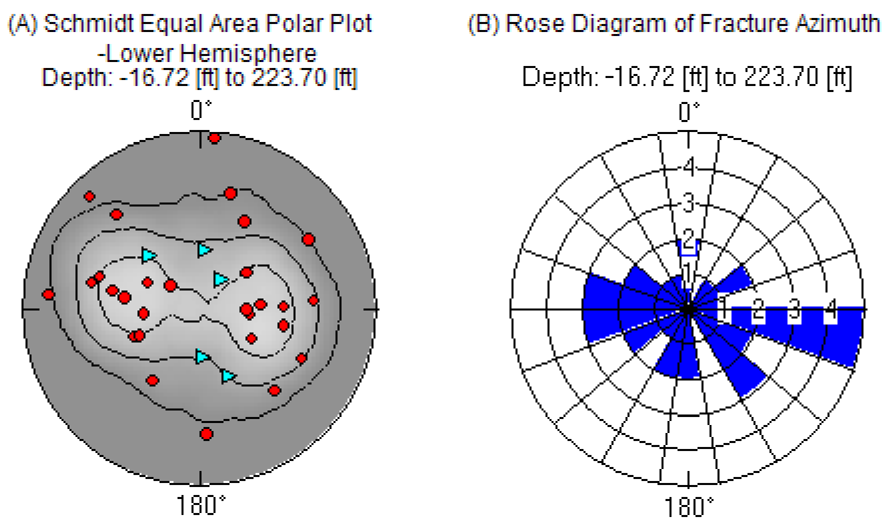
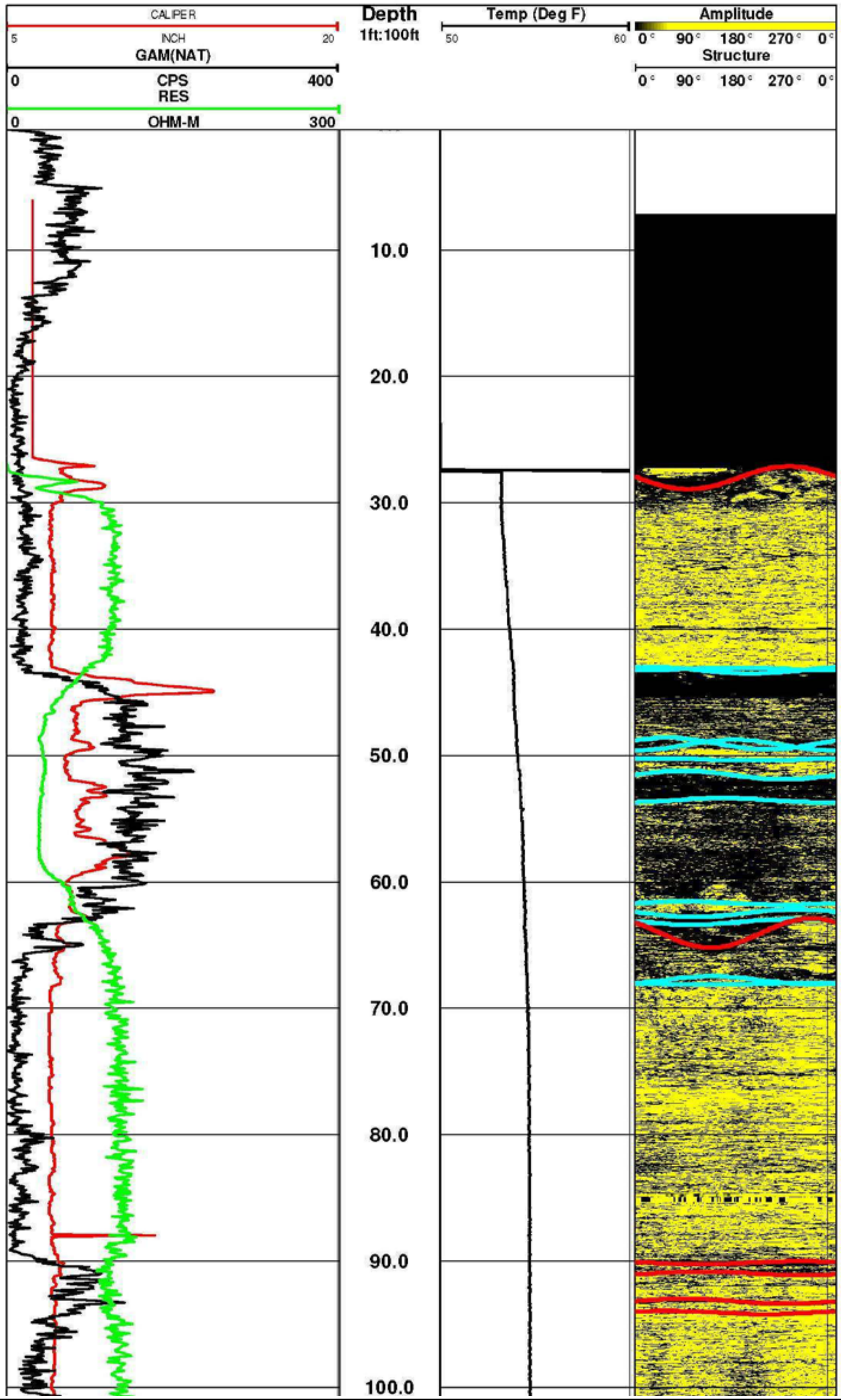



**Figure 13: Summary of fracture measurements for borehole Mng-0585. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.**



CALIPER
INCH
5
20
GAM(NAT)
0
CPS
400
RES
0
OHM-M
300
Depth
1ft:100ft
Temp (Deg F)
50
60
Amplitude
0° 90° 180° 270° 0°
Structure
0° 90° 180° 270° 0°
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0

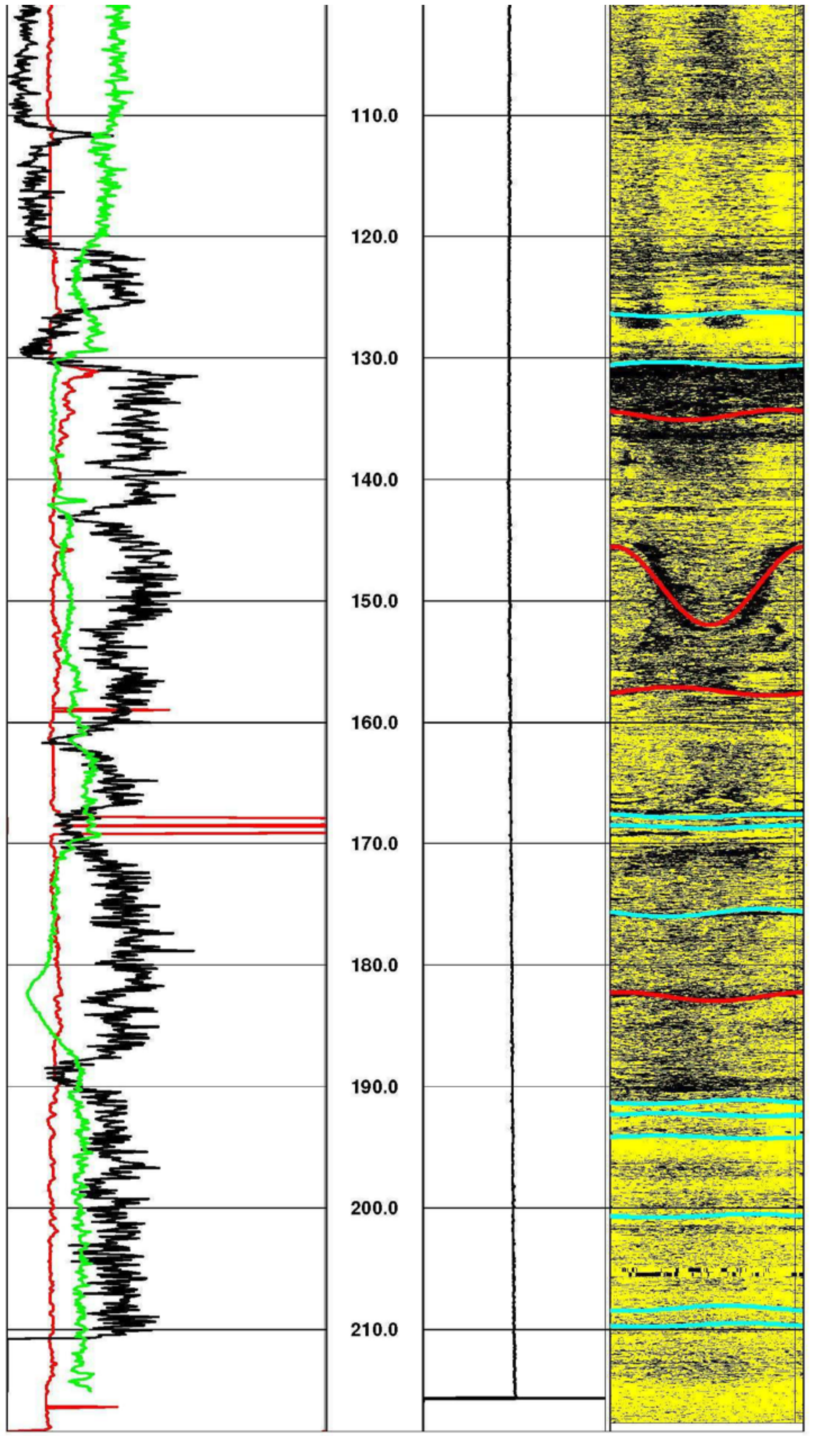



***Figure 14: Monongalia County #0585 geophysical well log.***

**Kan-0946**

The total depth of the borehole is 106 ft bls and is cased to 40 ft bls with 6-in.-diameter steel casing. The static water level at the time of logging was 28.48 ft bls. The natural-gamma log is relatively uniform indicating a single dominant lithology throughout the borehole except for a small coal interval at 78 ft bls. The resistivity log shows similar changes in lithology to those indicated in the natural-gamma log with the addition of a small coal-related peak at 84 ft bls.

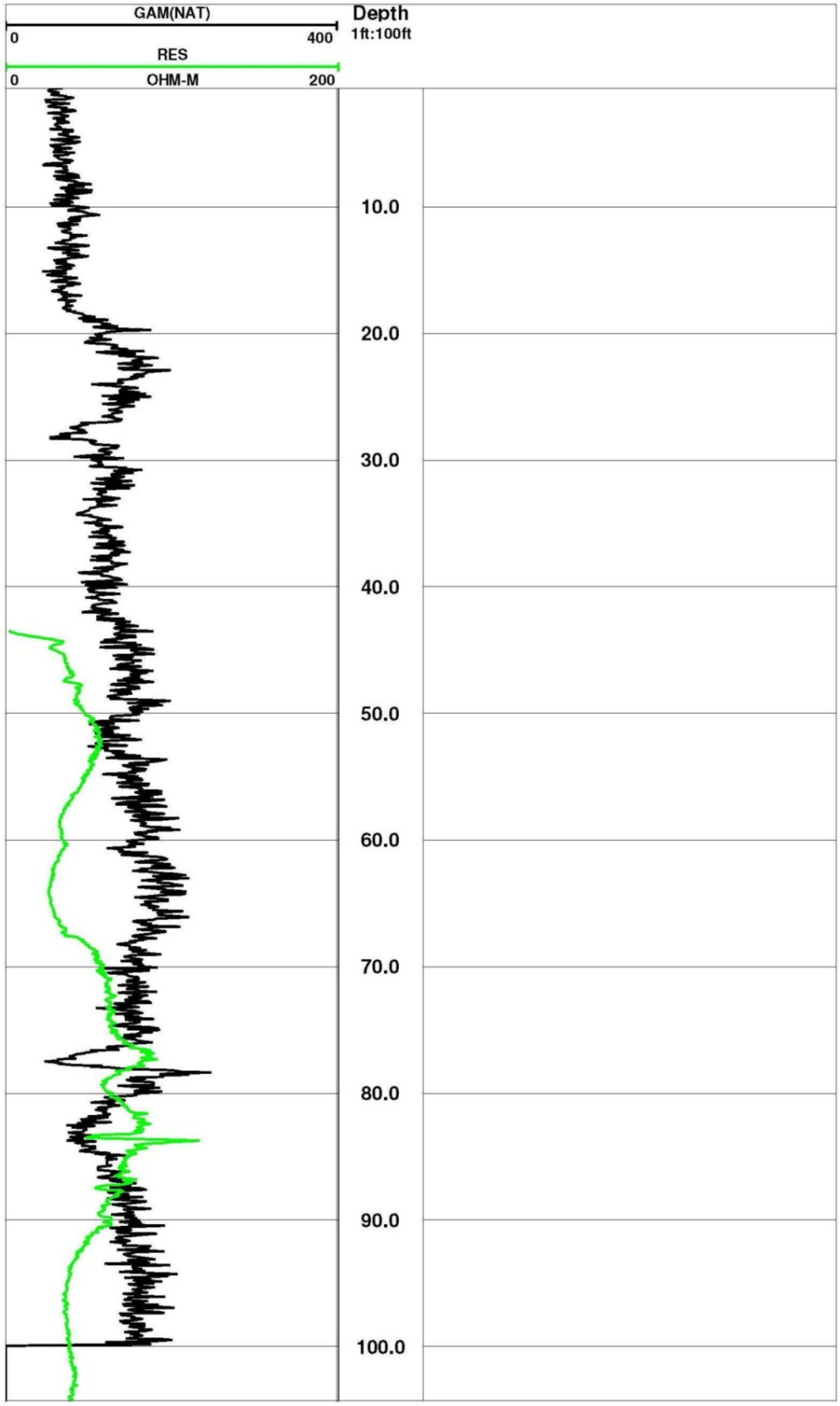



***Figure 15: Kanawha County #0946 geophysical well log***

## Ber-0445

The caliper log shows that the total depth of the borehole is 231 ft bls and is cased to 39 ft bls with 6-in.-diameter steel casing. The static water level at the time of logging was 39.02 ft bls. The caliper log shows notable fractures at 45, 48, 75, 129, 134, 145, and 161 ft bls and numerous smaller fractures throughout the borehole. Under nonpumping conditions the heatpulse flowmeter measured no borehole flow below 129 ft bls. Water enters the borehole at 52, 71, 129 ft bls at a respective rate of 2.2, 3.0, and 7.4 gpm (Table 2). All of the water exits the borehole at the 43 ft bls fracture. The natural-gamma log is unchanged throughout the borehole indicating that carbonate rocks are the single dominant lithology. The resistivity log shows a large inflection at 129 ft bls coincident with a large fracture in the caliper log. The fluid-temperature log shows a slight inverse geothermal. The ATV log shows numerous fractures (red) and/or bedding plane separations (fig. 5). There were 15 fractures mapped in the borehole with most fractures oriented orthogonal to bedding. The main water producing zone for this borehole is the fracture located at 129 ft bls. The borehole deviates from vertical approximately 4.1 feet to the NE.

**Table 6: Summary of heatpulse-flowmeter measurements for borehole Ber-0445**

[ft bls, feet below land surface; gal/min, gallon per minute

| Depth (ft bls) | Flow rate under nonpumping conditions (gal/min) |
|---|---|
| 43 | 10.9 out |
| 52 | 0.8 up |
| 71 | 2.4 up |
| 129 | 7.7 up |
| 134 | No flow |
| 145 | No flow |
| 161 | No flow |

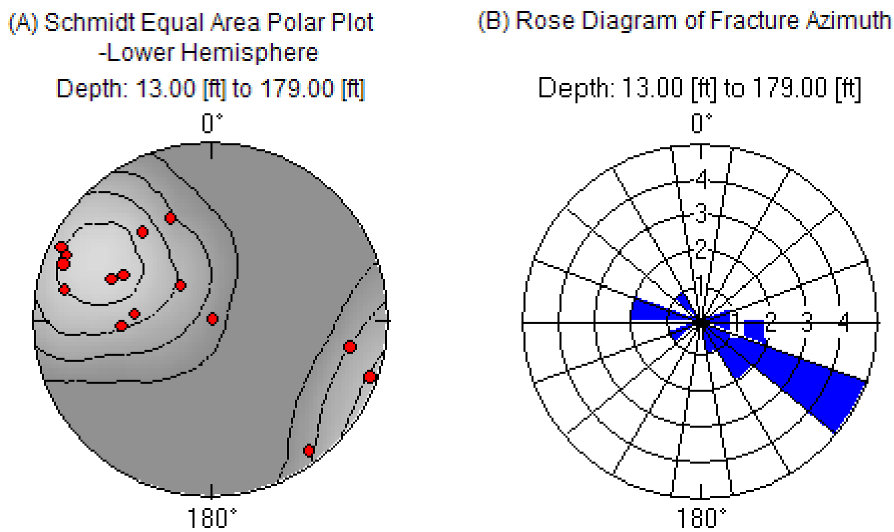
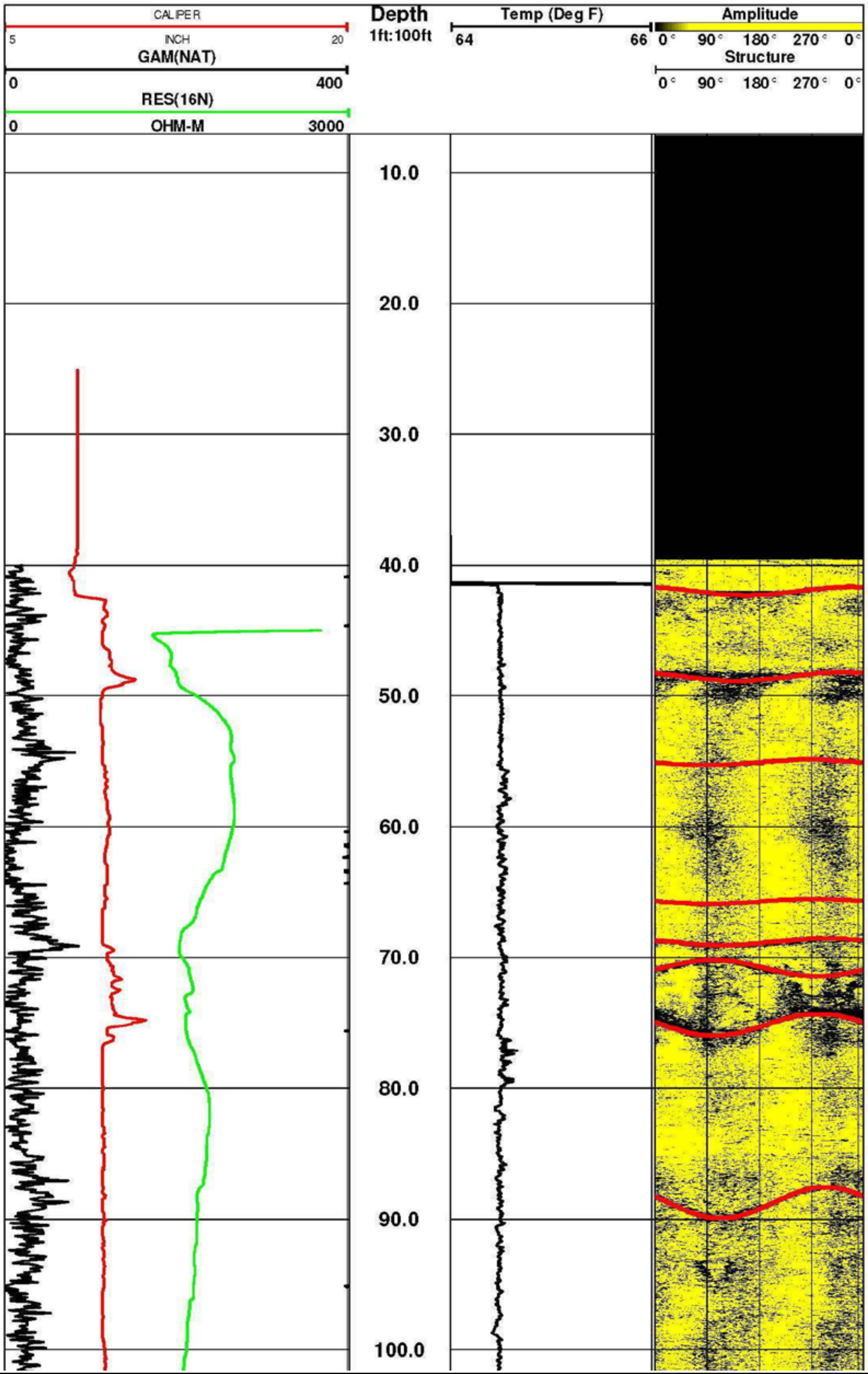
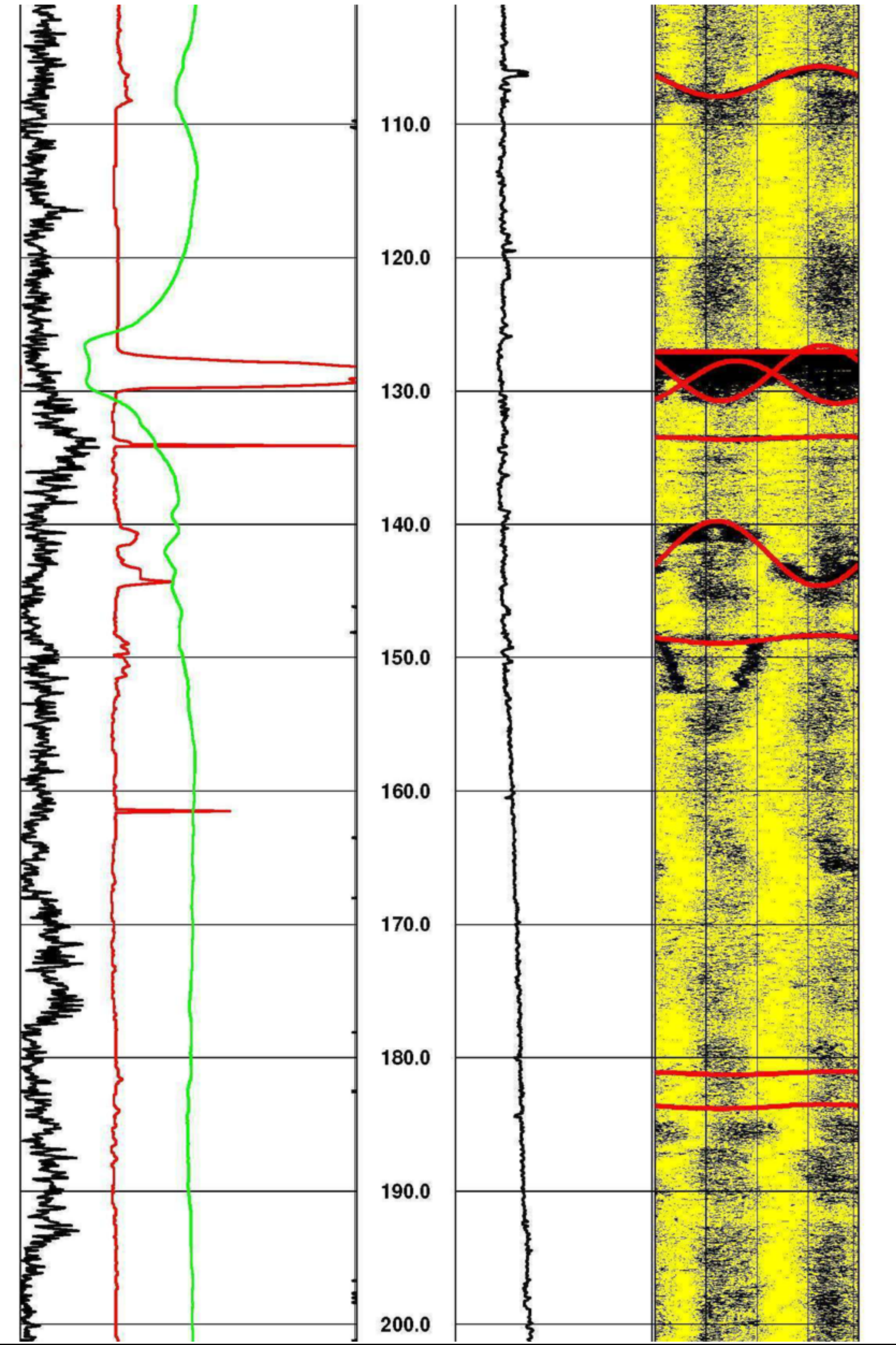



**Figure 16: Summary of fracture measurements for borehole Ber-0445. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.**


CALIPER
5 INCH 20
GAM(NAT)
0 400
RES(16N)
0 OHM-M 3000
Depth
1ft:100ft
Temp (Deg F)
64 66
Amplitude
0° 90° 180° 270° 0°
Structure
0° 90° 180° 270° 0°
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0



110.0
120.0
130.0
140.0
150.0
160.0
170.0
180.0
190.0
200.0

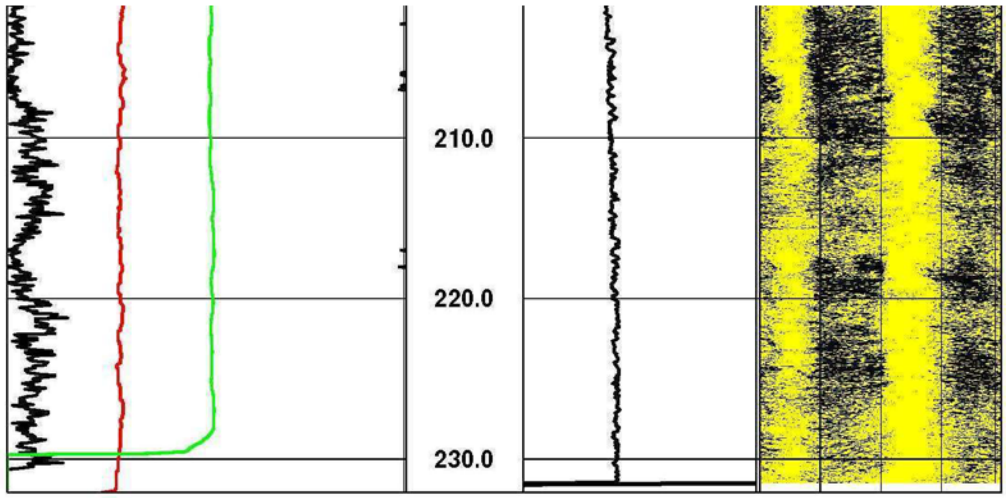



***Figure 16: Berkeley County #0445 geophysical well log***

**Bar-0135**

The caliper log shows that the total depth of the borehole is 179 ft bls and is cased to 40 ft bls with 6-in.-diameter steel casing. The caliper log shows notable fractures at 85, 104, 120-121, 132, 138-139, 162, and 175 ft bls and numerous smaller fractures throughout the borehole. Under nonpumping conditions the heatpulse flowmeter measured no borehole flow from any of the fractures noted by the caliper (Table 3). The natural-gamma log is shows lithologic changes from sandstone to coal at 105, 118, and 121 ft bls. The resistivity log shows a inflections coincident with the coals and a fracture in sandstone at 164 ft bls noted in the caliper log. The fluid-temperature log shows a slight inverse geothermal in upper portions of the borehole. The ATV log shows shows bedding planes (blue) and numerous fractures (red) and/or bedding plane separations (fig. 6). There were 12 fractures mapped in the borehole with most fractures oriented with bedding. The borehole deviates from vertical approximately 1.7 feet to the SSW.

**Table 7: Summary of heatpulse-flowmeter measurements for borehole Bar-0135**

[ft bls, feet below land surface; gal/min, gallon per minute

| Depth (ft bls) | Flow rate under nonpumping conditions (gal/min) |
|---|---|
| 85 | No flow |
| 104 | No flow |
| 120-121 | No flow |
| 132 | No flow |
| 138-139 | No flow |
| 162 | No flow |
| 175 | No flow |

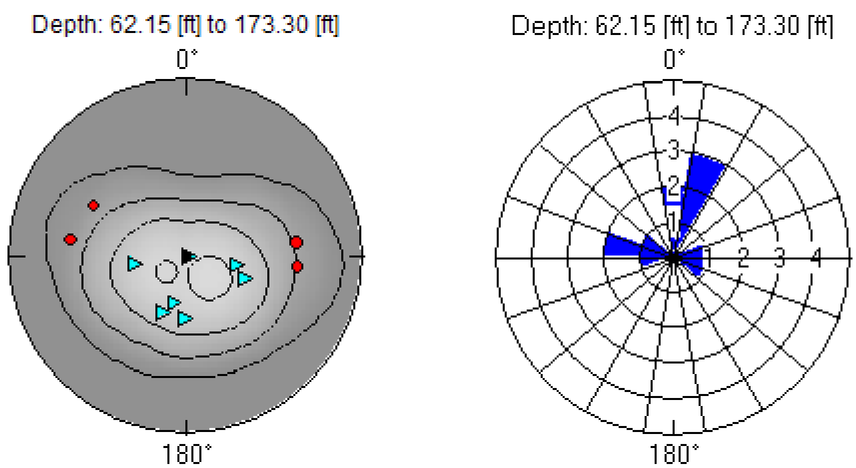
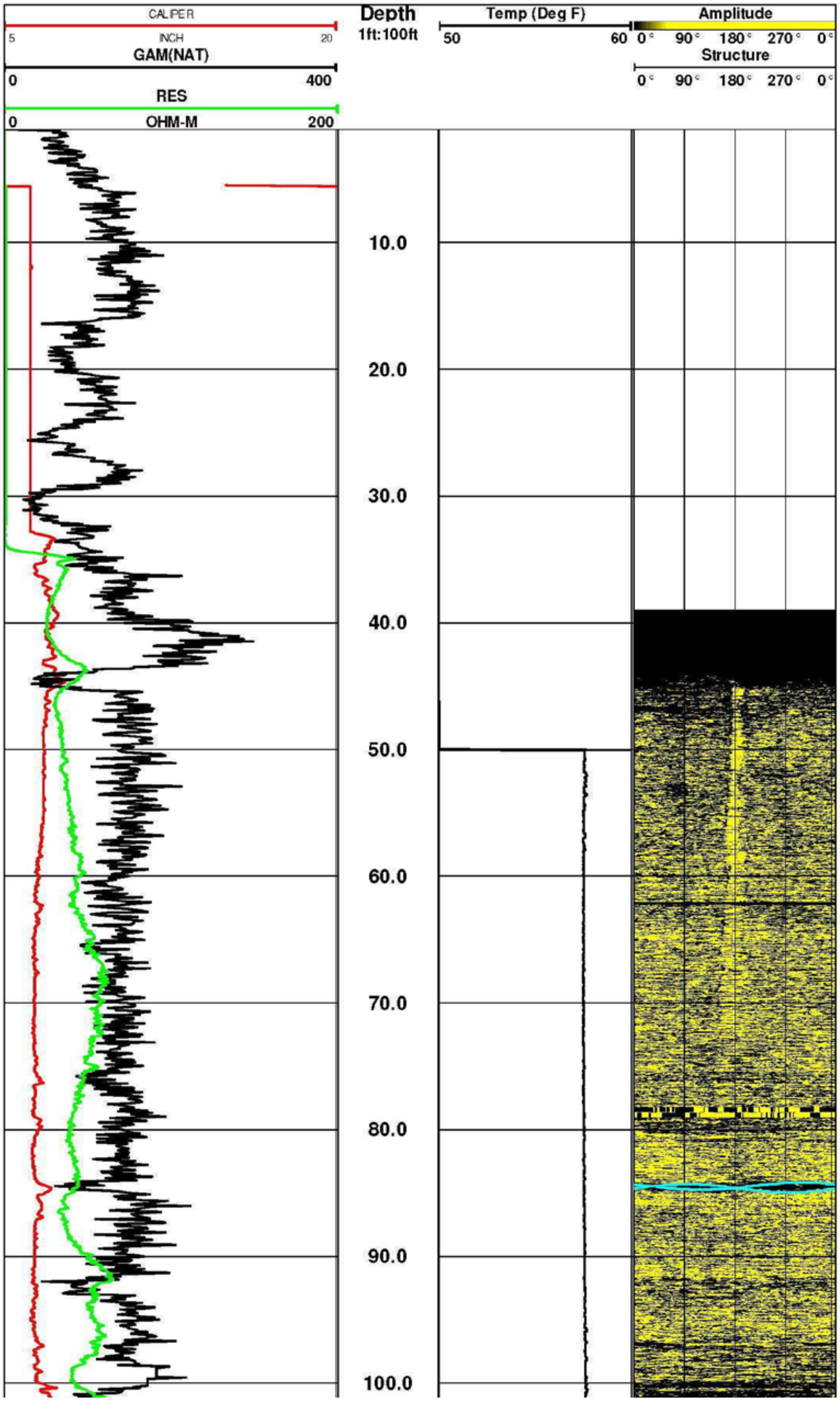



**Figure 17: Summary of fracture measurements for borehole Bar-0135. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.**



CALIPER
5 INCH 20
GAM(NAT)
0 400
RES
0 OHM-M 200
Depth
1ft:100ft
Temp (Deg F)
50 60
Amplitude
0° 90° 180° 270° 0°
Structure
0° 90° 180° 270° 0°
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0

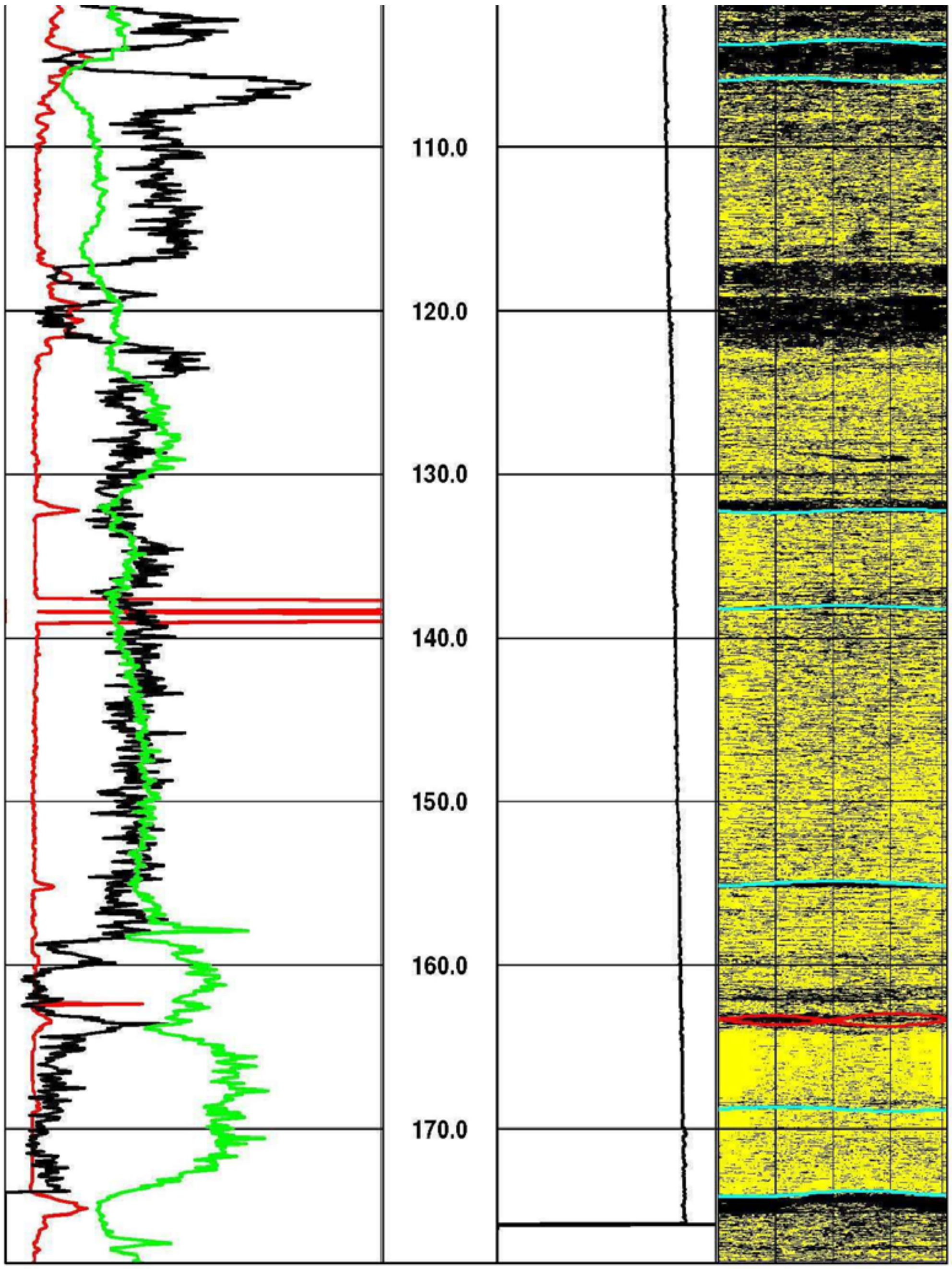



***Figure 19:  Barbour County #0136 geophysical well log***

As USGS projects are completed, the well logs for the investigations will be added to the archive to continue to build the database of well logs available for retrospective analyses. The archive at present contains well logs for only 29 wells, so additional wells are needed and will be added as opportunities occur. Plans are for a retrospective analysis of fracture data for water wells in West Virginia, but at least another 20 to 30 wells and funding are needed before such a retrospective analysis would be feasible.

# Appendix H

## Comparison of Programs and Water Use in West Virginia Border States

## Large Quantity User Programs

Of the 5 border states, all have a withdrawal registration program that require users who withdrawal more than 10,000 gallons of water per day (gpd), except Ohio who requires any user having the *capacity* to withdrawal more than 100,000 gpd, to register withdrawals. In conjunction with user registration Virginia, Ohio, Maryland, and Kentucky have permitting requirements that may vary based on the cost of the project, estimated amount of water to be withdrawn, intended duration of withdrawals and potential disturbance of stream flows or wetlands in conjunction with planned withdrawals. In each state multiple agencies may play a role in the permitting process and have varying instructions regarding limits, reporting requirements, permit duration, analysis and monitoring for the user to complete per source. Only Virginia requires payment of fees to obtain a withdrawal permit for general withdrawal operations (Table 1).

**Table 1 Current definitions, exemptions, and requirements for Border States regarding Large Quantity Users (LQU) in each state.**

| BORDER STATE | DELEGATION OF RESPONSIBILITY | USERS/EXEMPTIONS | REGISTRATION/REPORTING/PERMIT/ FEES | SOURCES |
|---|---|---|---|---|
| KY | Environmental Protection Cabinet<br>Division of Water<br>http://water.ky.gov | All withdrawal, transfer, and diversion >10,000gpd<br>EXEMPT<br>Single household, agriculture(unless impounded), Electricity producing plants regulated by KYPSC, UI for O&G | No Fee Permit limits user to current requirements, may provide protection for others, user must maintain accurate monthly records regarding daily withdrawals | Any surface, ground, or spring including private impound-ments |
| MD | Maryland Department of Environment (MDE)<br>http://www.mde.state.md.us | All withdrawal activities regardless of planned amounts<br>EXEMPT<br>Extinguishing a fire, agricultural use <10,000gpd, groundwater users <5,000gpd that are private or outside strategy area | No fee Permit must stay within limits and report periodically specific to permit, subject to review every 3years, other requirements relating to testing and analysis as well as approvals from other entities possible | Any of the State's surface and/or underground waters |
| OH | Ohio Department of Natural Resources (ODNR)<br>Division of Soil and Water Resources<br>http://www.dnr.state.oh.us | All users with the *capacity* to withdrawal >100,000gpd AND consumptive uses >2,000,000gpd | Required initial registration and annual reporting of withdrawals and discharges; published as part of online withdrawal atlas .pdf file. Permit required for consumptive uses >2,000,000gpd. | All sources of waters of the state |
| PA | Pennsylvania Department of Environmental Protection (DEP)<br>http://www.pawaterplan.dep.state.pa.us | Public water suppliers and hydropower facilities regardless of withdrawal amount, anyone withdrawing >10,000gpd or transferring >100,000gpd | Required registration and annual reporting as well as 5 year record retention. Public supply and hydropower must meter flows | All sources |

| | | | | |
|---|---|---|---|---|
| VA | Virginia Department of Environmental Quality (DEQ) http://www.deq.virginia.gov<br><br>Virginia Marine Resources Commission (VMRC) http://www.mrc.virginia.gov/hmac/hmoverview.shtm | Minor: Crop production >1,000,000gpm, ALL others >10,000gpd, voluntary reporting of lower withdrawals encouraged.<br>Major: >90,000,000gpm of if filling, flooding, or alteration of stream flow occurs.<br>Groundwater: Specified management areas | Required annual online reports of monthly withdrawals are published in Annual Water Resources Report. Permit required for minor with-drawals and encroachment. A Joint Permit is required for major with-drawals. Permit required for ground-water use in management areas. Applications are submitted to VMRC then distributed to participating agencies to decide separately. Permit fees are determined individually by each agency and subject to change. Permits validity varies based on the project from 3 – 15 year max terms. | Surface and groundwater withdrawals |
| SRBC | Susquehanna River Basin Commission http://www.srbc.net/ | Consumptive users who use an avg. >20,000gpd in 30 days<br>EXEMPT<br>Public Supply and Agriculture (conditionally)<br>Withdrawals from basin that avg. >100,000gpd in 30 days<br>EXEMPT<br>Hydroelectric (conditionally)<br>Diversions out of the basin that avg. >20,000gpd in 30 days<br>EXEMPT<br>Agriculture (conditionally) | Required application for initial use, withdrawals, and diversions as well as increases in uses or withdrawals regardless of proposed increase. No term of approval shall exceed 15 years. Fees and interest are subject to the amount consumed, which are set to meet the requirements of the Commission in order to cover its costs of administering the regulatory program. | Surface and/or groundwater in the basin before or after use/ withdrawal |

## Water Resource Planning Programs

Several of the border states chose to organize the planning process by local and regional government jurisdictions (Table 2). For example, Kentucky assigned water resource planning to 15 area development districts (ADD), each encompassing multiple counties, while Maryland and Virginia more loosely assigned responsibility to local jurisdictions such as single counties and other municipalities. By using this division, responsibility is split between state environmental and planning/infrastructure agencies. Ohio and Pennsylvania have designated local governments and sub-regional watersheds within larger area watersheds as the responsible parties for developing water resource plans to contribute to the overall state plan, thereby leaving the entire process in the hands of the respective environmental agencies. Within each overall management plan some additional resources are made available to the responsible parties to aid in their planning process. In order to make the necessary data available to local and regional planners most states have developed online resource look-up tools. All of the border states, except Virginia have developed an interactive online tool with varying degrees of information and capability. More detail regarding the type of tool and information available may be reviewed in Table 2. Kentucky, Pennsylvania, and Virginia assigned coordinators, committees, and councils, respectively, to provide consultations and information. Maryland developed a Models and Guidelines document – Planning for Water Supply and Wastewater and Stormwater Management for planners.

**Table 2 Current progress of Border States and available resources regarding a comprehensive state-wide water management plan.**

| **BORDER STATE** | **DELEGATION OF RESPONSIBILITY** | **STRUCTURE** | **ADDITIONAL PLANNING RESOURCES** | **RELATED DATABASE MANAGEMENT** |
|---|---|---|---|---|
| KY | Kentucky Infrastructure Authority (KIA)<br>http://kia.ky.gov/default.htm<br><br>Environmental Protection Cabinet Division of Water<br>http://water.ky.gov/Pages/default.aspx | 15 area development districts (ADD) by groups of county governments | ADD Water Management Coordinators – provide consultations and information | KIA Water Resource Information System (WRIS) – GIS, facilities, lines, sources, facilities, and projects |
| MD | Maryland Department of Planning (MDP)<br>http://www.mdp.state.md.us/OurWork/WaterResources.shtml<br><br>Maryland Department of Environment (MDE)<br>http://www.mde.state.md.us/programs/water/water_supply/ | Local jurisdictions – counties and municipalities | Models and Guidelines document – Planning for Water Supply and Wastewater and Stormwater Management | MDP interactive maps – Priority funding, land cover, ag., census 2010 (demographic / economic outlook), schools, political districts |
| OH | Ohio Department of Natural Resources (ODNR)<br>Division of Soil and Water Resources<br>http://www.dnr.state.oh.us/water/ | 5 Major watershed regions and communities and sub-regional hydrologic units | ODNR Water Inventory Program – precipitation, groundwater levels, reservoir storage, and stream flow data | ODNR Action Plan Map, links local plans with a state endorsement status regarding supply, quality, flooding, and land mgmt. |
| PA | Pennsylvania Department of Environmental Protection (DEP)<br>Office of Water Management<br>http://www.portal.state.pa.us/portal/server.pt/community/watershed_management/10593 | 6 Regional watersheds and local governments | State Water Plan Committee meetings and training, withdrawal data, WAVE and eMap PA tools for resource and environmental data, and stream stats | State Plan/ Digital Water Atlas an Interactive web GIS tool - Plan areas, resources, storm/flooding maps, geology, land cover, supply and WWT |
| VA | Virginia Department of Environmental Quality (DEQ)<br>http://www.deq.virginia.gov/Programs/Water.aspx | All counties, cities, and towns | State Supply Plan Advisory Committee, Proposed State Work Plan | Status of Virginia's Water Resources: A Report on VA Water Resources Management Program Activities, 2011 |

| | | | | |
|---|---|---|---|---|
| SRBC | Susquehanna River Basin Commission http://www.srbc.net/about/index.htm | 4 Commissioners (Federal, PA, MD, and NY) for entire Susquehanna basin | Biannual Water Resources Program used to implement the 'actions needed' listed in the Comprehensive Plan (updated every 5 years) | SRBC Maps & Data Atlas includes maps, downloadable GIS data, and a current projects map gallery |

## Water Demand

In 2005 West Virginia only used about 10% of the share of water withdrawn by it and the five states bordering it from the total used in the United States. Kentucky is the most comparable to West Virginia in volume, utilizing 9% of the total water withdrawn by the group. However, although comparable in total volume, the population in Kentucky is in excess of twice as much as West Virginia. Ohio, Virginia, an Pennsylvania are the highest use contributors to this group using about 24%, 22%, and 20% of the group total, respectively (Figure 1). Maryland has experienced similar fluctuations in use over time as West Virginia but uses more total water (Figures 1 and 2). Also, Maryland has a population more than three times as large as West Virginia but withdraws less than twice as much water (Figure 2).

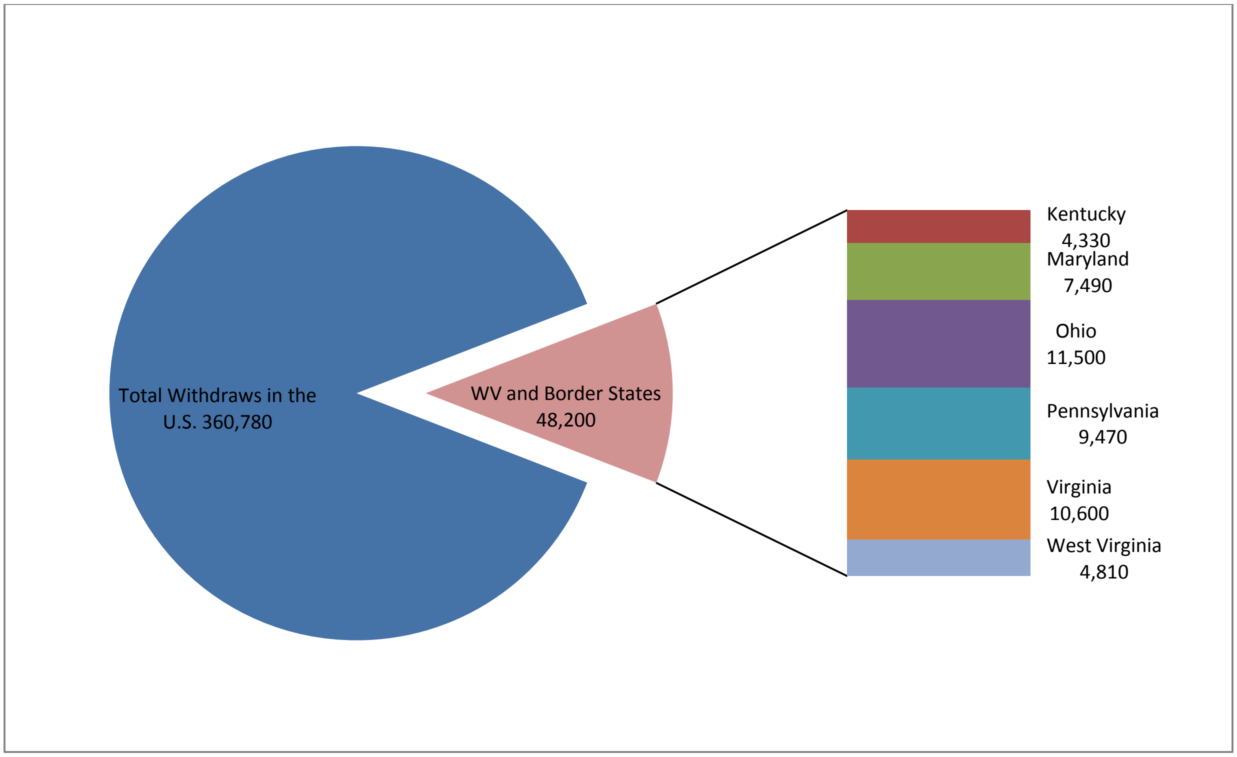



**Figure 1 West Virginia and Border States' Contribution to the USGS Estimates of Total Water Withdrawals in the United States in 2005 in Mgal/day.**

Since 1995, the two highest contributors in the group, Ohio and Virginia have seen a steady increase in water usage with Virginia having an increase in use of more than 28% from 1995 to 2005 (Figure 2). Pennsylvania, Maryland, and West Virginia all saw fluctuations in use with 2000 being the highest water use year in the 5 year intervals from 1995-2005 while Kentucky also fluctuated over the three time intervals, the lowest use year was 2000 (Figure 2). The steady increase in water withdrawals in Ohio and Virginia coincide with the USGS estimates of percent change in population from 1995 (Figure 3).

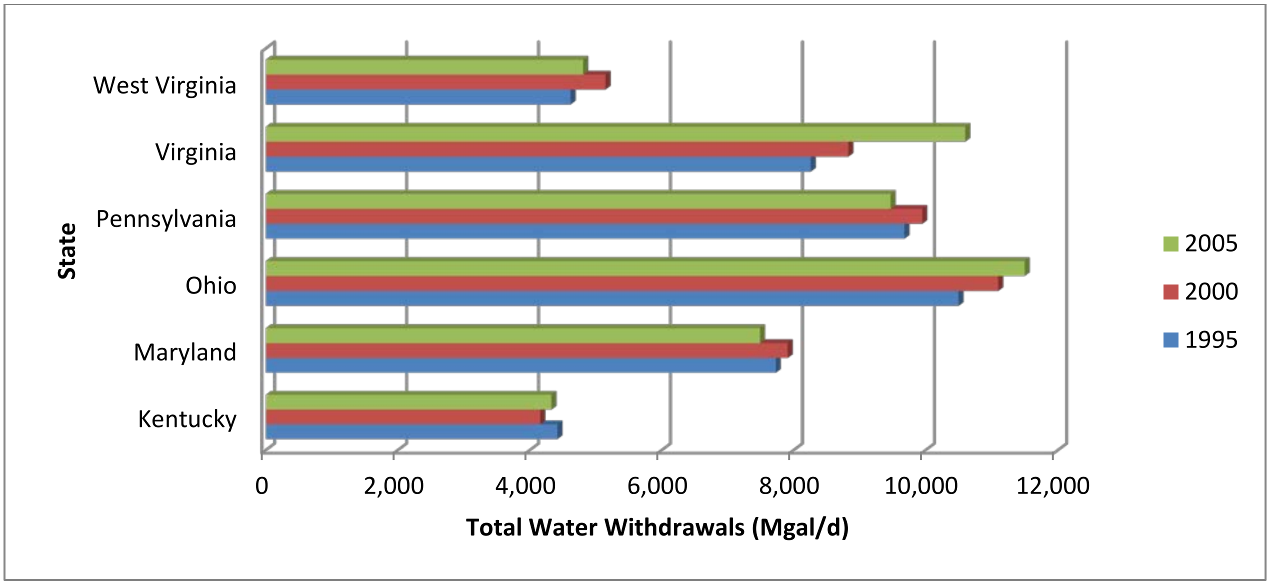
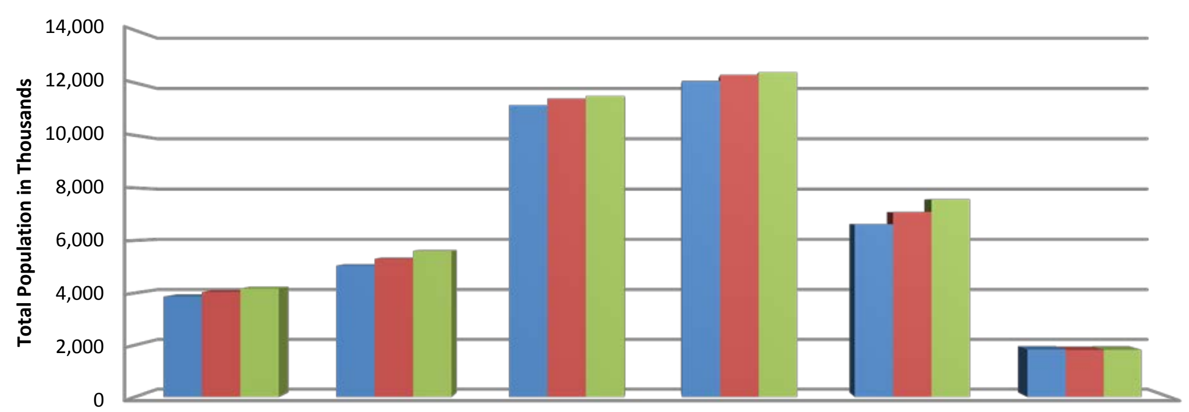



Figure 2 USGS Estimates of Total Water Withdrawals by State for 5 year Intervals in Mgal/day.




| | Kentucky | Maryland | Ohio | Pennsylvania | Virginia | West Virginia |
|---|---|---|---|---|---|---|
| 1995 | 3,860 | 5,042 | 11,151 | 12,072 | 6,618 | 1,828 |
| 2000 | 4,040 | 5,300 | 11,400 | 12,300 | 7,080 | 1,810 |
| 2005 | 4,170 | 5,600 | 11,500 | 12,400 | 7,570 | 1,820 |

Figure 3 USGS Statewide Population Estimates for 1995, 2000, and 2005.

According to USGS estimates the majority of water used by Ohio is used for public supply which again confirms the steady increase in total withdrawals over the available time intervals (Figure 4). Virginia also uses a large portion of its withdrawals for public supply and has seen increases in population however, the largest jump in total withdrawals, from 2000 to 2005, may also be attributed to the addition of withdrawals for aquaculture to the overall total in 2005 as well as better recording methods across all categories (Figure 5).

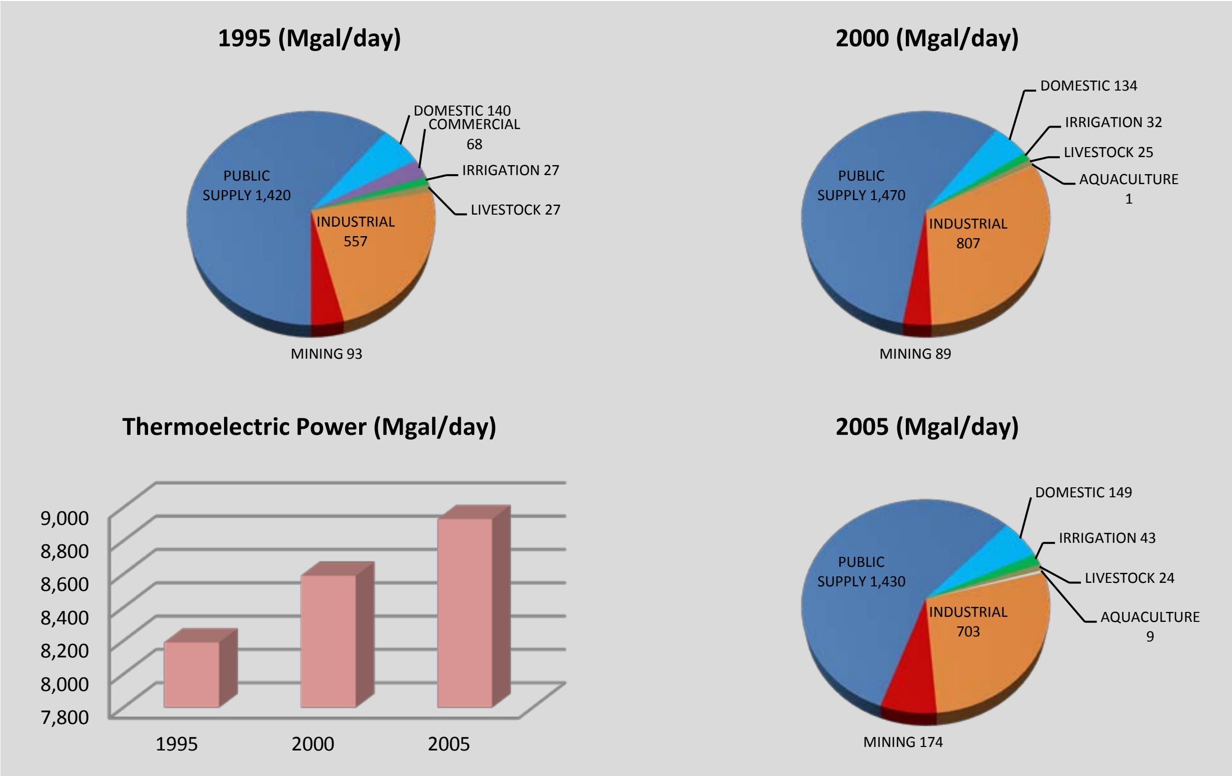


**Figure 4 USGS Estimate of Ohio's Water Withdrawals (Mgal/day) by Category of Use and Year.**

Pennsylvania, Maryland, and Kentucky all saw increases in the percent of population from 1995 to 2000 and 2005, however the increase in water use for thermoelectric power in 2000 when compared to both 1995 and 2005 in Pennsylvania (Figure 6) and Maryland (Figure 7) may account for the larger increase in total withdrawals in 2000 for those states (Figure 2.). Kentucky's decrease in total water withdrawals in 2000 may be attributable, at least in part, to the decrease in recorded water use estimates for thermoelectric power that year (Figure 8).

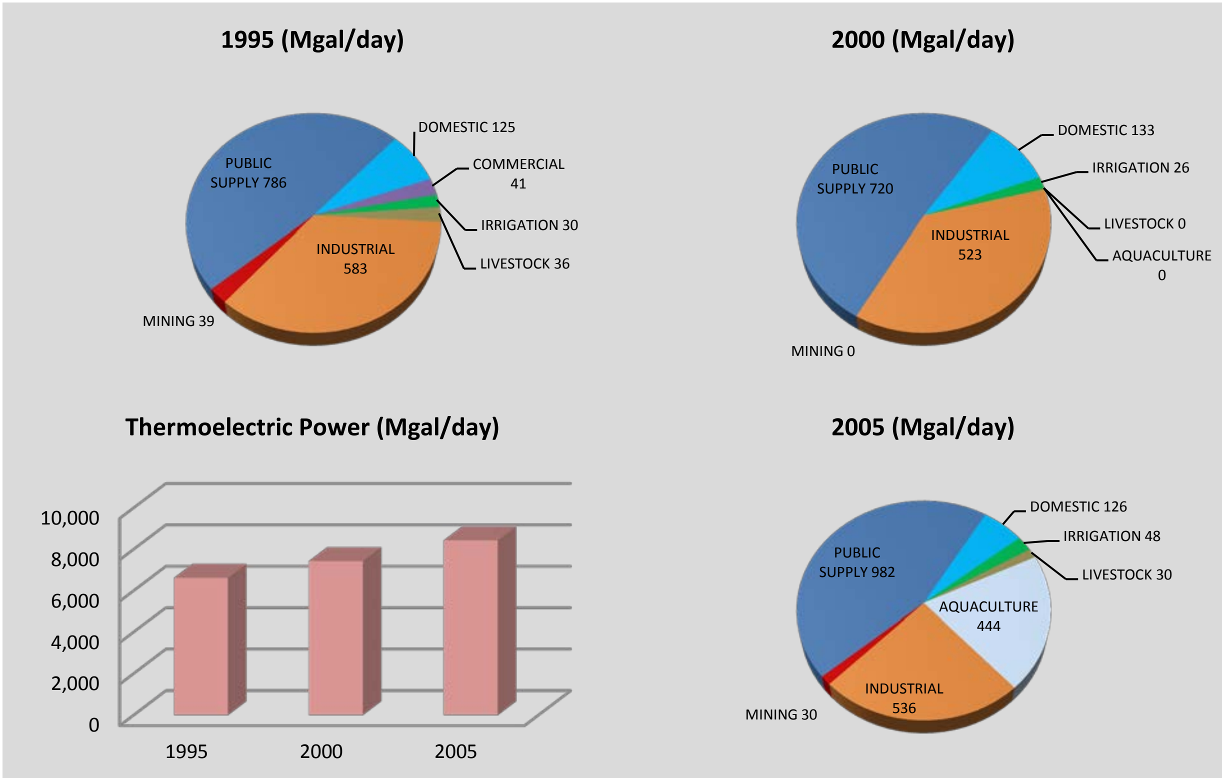



**Figure 5 USGS Estimate of Virginia's Water Withdrawals (Mgal/day) by Category of Use and Year.**

Attributing water use estimates in West Virginia to the various factors estimated by USGS differs from its border states in several ways. West Virginia saw a fluctuation in total water use most similar to the fluctuation in Pennsylvania and Maryland which saw the highest use year in 2000 (Figure 2). However, unlike Pennsylvania and Maryland, West Virginia was not estimated to have as sharp of an increase in water use for thermoelectric power generation in 2000 (Figure 9). Additionally, although West Virginia was the only state considered here to see a decrease in the percent change of population from 1995 to 2000 and 2005, as seen in Figure 3, the water use USGS estimates for public supply still increased in 2000 which along with the small increase in thermoelectric use is the greatest contributor to the total withdrawal increase calculated by USGS (Figure 9).

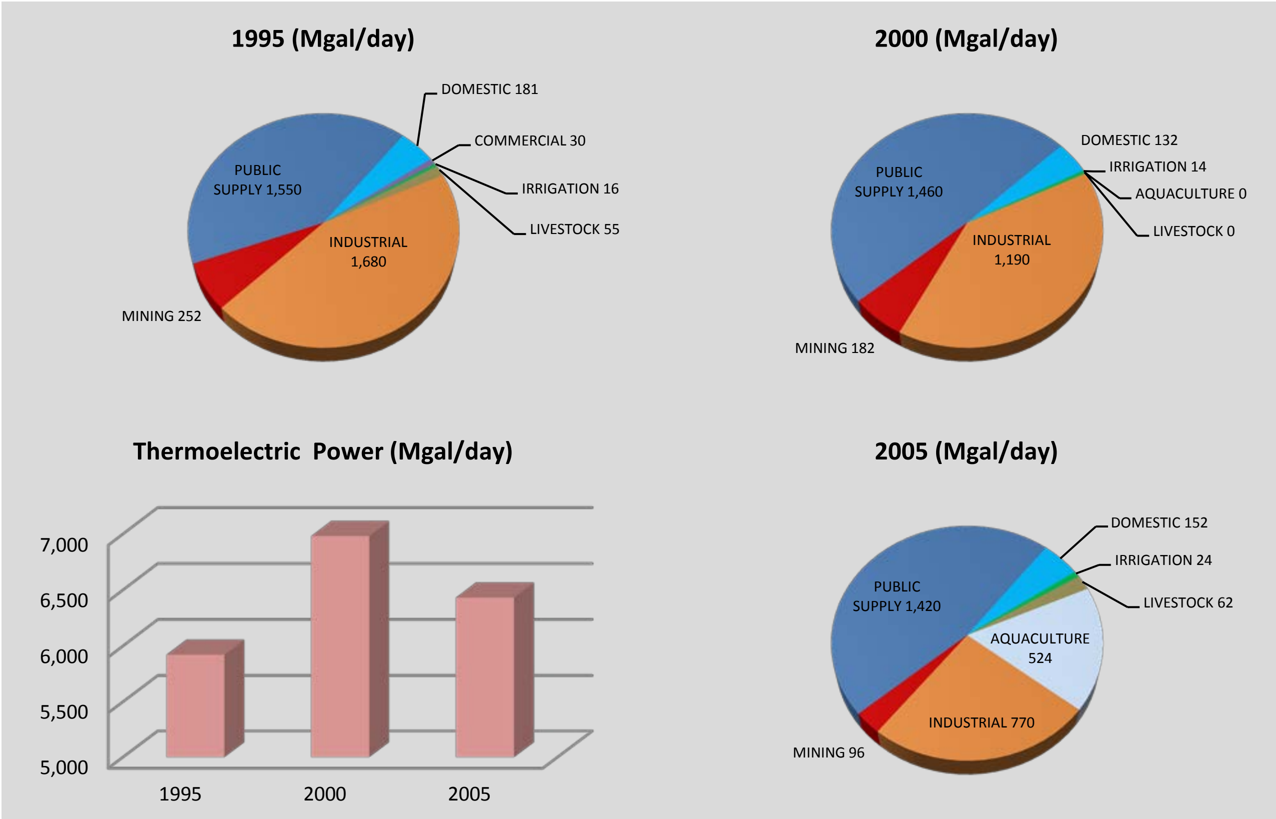



**Figure 6 USGS Estimate of Pennsylvania's Water Withdrawals (Mgal/day) by Category of Use and Year.**

The starkest contrast between West Virginia and its border states is not the total amount of water used per year, the changes in use over time, or even that it is the only state considered to have seen a decrease in population over the intervals of investigation from the initial year. Instead the greatest difference between West Virginia and the bordering states is seen when comparing the proportion of water withdrawn by the various users in the state (Figure 9). In every other state the greatest single proportion of water used is for the public supply and in some cases such as Ohio, Maryland, and Kentucky public use accounts for more than half of the proportion of water withdrawn (excluding thermoelectric). In West Virginia, the proportion of public supply is second largest. In West Virginia, the public supply amount is surpassed by the industry withdrawal estimates and is in direct contrast to all of the surrounding states (Figure 6).

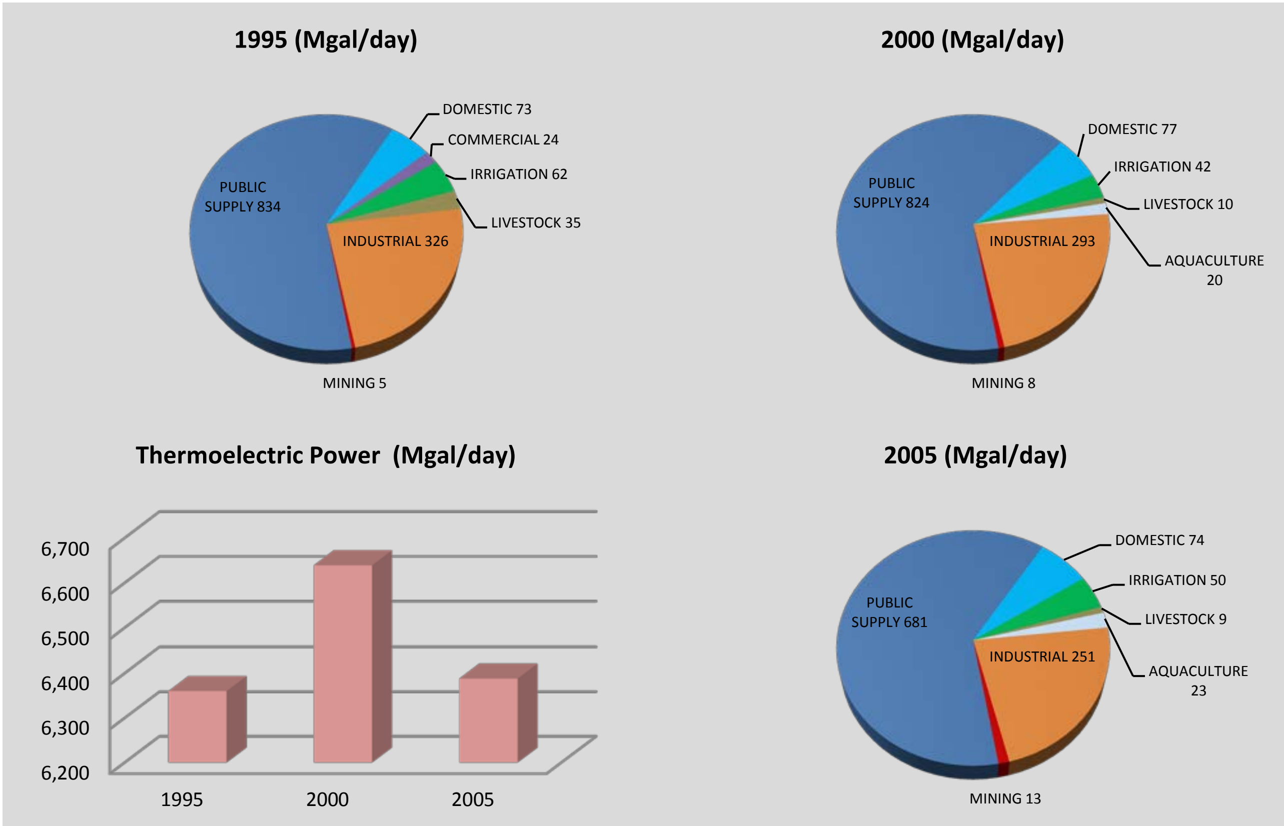



**Figure7 USGS Estimate of Maryland's Water Withdrawals (Mgal/day) by Category of Use and Year.**

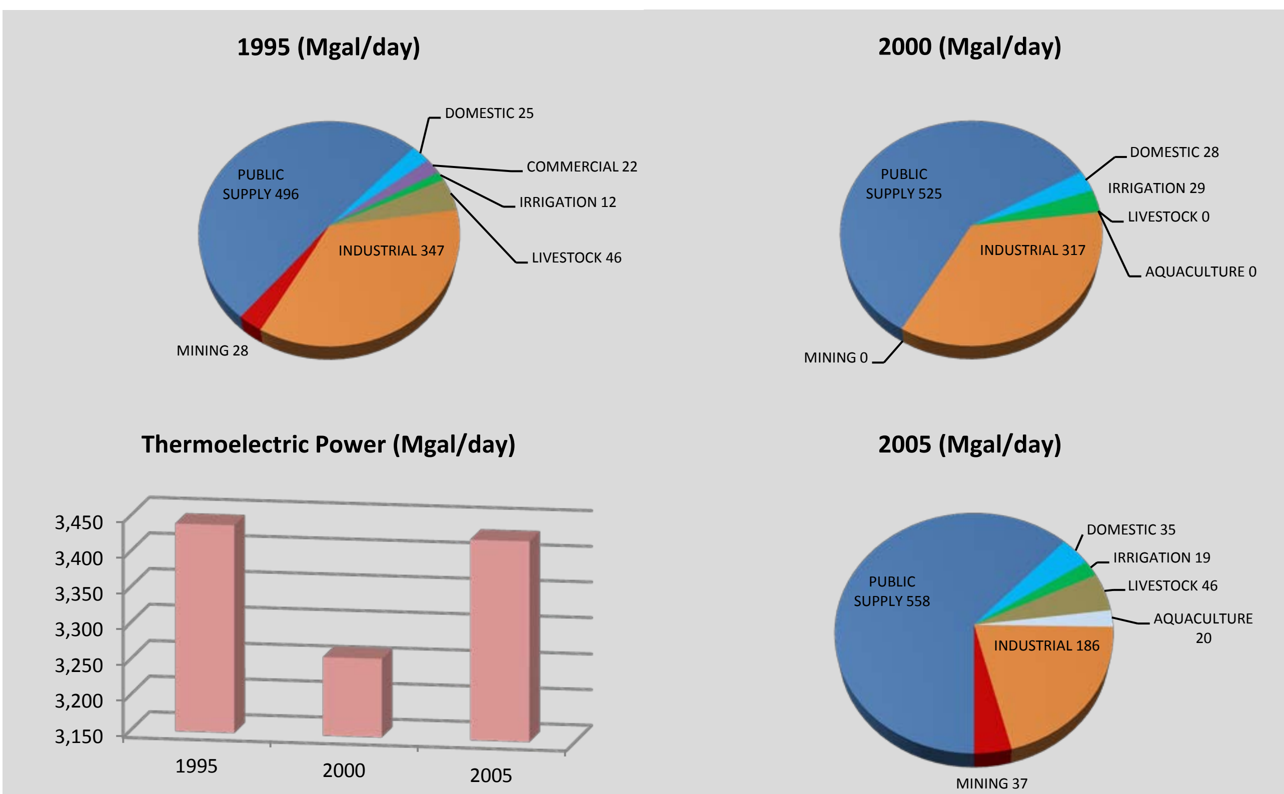



**Figure8 USGS Estimate of Kentucky's Water Withdrawals (Mgal/day) by Category of Use and Year.**

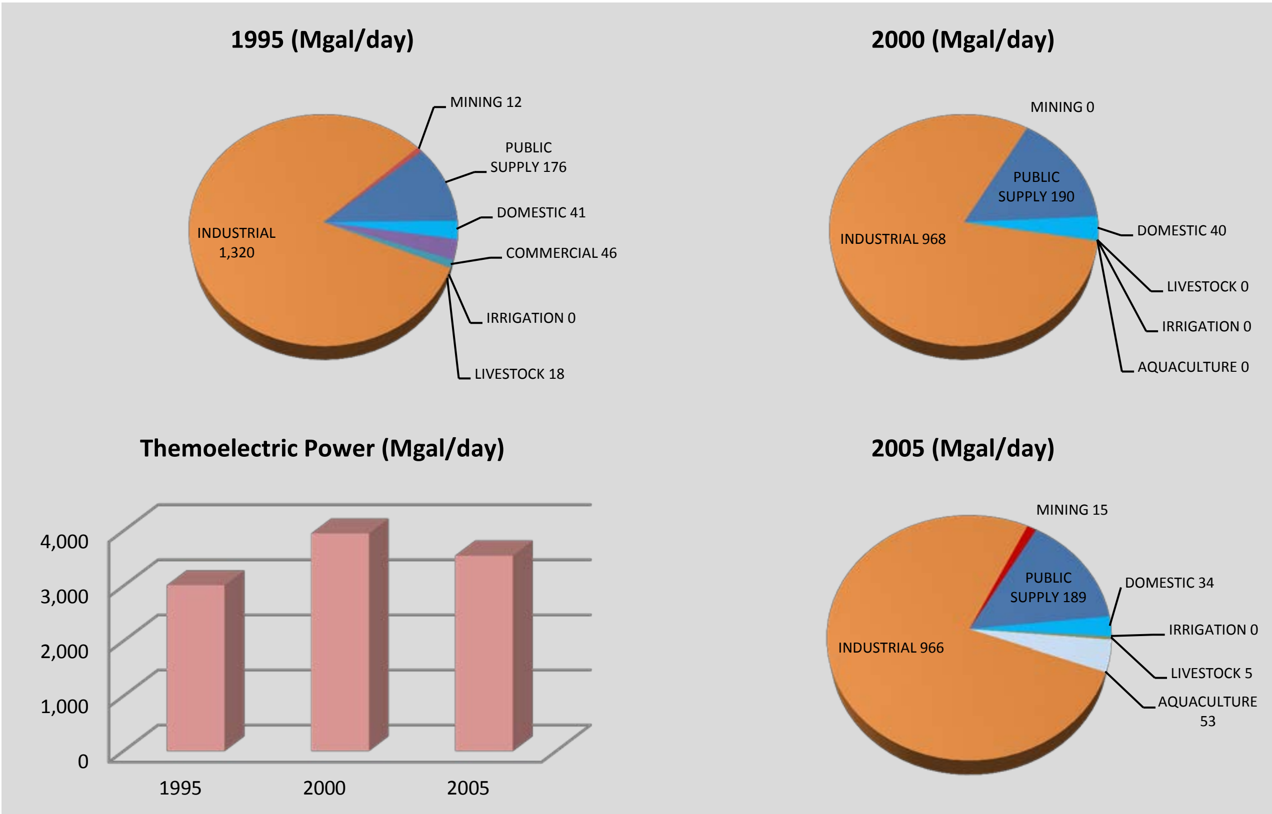



**Figure 9 USGS Estimate of West Virginia's Water Withdrawals (Mgal/day) by Category of Use and Year.**

# Appendix I

## West Virginia Bottled Water Plants

There were seven bottled water plants that reported withdrawing water from waters of West Virginia in 2013. However, all plants with data starting in May, 2010 were included in the appendix. Brand names were included when available regardless of current withdrawal reports.

## 1. Plant Name:

Allegheny Lodge Enterprises, LLC

### Address:

HC 82 Box 130, Marlinton, WV 24954

### Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Spring | 25,000 |
| October 30, 2012 | Spring | 25,000 |
| June 6, 2013 | Spring | 20,000 |

### Brands:

1) Allegheny Insurance Natural Spring Water
2) Allegheny Lodge Natural Spring Water
3) Charleston Area Medical Center Natural Spring Water
4) Dinner of Champions Natural Spring Water
5) Don't Move Plant Pests Natural Spring Water
6) Gandeeville Community Church Natural Spring Water
7) Hatfield-McCoy Trails Natural Spring Water
8) Mardi Gras Casino & Resort Natural Spring Water
9) Marlinton Church of God Natural Spring Water
10) Martin & Ritz Accounting Natural Spring Water
11) Minnehaha Mist Natural Spring Water
12) Mountain Lutheran Parish Natural Spring Water
13) Pocahontas County Warriors Natural Spring Water
14) Pocahontas County Spring Water 100% West Virginia Spring Water
15) Senator Helmick Re-Election Natural Spring Water
16) United Methodist Men Natural Spring Water
17) Waco Oil & Gas Natural Spring Water
18) Walt Helmick for Ag Commissioner Natural Spring Water
19) Women on the Move Luncheon Natural Spring Water

## 2. Plant Name:

Allegheny Products, Inc.

### Address:

PO Box 1382, Shady Springs, WV 25918

### Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Spring | 524,400 |
| October 30, 2012 | Spring | - |
| June 6, 2013 | Spring | - |

## 3. Plant Name:

Berkeley Club Beverages, Inc.

### Address:

PO Box 190, 4 Howard Street, Berkeley Springs, WV 25411

## Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Spring | 1,139,829 |
| October 30, 2012 | Spring | 1,139,829 |
| June 6, 2013 | Spring | 1,139,829 |

### Brands:

1) Allstate Natural Spring Water
2) Almost Heaven Natural Spring Water
3) Arndt-McBee Insurance Natural Spring Water
4) Bank of Clarke County Natural Spring Water
5) Berkeley Springs Distilled Water
6) Berkeley Springs Natural Spring Water
7) Cal Ripken World Series Baseball Natural Spring Water
8) CNB Natural Spring Water
9) Commonwealth Bottled Water
10) Denton Natural Spring Water
11) Denton Spring Water Col Natural Spring Water
12) Fallon Insurance Agency Natural Spring Water
13) Farm Bureau Insurance Natural Spring Water
14) Grafton Integrated Health Network Natural Spring Water
15) Hedgesville Little League Natural Spring Water
16) Henry's Grocery Natural Spring Water
17) Jesus Loves you Natural Spring Water
18) Kesecker Realty, Inc. Natural Spring Water
19) Legz Club Water
20) Legz Entertainment Natural Spring Water
21) Liberty Pure Water
22) Massanutten Natural Spring Water
23) Morning Dew Natural Spring Water
24) Mount Zion Episcopal Church Natural Spring Water
25) Mountain Drop Natu4ral Spring Water
26) Mr. Natural Bottled Water Inc. Water
27) Rock Harbor Golf Course Water
28) Sherando Warriors Natural Spring Water
29) State Farm Dave Pipenbrink Natural Spring Water

30) State Farm Dawn Newlin Natural Spring Water
31) State Farm Eric Gates Natural Spring Water
32) State Farm Insurance Jerry Williams Natural Spring Water
33) State Farm Insurance Kathy Schultze Natural Spring Water
34) State Farm Insurance Kay Lewis Natural Spring Water
35) State Farm Insurance3 Luke Christie Natural Spring Water
36) Sun Cool Ultra Purified Water
37) The Inn at Little Washington Natural Spring Water
38) The Woods Natural Spring Water
39) Timothy B. Close Insurance Agency Natural Spring Water
40) Valley Health War Memorial Hospital Natural Spring Water
41) West Virginia Spring House Natural Spring Water

## 4. Plant Name:

Blind Industries of Maryland

### Address:

418 S. Washington Street, Berkeley Springs, WV 25411

### Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Spring | 120,000 |
| October 30, 2012 | Spring | - |
| June 6, 2013 | Spring | - |

## 5. Plant Name:

Capon Springs & Farms, Inc.

### Address:

PO Box O, Capon Springs, WV 26823

### Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Spring | 16,000 |
| October 30, 2012 | Spring | 16,000 |
| June 6, 2013 | Spring | 16,000 |

### Brands:

1) Capon Springs Water

## 6. Plant Name:

Green Acres Regional Center, Inc. – Lesage Natural Wells

### Address:

Rt. 2 Box 240, Lesage, WV 25537

### Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Well | 700,000 |
| October 30, 2012 | Well | 700,000 |
| June 6, 2013 | Well | 700,000 |

### Brands:

1) Jemika Premium Drinking Water
2) Lesage Natural Wells Pure Table Water
3) Lesage Premium Water
4) Lesage Pure Table Water
5) Mountain State School of Massage Premium Drinking Water
6) West Virginia State Parks and Forests Premium Drinking Water
7) Wild Wonderful West Virginia Premium Drinking Water (Nicolas Co. Workshop)

## 7. Plant Name:

Smiths Beverage/Sweet Sommer Water Company

### Address:

271 Sweet Springs Valley, Gap Mill, WV 24941

### Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Spring | 300,000 |
| October 30, 2012 | Spring | - |
| June 6, 2013 | Spring | - |

## 8. Plant Name:

Sweet Springs Valley Water Company

### Address:

798 Rowan Road, Gap Mills, WV 24941

## Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Spring | 2,000,000 |
| October 30, 2012 | Spring | 2,000,000 |
| June 6, 2013 | Spring | 1,800,000 |

### Brands:

1) Horizon Coffee & Water Service Water
2) Sweet Springs Natural Mountain Water

## 9. Plant Name:

Tyler Mountain Water Company, Inc (Poca)

### Address:

159 Harris Drive, Poca, WV

## Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Public Water Supply | 200,000 |
| October 30, 2012 | Public Water Supply | 200,000 |
| June 6, 2013 | Public Water Supply | - |

### Brands:

1) Tyler Mountain Drinking Water (Poca)

## 10. Plant Name:

United Dairy Inc. (Charleston)

### Address:

508 Roane Street, Charleston, WV 25302

## Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Public Water Supply | 850,000 |
| October 30, 2012 | Public Water Supply | 850,000 |
| June 6, 2013 | Public Water Supply | 475,000 |

### Brands:

1) Fas-Chek Drinking Water
2) Tyler Mountain Drinking Water
3) United Valley Pure Drinking Water

## 11. Plant Name:

West Virginia Pride of the Mountains, Inc.

### Address:

#53 Upper Jonathan Run, Parsons, WV 26287

### Volume Produced:

| Date | Source | Gallons (annual estimate) |
|---|---|---|
| May 12, 2010 | Spring | 200,000 |
| October 30, 2012 | Spring | 200,000 |
| June 6, 2013 | Spring | 200,000 |

### Brands:

1) Ebery-Wood Spring Water
2) WV Pride of the Mountains Pure Mountain Spring Water

# Appendix J

2011 Large Quantity User Registration Forms

# Appendix J.1

Industrial User Registration Form

# FIELDS WITH ASTERIK ARE REQUIRED

| | SECTION I - GENERAL INFORMATION | 2011 |
|---|---|---|
| 1 | Facility Name * | |
| 2 | Facility Mailing Address 1 * | |
| 3 | Facility Mailing Address 2 | |
| 4 | Facility Mailing City * | |
| 5 | Facility State * | |
| 6 | Facility Mailing Zip Code * | |
| 7 | Facility E-Mail | |
| 8 | Facility Phone * | |
| 9 | Facility Fax | |
| 10 | SIC Code * | |
| 11 | NAICS Code | |
| 12 | No. Employees at Facility * | |
| 13 | Facility FEIN * | |
| 14 | Facility Physical Address 1 * | |
| 15 | Facility Physical Address 2 | |
| 16 | Facility Physical City * | |
| 17 | Facility Physical State * | |
| 18 | Facility Physical Zip Code * | |
| 19 | Facility County * | |
| 20 | Owner Name * | |
| 21 | Owner FEIN | |
| 22 | Owner Address 1 * | |
| 23 | Owner Address 2 | |
| 24 | Owner City * | |
| 25 | Owner State * | |
| 26 | Owner Zip Code * | |
| 27 | Owner Phone * | |
| 28 | Owner E-Mail | |
| 29 | Contact First Name * | |
| 30 | Contact Last Name * | |
| 31 | Contact Phone * | |
| 32 | Contact E-Mail | |

| | | |
|---|---|---|
| 33 | If you are sharing intake and discharge points with multiple facilities and including them in your survey, please list facilities and their contact info | |

| | | |
|---|---|---|
| 34 | Brief description of processes requiring water withdrawals (cooling water, heating, irrigation, etc.) | |

| | | |
|---|---|---|
| 35 | Type of water use (not related to mineral extraction) * | Industrial ☐ Commercial ☐ Irrigation ☐ Recreational ☐ Public Water ☐ Power Generation ☐ |
| 35a | Type of water use (mineral extraction use) * | Coal ☐ Salt ☐ Quarry ☐ Oil/Gas ☐ |
| 36 | Do you have any water purchased from a provider? * | Yes ☐ No ☐ |
| 37 | What is your daily maximum potential (gal) to withdraw? | |
| 38 | What is your present monthly maximum potential (gal) to withdraw? | |
| 39 | Within the next 5 years, what is your anticipated monthly maximum potential (gal) to withdraw? | |
| 40 | For coal fired electric generators, what is the facility nominal design capacity (gal) per calendar day? | |
| 41 | Where do you discharge? * | POTW ☐ Stream ☐ UIW/Septic Tank ☐ Private Reservoir ☐ Lake ☐ |
| 42 | Describe stream flow conditions that impact withdrawal rates? | |
| 43 | Describe seasonal conditions that impact withdrawals? | |
| 44 | Have you implemented water conservation practices in the past five years? Describe. | Yes ☐ No ☐ |
| 45 | Estimate the water saved per month (in gal) by these practices. | |
| 46 | If you have work planned within the next five years to conserve water use, describe the project and give an estimated project cost. | |
| 47 | Estimate the water saved per month (gal) by the planned project. | |
| 48 | Additional Comments | |
| 49 | Year of Closure | |

**USE SEPARATE FORM FOR EACH FACILITY**

| | SECTION II - MULTIPLE FACILITIES | 2011 |
|---|---|---|
| 1 | Facility Name * | |
| 2 | Facility Address 1 * | |
| 3 | Facility Address 2 | |
| 4 | Facility City * | |
| 5 | Facility State * | |
| 6 | Facility Zip Code * | |
| 7 | Facility Phone * | |

| SECTION III -- WATER WITHDRAWALS | | |
|---|---|---|

**USE SEPARATE FORM FOR EACH SURFACE WATER WITHDRAWAL**

| | SURFACE WATER WITHDRAWAL | 2011 |
|---|---|---|
| 1 | Your Name for Intake * | |
| 2 | County * | |
| 3 | State * | |
| 4 | Decimal Latitude * | |
| 5 | Decimal Longitude * | |
| 6 | How was location determined? * | |
| 7 | Water source name * | |
| 8 | Water source type * | Spring ☐ Lake/Impoundment ☐ Stream/River ☐ |
| 9 | How did you determine withdrawal info * | Metered ☐ Calculated ☐ |
| 10 | If calculated, describe how calculated * | |
| 11 | INTENTIONALLY LEFT BLANK | |
| 12 | What is the water used for? * | Mining ☐ Petroleum ☐ Recreation ☐ Timber ☐<br>Agriculture / Aquaculture ☐ Industrial ☐<br>Public Water Suppliers ☐ Chemical ☐<br>Thermoelectric (Coal) ☐ Hydro Electric ☐ |

| 2011 Surface Water Withdrawal (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

**DEFINITIONS FOR "WHAT IS THE WATER USED FOR?"**

**Mining** – Coal mining, coal processing plants, quarries, any other type of mining activity where rocks or minerals are removed from the earth.

**Petroleum** – Waterfloods. Does not include water used when hydrofracing a well. That is reported on another form.

**Recreation** – hotels, golf course, campgrounds, water parks, etc.

**Timber** – Including facilities that manufacture wood products – pulp mills, charcoal manufacturers, dimentional lumber, etc.

**Agriculture / Aquaculture** – Irrigation, fish farming, production of feed for farm animals, etc.

**Industrial** – General manufacturing other than chemical.

**Public Water Supply** – Provide water primarily for human consumption.

**Chemical** – Manufacture of chemicals, chemical compounds, etc., regardless of feedstock source.

**Thermoelectric** – Generation of electric power where heat is the primary motive force and water is used for steam or cooling purposes (i.e. a coal burning plant that boils water creating steam to turn the turbines

**Hydroelectric** – Generation of electric power where water is the motive force. There is little or no consumptive use of the water in the generation process (i.e. a power plant at a dam that uses the water flowing out of the dam to turn the turbine.

## USE SEPARATE FORM FOR EACH GROUNDWATER WITHDRAWAL

| | GROUNDWATER WITHDRAWAL | 2011 |
|---|---|---|
| 1 | Your Name for Intake * | |
| 2 | County * | |
| 3 | State * | |
| 4 | Decimal Latitude * | |
| 5 | Decimal Longitude * | |
| 6 | How was location determined * | |
| 7 | Well Depth (feet) * | |
| 8 | Aquifer Source * | Alluvial Aquifer ☐ Middle Pennsylvanian ☐<br>Lower Pennsylvania ☐ Mississippian ☐<br>Upper Pennsylvanian & Permian ☐ Unknown ☐<br>Devonian/Silurian ☐ Ordovician & Cambrian ☐ |
| 9 | Type of Rock * | Sandstone ☐ Sand & Gravel ☐ Shale ☐<br>Limestone/Dolomite ☐ Underground Mine ☐<br>Interbedded Sandstone & Shale ☐ Unknown ☐<br>Interbedded Sandstone, Limestone & Shale ☐ |
| 10 | How did you determine withdrawal info * | Metered ☐ Calculated ☐ |
| 11 | If calculated, describe how calculated * | |
| 12 | What is the water used for? * | Mining ☐ Petroleum ☐ Recreation ☐ Timber ☐<br>Agriculture / Aquaculture ☐ Industrial ☐<br>Public Water Suppliers ☐ Chemical ☐<br>Thermoelectric (Coal) ☐ Hydro Electric ☐ |

| 2011 Groundwater Withdrawal (Gal/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

**DEFINITIONS FOR "WHAT IS THE WATER USED FOR?"**

**Mining** – Coal mining, coal processing plants, quarries, any other type of mining activity where rocks or minerals are removed from the earth.

**Petroleum** – Waterfloods. Does not include water used when hydrofracing a well. That is reported on another form.

**Recreation** – Hotels, golf courses, campgrounds, water parks, etc.

**Timber** – Including facilities that manufacture wood products - pulp mills, charcoal manufacturers, dimensional lumber, etc.

**Agriculture/Aquaculture** – Irrigation, fish farming, production of feed for farm animals, etc.

**Industrial** – General manufacturing other than chemical.

**Public Water Supply** – Provide water primarily for human consumption.

**Chemical** – Manufacture of chemicals, chemical compounds, etc., regardless of feedstock source.

**Thermoelectric** – Generation of electric power where heat is the primary motive force and water is used for steam or cooling purposes (i.e. a coal burning plant that boils water creating steam to turn the turbines.)

**Hydroelectric** – Generation of electric power where water is the motive force. There is little or no consumptive use of the water in the generation process (i.e. a power plant at a dam that uses the water flowing out of the dam to turn the turbine).

| | WATER PROVIDER (PURCHASED WATER) | 2011 |
|---|---|---|
| 1 | Provider Name * | |

| 2011 Purchased Water (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

## SECTION IV -- WATER DISCHARGE

## USE SEPARATE FORM FOR EACH POTW DISCHARGE

| | POTW - WATER DISCHARGE | 2011 |
|---|---|---|
| 1 | POTW Name * | |
| 2 | Decimal Latitude * | |
| 3 | Decimal Longitude * | |
| 4 | How was location determined? * | |

| 2011 POTW Discharge (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

## USE SEPARATE FORM FOR EACH STREAM DISCHARGE

| | STREAM DISCHARGE | 2011 |
|---|---|---|
| 1 | Stream Name * | |
| 2 | NPDES Permit Number * | |
| 3 | Decimal Latitude * | |
| 4 | Decimal Longitude * | |
| 5 | How was location determined? * | |

| 2011 Stream Discharge (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

## USE SEPARATE FORM FOR EACH UNDERGROUND INJECTION WELL

| | UNDERGROUND INJECTION WELL - SUBSURFACE | 2011 |
|---|---|---|
| 1 | Name of UIW or Subsurface Disposal * | |
| 2 | UIC Code * | |
| 3 | UIC Permit No. * | |
| 4 | Decimal Latitude * | |
| 5 | Decimal Longitude * | |
| 6 | How was location determined? * | |

| 2011 UIW Discharge (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

## USE SEPARATE FORM FOR EACH RESERVOIR DISCHARGE

| | PRIVATE RESERVOIR DISCHARGE | 2011 |
|---|---|---|
| 1 | Name of Reservoir * | |
| 2 | NPDES Permit No. * | |
| 3 | Decimal Latitude * | |
| 4 | Decimal Longitude * | |
| 5 | How was location determined? * | |

| 2011 Private Reservoir Discharge (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

## USE SEPARATE FORM FOR EACH PUBLIC LAKE DISCHARGE

| | PUBLIC LAKE DISCHARGE | 2011 |
|---|---|---|
| 1 | Name of Lake * | |
| 2 | NPDES No. * | |
| 3 | Decimal Latitude * | |
| 4 | Decimal Longitude * | |
| 5 | How was location determined? * | |

| 2011 Public Lake Discharge (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

## USE SEPARATE FORM FOR EACH "OTHER" DISCHARGE

| | OTHER DISCHARGE | 2011 |
|---|---|---|
| 1 | Name of Discharge * | |
| 2 | Decimal Latitude * | |
| 3 | Decimal Longitude * | |
| 4 | How was location determined * | |
| 5 | Describe Other Discharge * | |

| 2011 Other Discharge (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

# Appendix J.2

Water Provider Registration Form

# FIELDS WITH ASTERIK ARE REQUIRED

| | SECTION I - GENERAL INFORMATION | 2012 |
|---|---|---|
| 1 | Facility Name * | |
| 2 | Facility Mailing Address 1 * | |
| 3 | Facility Mailing Address 2 | |
| 4 | Facility Mailing City * | |
| 5 | Facility State * | |
| 6 | Facility Mailing Zip Code * | |
| 7 | Facility E-Mail | |
| 8 | Facility Phone * | |
| 9 | Facility Fax | |
| 10 | SIC Code * | |
| 11 | NAICS Code | |
| 12 | No. Employees at Facility * | |
| 13 | Facility FEIN * | |
| 14 | Facility Physical Address 1 * | |
| 15 | Facility Physical Address 2 | |
| 16 | Facility Physical City * | |
| 17 | Facility Physical State * | |
| 18 | Facility Physical Zip Code * | |
| 19 | Facility County * | |
| 20 | Owner Name * | |
| 21 | Owner FEIN | |
| 22 | Owner Address 1 * | |
| 23 | Owner Address 2 | |
| 24 | Owner City * | |
| 25 | Owner State * | |
| 26 | Owner Zip Code * | |
| 27 | Owner Phone * | |
| 28 | Owner E-Mail | |
| 29 | Contact First Name * | |
| 30 | Contact Last Name * | |
| 31 | Contact Phone * | |
| 32 | Contact E-Mail | |
| 33 | Facility PWSID Code * | |
| 34 | Do you have water purchased from a provider? * | Yes ☐ No ☐ |

| | | |
|---|---|---|
| 35 | What is your daily maximum potential (gal/day) to withdraw? | |

| | | |
|---|---|---|
| 36 | What is your present monthly maximum potential (gal) to withdraw? | |

| | | |
|---|---|---|
| 37 | Within next 5 years, what is your anticipated monthly maximum potential (gal) to withdraw? | |
| 38 | List zip codes for areas you serve | ☐ ☐ ☐ ☐ ☐<br>☐ ☐ ☐ ☐ ☐ |
| 39 | Describe stream flow conditions that impact withdrawal rates. | |
| 40 | Describe seasonal conditions that impact withdrawals. | |
| 41 | Have you implemented water conservation practices in the past 5 years? Describe. | Yes ☐ No ☐ |
| 42 | Estimate the water saved per month (in gal) by these practices. | |
| 43 | If you have work planned within next 5 years to conserve water use, describe the project and give an estimated project cost. | |
| 44 | Estimate the water saved per month (gal) by the planned project. | |
| 45 | On average, what % of water is lost during conveyance? | |
| 46 | Additional Comments: | |
| 47 | Year of Closure | |

## USE SEPARATE FORM FOR EACH SURFACE WATER WITHDRAWAL

| SURFACE WATER WITHDRAWAL | 2012 |
|---|---|
| Your Name for Intake * | |
| County * | |
| State * | |
| Decimal Latitude * | |
| Decimal Longitude * | |
| How was location determined? * | |
| Water source name * | |
| Water source type * | Spring ☐ Lake/Impoundment ☐ Stream/River ☐ |
| How did you determine withdrawal info? * | Metered ☐ Calculated ☐ |
| If calculated, describe how calculation was made * | |

| 2012 Surface Water Withdrawal (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

## USE SEPARATE FORM FOR EACH GROUNDWATER WITHDRAWAL

| GROUNDWATER WITHDRAWAL | 2012 |
|---|---|
| Your Name for Intake * | |
| County * | |
| State * | |
| Decimal Latitude * | |
| Decimal Longitude * | |
| How was location determined? * | |
| Well Depth (feet) * | |
| Aquifer Source * | Alluvial Aquifer ☐ Mississippian ☐<br>Upper Pennsylvanian & Permian ☐<br>Middle Pennsylvanian ☐<br>Lower Pennsylvanian ☐<br>Devonian / Silurian ☐<br>Ordovician/Cambrian ☐ Unknown ☐ |
| Type of Rock * | Sandstone ☐ Sand & Gravel ☐ Shale ☐<br>Limestone/Dolomite ☐ Underground Mine ☐<br>Interbedded Sandstone & Shale ☐<br>Interbedded Sandstone, Limestone & Shale ☐<br>Unknown ☐ |
| How did you determine withdrawal info? * | Metered ☐ Calculated ☐ |
| If calculated, describe how calculation was made * | |

| 2012 Groundwater Withdrawal (Gallons/Month) | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

| **WATER PROVIDER (PURCHASED WATER)** | **2012** |
|---|---|
| Provider Name * | |

| **2012 Purchased Water - Gallons/Month** | |
|---|---|
| January * | |
| February * | |
| March * | |
| April * | |
| May * | |
| June * | |
| July * | |
| August * | |
| September * | |
| October * | |
| November * | |
| December * | |

# Appendix K

## West Virginia Large Quantity Users

All currently operating Large Quantity Users in the state are included and are organized by Industrial SIC code. The percentages of water withdrawn from multiple watersheds and/or counties are included where appropriate. The three year annual average water withdrawn is presented in gallons and was calculated using the most recent three years of monthly data.

| Agriculture/Aquaculture | | | | | |
|---|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | | 3 Year Average (gallons) |
| 4153 | G & G Nursery | Lower Ohio 100.00% | Cabell 71.43% | Mason 28.57% | 20,160,000 |
| 3626 | National Center for Cool & Cold Water Aquaculture | Potomac Direct Drains 100.00% | Jefferson 100.00% | | 307,087,120 |
| 4213 | The Conservation Fund Freshwater Institute | Potomac Direct Drains 100.00% | Jefferson 100.00% | | 341,207,333 |
| 8134 | WVDNR - Apple Grove Fish Hatchery | Lower Ohio 100.00% | Mason 100.00% | | 90,071,267 |
| 8111 | WVDNR - Bowden Hatchery | Cheat 100.00% | Randolph 100.00% | | 1,632,960,000 |
| 8163 | WVDNR - Edray Hatchery | Greenbrier 100.00% | Pocahontas 100.00% | | 414,720,000 |
| 8124 | WVDNR - Palestine State Fish Hatchery | Little Kanawha 100.00% | Wirt 100.00% | | 79,632,000 |
| 8106 | WVDNR - Petersburg Hatchery | South Branch Potomac 100.00% | Grant 100.00% | | 207,360,000 |
| 8158 | WVDNR - Reeds Creek Hatchery | South Branch Potomac 100.00% | Pendleton 100.00% | | 466,560,000 |
| 8155 | WVDNR - Ridge Hatchery | Potomac Direct Drains 100.00% | Morgan 100.00% | | 233,280,000 |
| 8108 | WVDNR - Spring Run Hatchery | South Branch Potomac 100.00% | Grant 100.00% | | 1,658,880,000 |
| 8115 | WVDNR - Tate Lohr Hatchery | Upper New 100.00% | Mercer 100.00% | | 129,600,000 |
| **Chemical** | | | | | |
| 2082 | Bayer CropScience - Institute Plant | Lower Kanawha 100.00% | Kanawha 100.00% | | 40,648,925,000 |

| Chemical, continued | | | | | |
|---|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | | County and % of 3 Year Average | 3 Year Average (gallons) |
| 2904 | Bayer MaterialScience LLC | Middle Ohio North 96.96% | Upper Ohio South 3.04% | Marshall 100.00% | 735,624,151 |
| 4887 | Braskem America, Inc. - Neal Plant | Big Sandy 100.00% | | Wayne 100.00% | 68,922,771 |
| 2419 | Clearon Corporation | Lower Kanawha 100.00% | | Kanawha 100.00% | 261,917,280 |
| 3139 | Consol Energy, Inc. | Middle Ohio North 100.00% | | Marshall 100.00% | 89,856,000 |
| 7568 | Cytec Industries, Inc. | Middle Ohio North 100.00% | | Pleasants 100.00% | 1,286,996,426 |
| 1180 | DuPont Belle Plant | Upper Kanawha 100.00% | | Kanawha 100.00% | 37,317,600,000 |
| 3127 | Dupont Washington Works | Middle Ohio South 100.00% | | Wood 100.00% | 16,994,376,000 |
| 1289 | ICL-IP America, Inc. | Lower Ohio 100.00% | | Mason 100.00% | 242,466,093 |
| 1120 | M&G Polymers USA - Apple Grove Plant | Lower Ohio 100.00% | | Mason 100.00% | 50,761,779 |
| 3788 | MPM Silicones | Middle Ohio North 100.00% | | Tyler 100.00% | 2,050,754,923 |
| 2781 | PPG (Natrium) | Middle Ohio North 100.00% | | Marshall 100.00% | 45,682,717,073 |
| 3165 | SABIC Innovative Plastics | Middle Ohio South 100.00% | | Wood 100.00% | 704,329,980 |
| 1620 | Union Carbide South Charleston Facility | Lower Kanawha 100.00% | | Kanawha 100.00% | 22,207,680,000 |

| **Frac Water*** | | | | |
|---|---|---|---|---|
| **Facility ID** | **Facility Name** | **Watershed and % of 3 Year Average** | **County and % of 3 Year Average** | **3 Year Average (gallons)** |
| 10119 | Eureka Hunter Pipeline, LLC - Carbide Service Cent | Middle Ohio North 100.00% | Wetzel 100.00% | 0 |
| 10013 | Salem Water Board | West Fork 100.00% | Harrison 100.00% | 117,031,667 |
| 10116 | Select Energy Service, LLC | Middle Ohio North 100.00% | Pleasants 100.00% | 21,092,799 |
| **Hydroelectric** | | | | |
| 8176 | Belleville Hydroelectric Facility | Middle Ohio South 100.00% | Wood 100.00% | 4,718,113,048,800 |
| 10093 | Brookfield Renewable Power - Hawks Nest Hydro | Lower New 100.00% | Fayette 100.00% | 1,479,558,325,833 |
| 10096 | London Hydroelectric Project | Upper Kanawha 100.00% | Kanawha 100.00% | 1,214,105,592,765 |
| 10098 | Marmet Hydroelectric Project | Upper Kanawha 100.00% | Kanawha 100.00% | 1,230,245,785,037 |
| 10100 | New Martinsville Hannibal Hydroelectric Plant | Middle Ohio North 100.00% | Wetzel 100.00% | 4,431,196,545,957 |
| 10102 | Summersville Hydroelectric Facility | Gauley 100.00% | Nicholas 100.00% | 326,095,879,431 |
| 10104 | Winfield Hydroelectric Project | Lower Kanawha 100.00% | Putnam 100.00% | 1,552,169,273,905 |
| **Industrial** | | | | |
| 10079 | Alcan Rolled Products | Middle Ohio South 100.00% | Jackson 100.00% | 144,992,733 |
| 2398 | Allegany Ballistics Laboratory | North Branch Potomac 100.00% | Mineral 100.00% | 69,240,020 |

| Industrial, continued | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 10078 | ArcelorMittal Weirton | Upper Ohio North 100.00% | Hancock 100.00% | 11,253,300,000 |
| 5152 | Arroyo Air Separation Plant | Upper Ohio North 100.00% | Hancock 100.00% | 136,235,520 |
| 5089 | Capitol Cement Corporation | Potomac Direct Drains 100.00% | Berkeley 100.00% | 2,912,696,000 |
| 2202 | Goodrich Corporation | Upper New 100.00% | Monroe 100.00% | 19,179,191 |
| 2023 | Huntington Alloys Corporation | Lower Guyandotte 100.00% | Cabell 100.00% | 277,433,755 |
| 1923 | Mountain State Carbon - Follansbee Coke Plant | Upper Ohio North 100.00% | Brooke 100.00% | 2,736,773,333 |
| 1224 | National Conservation Training Center | Potomac Direct Drains 100.00% | Jefferson 100.00% | 11,128,533 |
| 2250 | Reynolds Memorial Hospital | Upper Ohio South 100.00% | Marshall 100.00% | 19,490,667 |
| 8056 | RG Steel Wheeling, LLC - Beech Bottom Plant | Upper Ohio South 100.00% | Brooke 100.00% | 142,360,667 |
| 3554 | Wheeling-Nisshin | Upper Ohio North 100.00% | Brooke 100.00% | 146,016,000 |
| 1944 | WVA Manufacturing | Upper Kanawha 100.00% | Fayette 100.00% | 2,208,933,333 |
| **Mining** | | | | |
| 3460 | Aggregates Quarry | Tygart Valley 100.00% | Randolph 100.00% | 9,052,333 |
| 10095 | Alex Energy - Jerry Fork Eagle Deep Mine | Gauley 100.00% | Nicholas 100.00% | 5,641,000 |
| 5013 | Alex Energy - Surface Mines | Gauley 100.00% | Nicholas 100.00% | 128,247,341 |

| Mining, continued | | | | | | |
|---|---|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | | County and % of 3 Year Average | | 3 Year Average (gallons) |
| 3772 | Apogee Coal Company - Fanco Loadout and Beltline | Upper Guyandotte 100.00% | | Logan 100.00% | | 17,454,000 |
| 4388 | Apogee Coal Company - Guyan Surface Mine | Coal 100.00% | | Logan 100.00% | | 56,924,588 |
| 3721 | Apogee Coal Co-Ruffner & Winifrede Mine-Fanco Plt | Upper Guyandotte 100.00% | | Logan 100.00% | | 299,865,600 |
| 4544 | Aracoma Coal - Alma Mine | Upper Guyandotte 100.00% | | Logan 100.00% | | 261,504,000 |
| 4527 | Aracoma Coal - Hernshaw Mine | Upper Guyandotte 100.00% | | Logan 100.00% | | 25,488,000 |
| 4161 | Arch Coal - Coal-Mac, Inc. | Tug Fork 45.69% | Upper Guyandotte 54.31% | Mingo 45.69% | Logan 54.31% | 97,403,267 |
| 3508 | Argus Energy - Kiah Creek Operation | Twelvepole 100.00% | | Wayne 100.00% | | 96,472,000 |
| 4343 | Bandmill Coal Corp - Bandmill Preparation Plant | Upper Guyandotte 100.00% | | Logan 100.00% | | 21,352,000 |
| 3911 | Bandmill Coal Corp - Bandmill Surface | Upper Guyandotte 100.00% | | Logan 100.00% | | 10,726,667 |
| 5160 | Bluestone Coal - Pinnacle Ridge Surface Mine | Tug Fork 100.00% | | McDowell 100.00% | | 11,520,000 |
| 3631 | Brooks Run Mining - Erbacon Plant | Elk 100.00% | | Webster 100.00% | | 162,329,000 |
| 8309 | Carter Roag Coal - Star Bridge Preparation Plant | Tygart Valley 100.00% | | Randolph 100.00% | | 14,990,300 |
| 4685 | Catenary Coal Company - Samples Mine Complex | Coal 48.06% | Upper Kanawha 51.94% | Boone 48.06% | Kanawha 51.94% | 102,356,004 |
| 4413 | Coal River Processing | Coal 100.00% | | Boone 100.00% | | 89,106,667 |

| Mining, continued | | | | | | |
|---|---|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | | County and % of 3 Year Average | | 3 Year Average (gallons) |
| 4564 | Cobra Natural Resources-Mountaineer Mine & Plant | Tug Fork 1.18% | Upper Guyandotte 98.82% | Mingo 100.00% | | 158,548,357 |
| 3410 | Consol Energy - Blacksville # 2 | Dunkard 100.00% | | Monongalia 100.00% | | 260,074,633 |
| 3414 | Consol Energy - Loveridge | Dunkard 6.73% | Monongahela 93.27% | Monongalia 6.73% | Marion 93.27% | 249,201,093 |
| 3411 | Consol Energy - Robinson Run | West Fork 100.00% | | Harrison 90.20% | Marion 9.80% | 192,785,167 |
| 3360 | Consol Energy - Shoemaker Mine & Preparation Plant | Upper Ohio South 100.00% | | Marshall 100.00% | | 611,320,000 |
| 4369 | Consol of Kentucky - Miller Creek Prep Plant | Tug Fork 100.00% | | Mingo 100.00% | | 162,183,756 |
| 3184 | Consolidation Coal Co - Flaggy Meadows AMD Plant | Monongahela 100.00% | | Monongalia 100.00% | | 54,493,335 |
| 10081 | Deckers Creek Limestone Company | Monongahela 100.00% | | Monongalia 100.00% | | 7,223,659 |
| 7623 | Delbarton Mining Company | Tug Fork 100.00% | | Mingo 100.00% | | 168,240,000 |
| 4520 | Eastern Assoc - Harris Operating Unit - Pond Fork | Coal 100.00% | | Boone 100.00% | | 77,288,760 |
| 3722 | Eastern Associated Coal - Jasper Workman | Coal 100.00% | | Boone 100.00% | | 14,848,000 |
| 3782 | Eastern Associated Coal - Rocklick Prep Plant | Tug Fork 100.00% | | McDowell 100.00% | | 248,832,000 |
| 3764 | Eastern Associated Coal Corp - Wells Complex | Coal 100.00% | | Boone 100.00% | | 20,277,231 |
| 3421 | Elk Run Coal Company | Coal 100.00% | | Boone 100.00% | | 187,224,924 |

| Mining, continued | | | | | | |
|---|---|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | | County and % of 3 Year Average | | 3 Year Average (gallons) |
| 4753 | Fola Coal Co - Fola Prep Plant facilities | Gauley 100.00% | | Nicholas 100.00% | | 152,928,000 |
| 3348 | Goals Coal Company, Inc. | Coal 100.00% | | Raleigh 100.00% | | 453,927,332 |
| 4803 | Green Valley Coal - Grassy Creek #1 Deep Mine | Gauley 100.00% | | Nicholas 100.00% | | 19,200,000 |
| 4822 | Green Valley Coal Company - Quinwood Prep Plant | Gauley 100.00% | | Nicholas 100.00% | | 47,517,333 |
| 4001 | Greer Lime Company | South Branch Potomac 100.00% | | Pendleton 100.00% | | 33,415,680 |
| 8059 | Hampden Coal Company Prep Plant | Upper Guyandotte 100.00% | | Mingo 100.00% | | 116,361,600 |
| 10094 | Hawthorne Coal Company - Sawmill Run Complex | Tygart Valley 100.00% | | Upshur 100.00% | | 15,085,867 |
| 4149 | Highland Mining Co - Highland Surface | Upper Guyandotte 100.00% | | Logan 100.00% | | 5,081,667 |
| 4454 | Hobet Mining - Hobet 21 Mine | Coal 81.36% | Lower Guyandotte 18.64% | Boone 94.92% | Lincoln 5.08% | 914,308,971 |
| 10084 | ICG Beckley, LLC | Lower New 100.00% | | Raleigh 100.00% | | 176,114,250 |
| 3034 | ICG Eastern - Birch River Operation | Elk 9.12% | Gauley 90.88% | Webster 100.00% | | 118,152,753 |
| 4896 | Independence Coal Co - Liberty Processing | Coal 100.00% | | Boone 100.00% | | 78,811,004 |
| 10108 | Jack's Branch Coal Co - Admiral Processing | Coal 100.00% | | Boone 100.00% | | 119,819,000 |
| 2990 | Jacks Branch River Terminal | Upper Kanawha 100.00% | | Kanawha 100.00% | | 18,351,943 |

| Mining, continued | | | | | |
|---|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | | County and % of 3 Year Average | 3 Year Average (gallons) |
| 2075 | Kanawha River Terminals - Ceredo Dock | Lower Ohio 19.18% | Twelvepole 80.82% | Wayne 100.00% | 9,841,011 |
| 2988 | Kanawha River Terminals - Quincy Dock | Upper Kanawha 100.00% | | Kanawha 100.00% | 45,467,855 |
| 4591 | Keplar Pocahontas No. 51 Prep Plant | Upper Guyandotte 100.00% | | Wyoming 100.00% | 116,109,200 |
| 3378 | Kingston Resources, Inc. | Upper Kanawha 100.00% | | Fayette 100.00% | 232,323,840 |
| 4128 | Litwar Processing Company, LLC | Tug Fork 100.00% | | McDowell 100.00% | 31,860,747 |
| 7977 | Mammoth Coal Co - #2 Gas Mine | Upper Kanawha 100.00% | | Kanawha 100.00% | 9,088,720 |
| 10111 | Mammoth Coal Co - Alloy Powellton | Upper Kanawha 66.67% | | Fayette 100.00% | 13,748,940 |
| 10109 | Mammoth Coal Co - Laurel Hollow Coalburg | Upper Kanawha 100.00% | | Kanawha 100.00% | 5,902,848 |
| 4208 | Mammoth Coal Co - Mammoth Processing | Upper Kanawha 100.00% | | Kanawha 100.00% | 1,917,368,960 |
| 10110 | Mammoth Coal Co - Slab Camp Stockton | Upper Kanawha 100.00% | | Kanawha 100.00% | 18,240,768 |
| 3419 | Marfork Coal Company, Inc. | Coal 100.00% | | Raleigh 100.00% | 1,245,669,792 |
| 3362 | McElroy Coal - McElroy Mine and Prep Plant | Upper Ohio South 100.00% | | Marshall 100.00% | 630,737,181 |
| 10105 | Midland Trail Energy - Blue Creek Complex | Upper Kanawha 100.00% | | Kanawha 100.00% | 93,645,797 |
| 4865 | Midland Trail Energy - Campbells Creek Complex | Upper Kanawha 100.00% | | Kanawha 100.00% | 178,940,037 |

| Mining, continued | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 10087 | Mingo Logan Coal Company - Left Fork No. 2 Surface | Coal 100.00% | Raleigh 100.00% | 5,176,000 |
| 10091 | Mingo Logan Coal Company - Mountain Laurel Complex | Upper Guyandotte 100.00% | Logan 100.00% | 780,356,925 |
| 10086 | Mingo Logan Coal Company - Spruce No. 1 Mine | Coal 100.00% | Logan 100.00% | 7,320,000 |
| 4904 | Omar Mining Co - Chesterfield Prep Plant | Coal 100.00% | Boone 100.00% | 57,408,000 |
| 10082 | Patriot Coal - Federal #2 Mine | Dunkard 100.00% | Monongalia 100.00% | 322,038,452 |
| 3321 | Performance Coal Company | Coal 100.00% | Raleigh 100.00% | 151,263,660 |
| 4056 | Pine Ridge Coal Company | Coal 100.00% | Boone 100.00% | 291,137,280 |
| 1174 | Pinnacle Mining Company, LLC | Upper Guyandotte 100.00% | Wyoming 100.00% | 223,880,001 |
| 7607 | Pioneer Fuel - Ewing Fork Surface Mine | Coal 100.00% | Raleigh 100.00% | 26,160,000 |
| 3547 | Pioneer Fuel Corp - Pioneer Load-out Facility | Upper Guyandotte 100.00% | Wyoming 100.00% | 11,424,000 |
| 8312 | Pocahontas Coal Co. - East Gulf Preparation Plant | Upper Guyandotte 100.00% | Raleigh 100.00% | 78,962,390 |
| 7851 | Power Mountain Coal Processing | Gauley 100.00% | Nicholas 100.00% | 92,007,670 |
| 4230 | Premium Energy - Surface Mine No. 2 | Tug Fork 100.00% | Mingo 100.00% | 14,904,120 |
| 3453 | Progress Coal - Twilight MTR Surface Mine | Coal 100.00% | Raleigh 100.00% | 44,610,067 |

| Mining, continued | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 3785 | Rivers Edge Mining - Rivers Edge Mine | Coal<br>100.00% | Boone<br>100.00% | 11,073,226 |
| 4710 | Rockspring Development-Camp Creek Mine/Prep Plant | Twelvepole<br>100.00% | Wayne<br>100.00% | 134,171,417 |
| 3941 | Rum Creek Coal Sales - Anna Branch Surface | Upper Guyandotte<br>100.00% | Logan<br>100.00% | 8,096,667 |
| 1586 | Second Sterling Corp - Keystone No. 1 Prep Plant | Tug Fork<br>100.00% | McDowell<br>100.00% | 58,318,333 |
| 2439 | Southern Minerals - Superior Preparation Plant | Tug Fork<br>100.00% | 100.00%<br>0.00% | 26,121,000 |
| 4004 | U S Silica Company | Potomac Direct Drains<br>100.00% | Morgan<br>100.00% | 388,230,585 |
| 4749 | White Flame Energy - No. 9 Surface Mine | Tug Fork<br>100.00% | Mingo<br>100.00% | 7,189,583 |
| 10103 | Wolf Run Mining - Sentinel Complex | Tygart Valley 99.93%<br>West Fork 0.07% | Barbour<br>100.00% | 81,209,500 |
| **Petroleum** | | | | |
| 1112 | Ergon West Virginia, Inc. | Upper Ohio North<br>100.00% | Hancock 38.67%<br>PA 61.33% | 213,093,153 |
| 3558 | Koppers Inc. | Upper Ohio North<br>100.00% | Brooke<br>100.00% | 112,478,235 |
| 2960 | Mars Water Supply Well | West Fork<br>100.00% | Harrison<br>100.00% | 32,087,048 |
| 1590 | New Martinsville Booster Plant | Middle Ohio North<br>100.00% | Wetzel<br>100.00% | 78,556,680 |
| 1499 | Rain CII Carbon LLC | Upper Ohio South<br>100.00% | Marshall<br>100.00% | 48,722,299 |

| Public Water Supply | | | | | |
|---|---|---|---|---|---|
| 3569 | Alderson Water Treatment Plant | Greenbrier<br>100.00% | | Monroe<br>100.00% | 154,730,000 |
| 2678 | Alpine Lake Public Utilities Company | Youghiogheny<br>100.00% | | Preston<br>100.00% | 31,950,000 |
| 10009 | Armstrong PSD | Upper Kanawha<br>100.00% | | Fayette<br>100.00% | 83,785,791 |
| 10065 | Arthurdale Water Company | Monongahela<br>100.00% | | Preston<br>100.00% | 8,060,800 |
| 1325 | Athens Water Plant | Upper New<br>100.00% | | Mercer<br>100.00% | 172,351,000 |
| 3077 | Beckley Water Company | Lower New<br>89.45% | Upper Kanawha<br>10.55% | Raleigh<br>100.00% | 3,269,161,633 |
| 10040 | Beech Bottom Water Department | Upper Ohio South<br>100.00% | | Brooke<br>100.00% | 14,688,443 |
| 1972 | Belington Water Treatment Plant | Tygart Valley<br>100.00% | | Barbour<br>100.00% | 80,445,667 |
| 10056 | Benwood Municipal Utilities | Upper Ohio South<br>100.00% | | Marshall<br>100.00% | 68,721,667 |
| 7133 | Berkeley County PSD - BHWTP | Potomac Direct Drains<br>100.00% | | Berkeley<br>100.00% | 636,676,000 |
| 10002 | Berkeley County PSD - PRWTP | Potomac Direct Drains<br>100.00% | | Berkeley<br>100.00% | 1,015,631,333 |
| 7134 | Berkeley County PSWD - GFU | Potomac Direct Drains<br>100.00% | | Berkeley<br>100.00% | 26,127,667 |
| 2547 | Berkeley Springs Water Works | Potomac Direct Drains<br>100.00% | | Morgan<br>100.00% | 156,177,605 |
| 1142 | Beverly Water Plant | Tygart Valley<br>100.00% | | Randolph<br>100.00% | 153,598,604 |
| 7906 | Big Bend PSD | Greenbrier<br>100.00% | | Summers<br>100.00% | 33,821,320 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 3863 | Bluewell Public Service District | Upper New<br>100.00% | Mercer<br>100.00% | 219,013,396 |
| 10003 | Boone Raleigh PSD | Coal<br>100.00% | Boone<br>100.00% | 56,110,053 |
| 1768 | Bradshaw Water Works | Tug Fork<br>100.00% | McDowell<br>100.00% | 15,012,227 |
| 4757 | Brenton PSD | Upper Guyandotte<br>100.00% | Wyoming<br>100.00% | 17,075,200 |
| 1720 | Buffalo Creek PSD | Upper Guyandotte<br>100.00% | Logan<br>100.00% | 124,299,329 |
| 7764 | Burnsville Public Utility | Little Kanawha<br>100.00% | Braxton<br>100.00% | 29,581,340 |
| 1097 | Burr Industrial Park | Potomac Direct Drains<br>100.00% | Jefferson<br>100.00% | 26,513,300 |
| 1159 | Cacapon State Park | Potomac Direct Drains<br>100.00% | Morgan<br>100.00% | 25,577,333 |
| 10020 | Cameron Water | Upper Ohio South<br>100.00% | Marshall<br>100.00% | 41,178,792 |
| 3226 | Canaan Valley State Park | Cheat<br>100.00% | Tucker<br>100.00% | 27,256,869 |
| 8195 | Cedar Grove Water Works | Upper Kanawha<br>100.00% | Kanawha<br>100.00% | 215,774,333 |
| 4086 | Charles Town Water Treatment Plant | Shenandoah Jefferson<br>100.00% | Jefferson<br>100.00% | 616,400,487 |
| 5082 | Cheat Mountain Water Company | Cheat 74.58%<br>Elk 25.42% | Pocahontas<br>100.00% | 10,911,345 |
| 10062 | City of Belmont | Middle Ohio North<br>100.00% | Pleasants<br>100.00% | 63,764,311 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 1228 | City of Buckhannon Water Plant | Tygart Valley 100.00% | Upshur 100.00% | 781,452,937 |
| 10012 | City of Chester | Upper Ohio North 100.00% | Hancock 100.00% | 123,690,000 |
| 1247 | City of Fairmont | Tygart Valley 100.00% | Marion 100.00% | 2,387,969,191 |
| 10050 | City of Gary | Tug Fork 100.00% | McDowell 100.00% | 130,502,333 |
| 10022 | City of Keyser | North Branch Potomac 100.00% | Mineral 100.00% | 395,109,333 |
| 2049 | City of Lewisburg Water Plant | Greenbrier 100.00% | Greenbrier 100.00% | 607,863,850 |
| 2762 | City of Logan Water Department | Upper Guyandotte 100.00% | Logan 100.00% | 505,653,620 |
| 3872 | City of Martinsburg | Potomac Direct Drains 100.00% | Berkeley 100.00% | 1,460,137,934 |
| 7022 | City of New Cumberland | Upper Ohio North 100.00% | Hancock 100.00% | 163,820,667 |
| 2106 | City of Parsons | Cheat 100.00% | Tucker 100.00% | 105,971,667 |
| 2102 | City of Ravenswood | Middle Ohio South 100.00% | Jackson 100.00% | 234,927,602 |
| 1794 | City of Romney | South Branch Potomac 100.00% | Hampshire 100.00% | 174,549,000 |
| 4891 | City of Sistersville | Middle Ohio North 100.00% | Tyler 100.00% | 115,259,152 |
| 7461 | City of Spencer Waterworks | Little Kanawha 100.00% | Roane 100.00% | 218,337,464 |

| Public Water Supply, cont. | | | | | | |
|---|---|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | | County and % of 3 Year Average | | 3 Year Average (gallons) |
| 10063 | City of St. Marys | Middle Ohio North 100.00% | | Pleasants 100.00% | | 168,407,333 |
| 10033 | City of Thomas | Cheat 100.00% | | Tucker 100.00% | | 33,233,884 |
| 10070 | City of Vienna | Middle Ohio North 8.64% | Middle Ohio South 91.36% | Pleasants 8.64% | Wood 91.36% | 430,025,044 |
| 1703 | City of Welch Water Department | Tug Fork 100.00% | | McDowell 100.00% | | 242,426,333 |
| 1318 | City of Wellsburg | Upper Ohio South 100.00% | | Brooke 100.00% | | 220,597,000 |
| 1237 | City of White Sulphur Springs Water Plant | Greenbrier 100.00% | | Greenbrier 100.00% | | 260,740,333 |
| 1696 | City of Williamstown | Middle Ohio North 100.00% | | Wood 100.00% | | 97,947,333 |
| 4143 | Clarksburg Water Board | West Fork 100.00% | | Harrison 100.00% | | 2,588,148,333 |
| 10006 | Clay Municipal Water | Elk 100.00% | | Clay 100.00% | | 137,203,667 |
| 10007 | Clay-Roane PSD (Procious District) | Elk 100.00% | | Clay 100.00% | | 29,506,367 |
| 7850 | Claywood Park PSD | Little Kanawha 100.00% | | Wood 100.00% | | 443,996,333 |
| 5064 | Coal City Water Plant | Lower New 100.00% | | Raleigh 100.00% | | 88,621,000 |
| 10069 | Coalton Water System | Tygart Valley 100.00% | | Randolph 100.00% | | 8,380,200 |
| 1903 | Cottageville Public Service District | Middle Ohio South 100.00% | | Jackson 100.00% | | 84,242,933 |

## Public Water Supply, cont.

| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | | 3 Year Average (gallons) |
|---|---|---|---|---|---|
| 10073 | Covel Water Works | Upper Guyandotte<br>100.00% | Wyoming<br>100.00% | | 7,089,167 |
| 10035 | Cowen PSD | Gauley<br>100.00% | Webster<br>100.00% | | 118,313,467 |
| 4158 | Craigsville PSD | Gauley<br>100.00% | Nicholas<br>100.00% | | 205,629,500 |
| 10018 | Crumpler Community Water | Tug Fork<br>100.00% | McDowell<br>100.00% | | 9,690,000 |
| 4068 | Danese Public Service District | Lower New<br>100.00% | Fayette<br>100.00% | | 78,059,847 |
| 7748 | Davy Municipal Water Works | Tug Fork<br>100.00% | McDowell<br>100.00% | | 11,443,633 |
| 7934 | Deerwood | Potomac Direct Drains<br>100.00% | Berkeley<br>100.00% | | 8,171,333 |
| 7959 | Denmar Correctional Center | Greenbrier<br>100.00% | Pocahontas<br>100.00% | | 15,801,273 |
| 1900 | Elkins Water Works | Tygart Valley<br>100.00% | Randolph<br>100.00% | | 789,237,288 |
| 10004 | Flatwoods Canoe Run PSD | Elk<br>100.00% | Braxton<br>100.00% | | 208,389,667 |
| 1582 | Follansbee Hooverson Heights | Upper Ohio North<br>100.00% | Brooke<br>100.00% | | 155,115,000 |
| 3137 | Follansbee Municipal Water | Upper Ohio North<br>100.00% | Brooke<br>100.00% | | 311,318,500 |
| 3442 | Fort Gay Water Works | Tug Fork<br>100.00% | Wayne<br>100.00% | | 100,301,033 |
| 1134 | Fountain Public Service District | North Branch Potomac<br>100.00% | Grant<br>41.56% | Mineral<br>58.44% | 20,812,070 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 4387 | Fox Glen Utilites | Potomac Direct Drains 100.00% | Jefferson 100.00% | 49,463,867 |
| 7869 | Frankfort Public Service District | North Branch Potomac 100.00% | Mineral 100.00% | 204,603,636 |
| 3076 | Franklin Water Treatment Plant | South Branch Potomac 100.00% | Pendleton 100.00% | 87,390,999 |
| 4700 | Friendly PSD | Middle Ohio North 100.00% | Tyler 100.00% | 17,472,600 |
| 3446 | Gap Mills PSD | Greenbrier 100.00% | Monroe 100.00% | 15,695,944 |
| 10024 | Gilbert Water Works | Upper Guyandotte 100.00% | Mingo 100.00% | 44,495,463 |
| 10053 | Glen Dale Water Works | Upper Ohio South 100.00% | Marshall 100.00% | 88,872,335 |
| 7069 | Glenville Water Plant | Little Kanawha 100.00% | Gilmer 100.00% | 224,960,667 |
| 2751 | Grandview-Doolin PSD | Middle Ohio North 100.00% | Wetzel 100.00% | 54,814,667 |
| 10011 | Green Spring PSD (Springfield) | South Branch Potomac 100.00% | Hampshire 100.00% | 15,290,887 |
| 7840 | Green Valley / Glenwood PSD / New Glenwood | Upper New 100.00% | Mercer 100.00% | 224,192,212 |
| 10083 | Green Valley/Glenwood PSD - Bulltail Water Plant | Upper New 100.00% | Mercer 100.00% | 81,086,667 |
| 10041 | Greenbrier County PSD #2 | Gauley 100.00% | Greenbrier 100.00% | 58,550,937 |
| 3662 | Greenville Water Treatment Plant | Upper Guyandotte 100.00% | Logan 100.00% | 127,557,897 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 1829 | Hammond Public Service District | Upper Ohio South 100.00% | Brooke 100.00% | 61,694,163 |
| 2436 | Hamrick PSD | Cheat 100.00% | Tucker 100.00% | 41,204,600 |
| 7215 | Harman Water Works | Cheat 100.00% | Randolph 100.00% | 8,445,000 |
| 4331 | Harpers Ferry Water Works | Potomac Direct Drains 100.00% | Jefferson 100.00% | 105,044,667 |
| 2750 | Hundred-Littleton Public Service District | Upper Ohio South 100.00% | Wetzel 100.00% | 19,889,135 |
| 1871 | Hurricane Water Company | Lower Kanawha 100.00% | Putnam 100.00% | 232,325,000 |
| 10032 | Huttonsville Correctional Center | Tygart Valley 100.00% | Randolph 100.00% | 68,086,667 |
| 3052 | Kanawha Falls PSD | Upper Kanawha 100.00% | Fayette 100.00% | 257,671,433 |
| 10034 | Kenova Water Plant | Big Sandy 100.00% | Wayne 100.00% | 878,706,867 |
| 10025 | Kermit Water Works | Tug Fork 100.00% | Mingo 100.00% | 138,416,846 |
| 10051 | Keystone Municipal Water | Tug Fork 100.00% | McDowell 100.00% | 40,102,667 |
| 3444 | Kingwood Water Works | Cheat 100.00% | Preston 100.00% | 236,785,633 |
| 10017 | Lincoln Public Service District | Coal 100.00% | Kanawha 100.00% | 145,930,000 |
| 7702 | Louis Niebergall Ice Company | Upper Ohio South 100.00% | Ohio 100.00% | 9,476,400 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 2282 | Lubeck Public Service District | Middle Ohio South 100.00% | Wood 100.00% | 304,292,937 |
| 2778 | Lumberport Water | West Fork 100.00% | Harrison 100.00% | 59,705,333 |
| 10054 | Marshall County PSD 2 | Upper Ohio South 100.00% | Marshall 100.00% | 95,789,400 |
| 3043 | Mason County PSD - Crab Creek Well Field | Lower Ohio 100.00% | Mason 100.00% | 157,248,633 |
| 1870 | Mason County PSD - Lakin Well Field | Middle Ohio South 100.00% | Mason 100.00% | 114,415,000 |
| 3054 | Mason County PSD - Letart Well Field | Middle Ohio South 100.00% | Mason 100.00% | 81,340,890 |
| 10058 | Mason Water Department | Middle Ohio South 100.00% | Mason 100.00% | 64,038,047 |
| 2701 | Matewan Water | Tug Fork 100.00% | Mingo 100.00% | 112,752,800 |
| 4882 | Matoaka Water Works | Upper New 100.00% | Mercer 100.00% | 19,779,483 |
| 4017 | McDowell County PSD / Bartley | Tug Fork 100.00% | VA 100.00% | 42,907,667 |
| 4301 | McDowell County PSD / Berwind | Tug Fork 100.00% | McDowell 100.00% | 25,081,464 |
| 4422 | McDowell County PSD / Big Four | Tug Fork 100.00% | VA 100.00% | 11,589,233 |
| 3976 | McDowell County PSD / Coalwood | Tug Fork 100.00% | McDowell 100.00% | 13,471,800 |
| 3566 | McDowell County PSD / Elkhorn - Ennis - Crozer | Tug Fork 100.00% | McDowell 100.00% | 21,245,033 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 3674 | McDowell County PSD / Gilliam - Rolfe - Worth | Tug Fork 100.00% | McDowell 100.00% | 5,607,821 |
| 3990 | McDowell County PSD / Iaeger | Tug Fork 100.00% | McDowell 100.00% | 24,715,353 |
| 4680 | McDowell County PSD / Kimball - Carswell | Tug Fork 100.00% | VA 100.00% | 79,158,697 |
| 4699 | McDowell County PSD / Landgraff - Eckman | Tug Fork 100.00% | McDowell 100.00% | 13,190,664 |
| 3528 | McDowell County PSD / Maybeury-Switchback | Tug Fork 100.00% | McDowell 100.00% | 44,355,887 |
| 3534 | McDowell County PSD / Upland - Powhatan - Kyle | Tug Fork 100.00% | McDowell 100.00% | 66,368,750 |
| 4606 | McDowell County PSD / Vivian - Tidewater | Tug Fork 100.00% | McDowell 100.00% | 22,926,850 |
| 3636 | McDowell County PSD/ Greenbrier-Arlington-McDowell | Tug Fork 100.00% | McDowell 100.00% | 57,847,021 |
| 10055 | McMechen Municipal Water | Upper Ohio South 100.00% | Marshall 100.00% | 231,098,667 |
| 1153 | Meadowbrook Water System | Potomac Direct Drains 100.00% | Jefferson 100.00% | 30,304,833 |
| 4080 | Middlebourne Municipal Water Works | Middle Ohio North 100.00% | Tyler 100.00% | 40,773,333 |
| 3979 | Milton Municipal Utility Commission | Lower Guyandotte 100.00% | Cabell 100.00% | 212,046,838 |
| 3864 | Mingo County PSD - Naugatuck Water Plant | Tug Fork 100.00% | Mingo 100.00% | 255,209,000 |
| 7573 | Monongah Water Plant | Tygart Valley 100.00% | Marion 100.00% | 271,148,083 |

## Public Water Supply, cont.

| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
|---|---|---|---|---|
| 7102 | Moorefield Municipal Water System | South Branch Potomac 100.00% | Hardy 100.00% | 1,319,921,154 |
| 10026 | Morgantown Utility Board | Monongahela 100.00% | Monongalia 100.00% | 3,618,309,333 |
| 1352 | Moundsville Water Board | Upper Ohio South 100.00% | Marshall 100.00% | 557,674,333 |
| 2863 | Mt Hope Water Treatment Plant | Lower New 100.00% | Fayette 100.00% | 96,580,500 |
| 3178 | Mt. Top Public Service District | North Branch Potomac 100.00% | Grant 100.00% | 62,147,037 |
| 10028 | Nettie-Leivasy PSD | Gauley 100.00% | Nicholas 100.00% | 97,607,000 |
| 10059 | New Haven Water Department | Middle Ohio South 100.00% | Mason 100.00% | 57,188,333 |
| 1176 | New Martinsville Water Department | Middle Ohio North 100.00% | Wetzel 100.00% | 416,068,007 |
| 10031 | NIOC | South Branch Potomac 100.00% | Pendleton 100.00% | 9,407,267 |
| 3637 | Northern Regional Water Treatment Plant | Lower Guyandotte 100.00% | Logan 100.00% | 720,085,000 |
| 10048 | Northfork Water Works | Tug Fork 100.00% | McDowell 100.00% | 48,941,000 |
| 2223 | Norton-Harding-Jimtown Public Service District | Tygart Valley 100.00% | Randolph 100.00% | 85,703,533 |
| 10045 | Oakland Public Service District | Upper Ohio North 100.00% | Hancock 100.00% | 37,702,533 |
| 2124 | Paden City Water Works | Middle Ohio North 100.00% | Wetzel 100.00% | 107,505,987 |

| Public Water Supply, cont. | | | | | | |
|---|---|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | | County and % of 3 Year Average | | 3 Year Average (gallons) |
| 2998 | Page- Kincaid Public Service District | Upper Kanawha 100.00% | | Fayette 100.00% | | 111,807,667 |
| 1495 | Parkersburg Water Treatment Plant | Middle Ohio South 100.00% | | Wood 100.00% | | 2,958,506,333 |
| 1311 | Paw Paw Municipal Water and Sewer System | Cacapon 100.00% | | Morgan 100.00% | | 13,362,333 |
| 2006 | Pendleton County PSD- Brandywine | South Branch Potomac 100.00% | | Pendleton 100.00% | | 13,162,000 |
| 1996 | Pendleton County PSD- Upper Tract | South Branch Potomac 100.00% | | Pendleton 100.00% | | 10,837,983 |
| 10001 | Philippi Municipal Water | Tygart Valley 100.00% | | Barbour 100.00% | | 406,463,000 |
| 10023 | Piedmont Municipal Water Works | North Branch Potomac 100.00% | | MD 100.00% | | 37,384,667 |
| 10036 | Pine Grove Water | Middle Ohio North 100.00% | | Wetzel 100.00% | | 22,955,333 |
| 5097 | Pineville Municipal Water Works | Upper Guyandotte 100.00% | | Wyoming 100.00% | | 114,309,680 |
| 10064 | Pocahontas County Public Service District | Greenbrier 100.00% | | Pocahontas 100.00% | | 44,670,981 |
| 10021 | Pocahontas Water System | Upper New 100.00% | | Mercer 100.00% | | 125,378,553 |
| 1945 | Point Pleasant Water Works | Lower Ohio 35.30% | Middle Ohio South 64.70% | Mason 42.65% | OH 57.35% | 454,604,867 |
| 2651 | Pratt Water Works | Upper Kanawha 100.00% | | Kanawha 100.00% | | 68,031,649 |
| 7267 | Preston County Public Service District #1 WIP | Monongahela 100.00% | | Preston 100.00% | | 82,995,531 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 1815 | Preston County Public Service District #4 | Cheat 100.00% | Preston 100.00% | 166,830,700 |
| 2271 | Putnam Public Service District | Lower Kanawha 100.00% | Putnam 100.00% | 597,101,333 |
| 10043 | Rainelle Water Department | Gauley 100.00% | Greenbrier 100.00% | 92,690,967 |
| 2601 | Ravencliff-McGraws-Saulsville PSD | Upper Guyandotte 100.00% | Wyoming 100.00% | 114,396,335 |
| 10027 | Red Sulphur Public Service District | Upper New 100.00% | Monroe 100.00% | 131,528,051 |
| 10068 | Rhodell Water Works | Upper Guyandotte 100.00% | Raleigh 100.00% | 17,377,807 |
| 1653 | Richwood Water Department | Gauley 100.00% | Nicholas 100.00% | 123,479,914 |
| 2335 | Ripley Water Works | Middle Ohio South 100.00% | Jackson 100.00% | 332,909,602 |
| 1078 | Rocky Glen | Potomac Direct Drains 100.00% | Berkeley 100.00% | 23,454,651 |
| 3389 | Rowlesburg Water Works | Cheat 100.00% | Preston 100.00% | 46,528,631 |
| 5038 | Rupert Water Department | Gauley 100.00% | Greenbrier 100.00% | 43,500,733 |
| 1151 | Shenandoah Junction Public Water | Potomac Direct Drains 100.00% | Jefferson 100.00% | 15,338,233 |
| 10014 | Shinnston Water Board | Tygart Valley 100.00% | Marion 100.00% | 400,171,100 |
| 10016 | St Albans Water | Coal 100.00% | Kanawha 100.00% | 486,227,000 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 3697 | Stephenson Water Treatment Plant | Upper Guyandotte 100.00% | Wyoming 100.00% | 99,722,733 |
| 10005 | Sugar Creek PSD | Elk 100.00% | Braxton 100.00% | 29,183,000 |
| 10029 | Summersville Municipal Water | Gauley 100.00% | Nicholas 100.00% | 256,935,000 |
| 7522 | Sycamore Water Plant | Coal 100.00% | Raleigh 100.00% | 19,285,913 |
| 1856 | Taylor County PSD | Tygart Valley 100.00% | Barbour 100.00% | 703,633,667 |
| 2976 | Terra Alta Water Works | Youghiogheny 100.00% | Preston 100.00% | 63,126,233 |
| 7050 | The Woods & Walden Woods Subdivision | Potomac Direct Drains 100.00% | Berkeley 100.00% | 22,723,601 |
| 7070 | The Woods II & Walden Woods Subdivision | Potomac Direct Drains 100.00% | Berkeley 100.00% | 31,686,523 |
| 1218 | Timberline 4 Seasons Utilities | Cheat 100.00% | Tucker 100.00% | 19,731,813 |
| 1986 | Town of Capon Bridge Water Department | Cacapon 100.00% | Hampshire 100.00% | 19,885,633 |
| 2085 | Town of Carpendale | North Branch Potomac 100.00% | Mineral 100.00% | 22,940,333 |
| 3280 | Town of Davis | Cheat 100.00% | Tucker 100.00% | 36,554,790 |
| 2633 | Town of Fairview Water Department | Monongahela 100.00% | Marion 100.00% | 22,162,860 |
| 1681 | Town of Grantsville | Little Kanawha 100.00% | Calhoun 100.00% | 117,677,133 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 10057 | Town of Hartford | Middle Ohio South 100.00% | Mason 100.00% | 19,894,987 |
| 2197 | Town of Man Water Works | Upper Guyandotte 100.00% | Logan 100.00% | 46,089,001 |
| 3260 | Town of Marlinton | Greenbrier 100.00% | Pocahontas 100.00% | 65,554,967 |
| 2842 | Town of Meadow Bridge Water Dept. | Lower New 100.00% | Fayette 100.00% | 23,734,517 |
| 4339 | Town of Mill Creek Municipal Water Plant | Tygart Valley 100.00% | Randolph 100.00% | 74,262,000 |
| 10037 | Town of Oceana | Upper Guyandotte 100.00% | Wyoming 100.00% | 203,631,000 |
| 10010 | Town of Petersburg | South Branch Potomac 100.00% | Grant 100.00% | 310,763,827 |
| 10061 | Town of Union | Upper New 100.00% | Monroe 100.00% | 32,972,537 |
| 8251 | Town of West Hamlin Water Company | Lower Guyandotte 100.00% | Lincoln 100.00% | 127,566,000 |
| 3133 | Union Williams Public Service District | Middle Ohio North 100.00% | Wood 100.00% | 221,090,054 |
| 7615 | VAMC Martinsburg | Potomac Direct Drains 100.00% | Berkeley 100.00% | 78,610,842 |
| 1152 | Walnut Grove | Shenandoah Jefferson 100.00% | Jefferson 100.00% | 92,505,933 |
| 3126 | Walton PSD | Lower Kanawha 100.00% | Roane 100.00% | 47,306,890 |
| 4095 | War Water Works / City Realty | Tug Fork 100.00% | McDowell 100.00% | 14,677,800 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 1477 | Wardensville Water Department | Cacapon 100.00% | Hardy 100.00% | 30,820,100 |
| 1561 | Wayne Water Services | Twelvepole 100.00% | Wayne 100.00% | 207,817,538 |
| 1187 | Weirton Water Treatment Plant | Upper Ohio North 100.00% | Brooke 100.00% | 1,212,390,831 |
| 10008 | West Union Municipal Water Plant | Middle Ohio North 100.00% | Doddridge 100.00% | 56,309,000 |
| 2367 | West Virginia American Water - Bluefield | Upper New 100.00% | Mercer 100.00% | 670,095,333 |
| 2533 | West Virginia American Water - Bluestone | Upper New 100.00% | Summers 100.00% | 978,392,333 |
| 2113 | West Virginia American Water - Gassaway | Elk 100.00% | Braxton 100.00% | 104,552,667 |
| 2891 | West Virginia American Water - Huntington | Lower Ohio 100.00% | Cabell 100.00% | 4,637,048,333 |
| 1193 | West Virginia American Water - Kanawha Valley | Elk 100.00% | Kanawha 100.00% | 11,364,700,000 |
| 1470 | West Virginia American Water - Montgomery | Upper Kanawha 100.00% | Fayette 100.00% | 169,862,667 |
| 2524 | West Virginia American Water - New River District | Lower New 100.00% | Fayette 100.00% | 1,157,897,667 |
| 1471 | West Virginia American Water - Webster Springs | Elk 100.00% | Webster 100.00% | 47,538,000 |
| 1469 | West Virginia American Water - Weston WTP | West Fork 100.00% | Lewis 100.00% | 431,777,333 |
| 1156 | Westridge Hills Water Works | Shenandoah Jefferson 100.00% | Jefferson 100.00% | 8,870,100 |

| Public Water Supply, cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 1793 | Wheeling Water Plant | Upper Ohio South 100.00% | Ohio 100.00% | 2,464,776,833 |
| 10030 | Wilderness PSD | Gauley 100.00% | Nicholas 100.00% | 114,127,633 |
| 3033 | Williamson Utility Board | Tug Fork 100.00% | Mingo 100.00% | 816,359,000 |
| 1489 | WVPA - Morton | Upper Kanawha 100.00% | Kanawha 100.00% | 6,310,533 |
| **Recreation** | | | | |
| 4300 | Big Bear Lake Camplands | Cheat 100.00% | Preston 100.00% | 3,570,707 |
| 2649 | Capon Springs Hotel | Cacapon 100.00% | Hampshire 100.00% | 7,642,633 |
| 5128 | Cress Creek Country Club | Potomac Direct Drains >99.99%; Shenandoah Jefferson <0.01% | Jefferson 100.00% | 13,735,000 |
| 1185 | Edgewood Country Club - Golf Facility | Lower Kanawha 100.00% | Kanawha 100.00% | 12,350,000 |
| 4222 | Glade Springs Village P.O.A. - Chatham Lake | Lower New 100.00% | Raleigh 100.00% | 15,421,811 |
| 10090 | Glade Springs Village P.O.A. - Woodhaven Golf Course | Lower New 100.00% | Raleigh 100.00% | 11,314,407 |
| 7675 | Locust Hill Golf Course | Shenandoah Jefferson 100.00% | Jefferson 100.00% | 43,910,667 |
| 7767 | Mountaineer Race Track Casino | Upper Ohio North 100.00% | Hancock 100.00% | 87,153,876 |
| 5114 | Parkersburg Country Club | Middle Ohio South 100.00% | Wood 100.00% | 6,999,000 |

| Recreation, continued | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 10092 | Pikewood National Golf Course | Monongahela 100.00% | Monongalia 100.00% | 14,717,658 |
| 10074 | River Bend Membership Corporation | Potomac Direct Drains 100.00% | Berkeley 100.00% | 30,458,373 |
| 4639 | Snowshoe Mountain | Cheat 98.26% Elk 1.74% | Pocahontas 100.00% | 459,501,260 |
| 1677 | The Greenbrier | Greenbrier 100.00% | Greenbrier 100.00% | 129,087,372 |
| 2787 | The Greenbrier Hotel Corporation | Greenbrier 100.00% | Greenbrier 100.00% | 515,365,209 |
| 4738 | Twisted Gun Golf Club | Tug Fork 100.00% | Mingo 100.00% | 2,718,500 |
| 4580 | Valley View Golf Course | South Branch Potomac 100.00% | Hardy 100.00% | 8,188,418 |
| 3224 | Winterplace Ski Resort | Lower New 100.00% | Raleigh 100.00% | 147,267,333 |
| 2729 | WVDNR - Stonewall Jackson Lake State Park | West Fork 100.00% | Lewis 100.00% | 35,369,477 |
| **Thermoelectric (coal)** | | | | |
| 2549 | Allegheny Energy - Pleasants Power Station | Middle Ohio North 100.00% | Pleasants 100.00% | 5,676,038,175 |
| 2521 | Allegheny Energy Supply - Harrison Power Station | West Fork 100.00% | Harrison 100.00% | 13,560,292,200 |
| 10097 | Allegheny Energy Supply - Lake Lynn Power Station | Cheat 100.00% | Monongalia 100.00% | 627,741,586,112 |
| 10099 | Allegheny Energy Supply - Millville Power Station | Shenandoah Jefferson 100.00% | Jefferson 100.00% | 177,149,617,587 |

| Thermoelectric (coal), cont. | | | | |
|---|---|---|---|---|
| Facility ID | Facility Name | Watershed and % of 3 Year Average | County and % of 3 Year Average | 3 Year Average (gallons) |
| 3804 | Appalachian Power - Kanawha River Plant | Upper Kanawha 100.00% | Kanawha 100.00% | 87,314,848,603 |
| 3805 | Appalachian Power - Mountaineer Plant | Middle Ohio South 100.00% | Mason 100.00% | 5,853,907,572 |
| 3806 | Appalachian Power - Philip Sporn Plant | Middle Ohio South 100.00% | Mason 100.00% | 199,232,260,160 |
| 3803 | John E Amos Plant | Lower Kanawha 100.00% | Putnam 100.00% | 14,411,032,933 |
| 2619 | Monongahela Power Co - Rivesville Power Station | Monongahela 100.00% | Marion 100.00% | 1,175,755,609 |
| 2005 | Monongahela Power Co - Albright Power Station | Cheat 100.00% | Preston 100.00% | 843,748,700 |
| 2493 | Monongahela Power Co - Fort Martin Power Station | Monongahela 100.00% | Monongalia 100.00% | 3,671,588,650 |
| 2600 | Monongahela Power Co - Willow Island Power Station | Middle Ohio North 100.00% | Pleasants 100.00% | 11,854,943,333 |
| 3422 | Morgantown Energy Facility | Monongahela 100.00% | Monongalia 100.00% | 26,827,340,000 |
| 2699 | Mount Storm Power Station | North Branch Potomac 100.00% | Grant 100.00% | 403,202,680,000 |
| 3807 | Ohio Power Co - Kammer Plant | Upper Ohio South 100.00% | Marshall 100.00% | 132,394,974,000 |
| 3808 | Ohio Power Co - Mitchell Plant | Upper Ohio South 100.00% | Marshall 100.00% | 9,236,808,759 |

| Timber | | | | |
|---|---|---|---|---|
| **Facility ID** | **Facility Name** | **Watershed and % of 3 Year Average** | **County and % of 3 Year Average** | **3 Year Average (gallons)** |
| 2310 | Fibrek Recycling U.S. Inc. - Fairmont Mill | Monongahela 100.00% | Marion 100.00% | 1,169,002,867 |
| 1330 | Kingsford Manufacturing Company | Cheat 100.00% | Tucker 100.00% | 22,367,502 |
| 2811 | Ox Paperboard | Shenandoah Jefferson 100.00% | Jefferson 100.00% | 35,573,300 |
| 5183 | UFP Ranson, LLC | Shenandoah Jefferson 100.00% | Jefferson 100.00% | 6,999,907 |

# Appendix L

Interbasin Transfers

## Withdrawals (SW & GW) vs. Stream Discharges

Bayer Material Science LLC withdrawals a three year average of approximately 713 million gallons from surface and groundwater in the Middle Ohio North watershed and 67 million gallons of groundwater a year from the Upper Ohio South watershed. The water is used for industry related purposes including steam generation, process cooling, and on-site potable water. The three year average of all discharges equals approximately 728.4 million gallons which is all discharged back into the Middle Ohio North watershed each year.

Catenary Coal Company – Samples Mine Complex withdrawals a three year average of approximately 53 million gallons of water from a surface water source in the Upper Kanawha and approximately 49 million gallons of surface water from the Coal watershed. The water is used as process water, dust control, truck wash, and for domestic purposes. Reportedly, 49 million gallons are discharged into the surface water of the Coal watershed, and 53 million gallons are discharged into surface water sources of the Upper Kanawha watershed. Although haul water and truck wash is a reported use, no values for gallons discharged for this purpose have been provided.

Cobra Natural Resources – Mountaineer Mine & Plant withdrawals a three year average of approximately 157 million gallons from ground water sources in the Upper Guyandotte watershed and approximately 1.9 million gallons from ground water sources in the Tug Fork watershed for use in the bath house and office. Approximately 1.9 million gallons are discharged into surface water sources in the Tug Fork watershed annually.

Consol Energy – Robinson Run withdrawals a three year average of approximately 193 million from surface creeks and impoundments in the West Fork watershed. The water is used for the industrial operation of a coal preparation plant, surface fire suppression, and dust control on haul roads. A three year average of approximately 5.8 million gallons are discharged into a stream in West Fork, 1.8 million is discharged into a stream in the Monongahela watershed, and 2.1 million is discharged on haul roads most highly concentrated in the West Fork watershed.

Consol Energy – Loveridge withdrawals a three year average of approximately 232 million gallons of surface water from the Monongahela watershed and approximately 17 million gallons from the Dunkard watershed each year for operation of a coal preparation plant, underground mine fire suppression, potable water, and dust control. A three year average of approximately 152 million gallons is reportedly discharged into surface waters of the Monongahela watershed while approximately 6 million gallons are discharged into the surface waters of the Dunkard watershed. Another 54.5 million gallons are discharged into the Monongahela watershed via ground spray and underground usage for dust control and fire suppression.

Green Valley Coal – Grassy Creek #1 Deep Mine withdrawals a three year average of approximately 19 million gallons of water from the surface waters of the Gauley watershed for use in coal extraction and related activities. Approximately 7 million gallons are reportedly discharged into a surface water source of the Elk watershed.

Hobet Mining – Hobet 21 Mine withdrawals a three year average of approximately 170 million gallons of surface water from the Lower Guyndotte watershed and 744 million gallons from surface sources in the Coal watershed for use in the mining and processing of coal including spraying haul roads to suppress fugitive dust. The three year average discharge to surface sources in the Coal watershed is reported to be approximately 215 million gallons of water annually.

ICG Eastern – Birch River Operation withdrawals a three year average of approximately 107 million gallon from impoundment, surface water sources located in the Gauley watershed and approximately 11 million gallons from a surface impoundment in the Elk watershed. Additionally, an approximate annual average of 596 thousand gallons of water is purchased from the Gauley watershed via Cowen PSD. The water is reportedly used for preparation plant make up water and dust suppression. A three year average of approximately 27 million gallons of that water has been reportedly discharged via land application to suppress dust on haul roads most highly concentrated in the Gauley watershed. Stream discharges to the Gauley watershed have not occurred since 2008.

Kanawha River Terminals – Ceredo Dock has a three year average of around 1.9 million gallons of water a year withdrawn from surface and groundwater sources in the Lower Ohio watershed and approximately 8 million gallons are withdrawn from surface water sources in the Twelvepole watershed. This water is reportedly used for mining practices including dust suppression and wash-down applications. Of the withdrawn water, a three year average of 40,000 gallons per year is discharged into the Twelvepole watershed via Twelvepole Creek and 231,670 gallons are discharged into the Lower Ohio watershed via the Ohio River.

Rain CII Carbon LLC withdrawals a three year average of approximately 48.7 million gallons of water from the Upper Ohio South watershed for use as process water, potable water for employee use and consumption, cooling water, and fire suppression. A three year average equal to 14.3 million gallons of excess water is generally discharged into the Upper Ohio South watershed via NPDES outfalls on the Ohio River.

Snowshoe Mountain withdrawals a three year average of approximately 8 million gallons of water from a surface water source in the Elk watershed and approximately 452 million gallons from surface water sources in the Cheat watershed. Approximately 393.6 million gallons of water is used annually for snowmaking at the Snowshoe and Silver Creek Ski slopes in the Cheat watershed and approximately 8 million gallons is used for irrigation of the Raven Golf Course located in the Elk watershed.

Wolf Run Mining – Sentinel Complex withdrawals a three year average of approximately 81 million gallons of surface and ground water from Tygart Valley watershed and approximately 161 thousand gallons annually from ground water sources in West Fork watershed. The water is used as makeup water for the preparation plant and for safety and dust control underground. Water is released in unknown quantities into the surface waters of the Tygart Valley watershed via 12 outlet locations that all fall under one NPDES permit number.

## Withdrawals (SW & GW) vs. POTW Discharges

Huntington Alloys Corporation withdrawals a three year average of around 277 million gallons of surface water a year from the Lower Guyandotte Watershed. Water at this facility is reportedly used for industrial processes including cooling water for boilers and process water. According to the three year average, 347 million gallons of water a year are discharged by this facility into the Lower Ohio Watershed via the Huntington Sanitary POTW.

Rain CII Carbon LLC withdrawals a three year average of approximately 48.7 million gallons of water from the Upper Ohio South watershed for use as process water, potable water for employee use and consumption, cooling water, and fire suppression. A three year average equal to approximately 43,700 gallons is discharged annually to the Moundsville Sanitary Plant in the Upper Ohio South watershed. However, a three year average of 19,300 gallons of water is discharged annually into the Upper Ohio North watershed via the Jefferson County Ohio WWTP.

Snowshoe Mountain withdrawals a three year average of approximately 8 million gallons of water from a surface water source in the Elk watershed and approximately 452 million gallons from surface water sources in the Cheat watershed. Some of the water is used as potable supply at various locations. A three year average of approximately 8.5 million gallons is discharged into the Cheat Watershed via POTW discharge to the Black Run WWTP.

## Purchased Water vs. Stream/POTW Discharges

Allegheny Energy Supply – Harrison Power Station purchases a three year average of water from the City of Shinnston approximately equal to 105 million gallons and from the Town of Lumberport at about 822 thousand gallons per year, which are located in the Tygart Valley and West Fork watersheds, respectively. The water is reportedly used by the facility for coal-fired steam electric generation and associated closed-loop cooling water processes. The only form of discharge reported is stream discharge at three locations that fall under a single NPDES permit number. All water discharged from the facility at these locations enters the West Fork watershed at an average rate of 3.1 billion gallons per year.

Bayer CropScience – Institute Plant purchases a three year average of water from the West Virginia American Water Company in the Elk watershed approximately equal to 232.7 million gallons per year. The water is reportedly used as cooling water, zeolite treated process water, boiler feed water, and for emergency fire water. The only form of discharge reported is stream discharge at eight locations that fall under a single NPDES permit number. All water discharged from the facility at these locations enters the Lower Kanawha watershed at a 3 year average rate of 42.2 billion gallons per year.

Catenary Coal Company – Samples Mine Complex purchases an approximate annual average of 238 thousand gallons of water from the Upper Kanawha Watershed via West Virginia American Water. The water is used as process water, dust control, truck wash, and for domestic purposes. Reportedly, 49 million gallons are discharged into the surface water of the Coal watershed, and 53 million gallons are discharged into surface water sources of the Upper Kanawha Watershed. Although haul water and truck wash is a reported use, no values for gallons discharged for this purpose have been provided.

Consol Energy – Robinson Run purchases an approximate annual average of 8.9 million gallons of water from the Tygart Valley Watershed via Bingamon and Mannington PSDs. The water is used for the industrial operation of a coal preparation plant, surface fire suppression, and dust control on haul roads. A three year average of approximately 5.8 million gallons are discharged into a stream in West Fork, 1.8 million is discharged into a stream in the Monongahela watershed, and 2.1 million is discharged on haul roads most highly concentrated in the West Fork watershed.

Huntington Alloys Corporation purchases a three year average of 87 million gallons annually from West Virginia American Water in the Lower Ohio Watershed. Water at the facility is reportedly used for industrial processes including cooling water for boilers and process water. According to the three year average, 347 million gallons of water a year are discharged by this facility into the Lower Ohio Watershed via the Huntington Sanitary POTW.

Kanawha River Terminals – Ceredo Dock purchases an approximate three year average of 514 thousand gallons annually from the Big Sandy Watershed via Ceredo PSD. This water is reportedly used for mining practices including dust suppression and wash-down applications. The same amount purchased, approximately 514 thousand gallons, are discharged into the Lower Ohio Watershed via the Huntington Sewage Treatment POTW.

Mingo Logan Coal Company – Mountain Laurel Complex purchases an approximate annual average of 12.9 million gallons of water from the Elk Watershed via West Virginia American Water. The water is used at multiple facilities in the process of mining coal including the preparation plant and longwall miner. A three year average of approximately 345 million gallons of water a year is discharged into the Upper Guyandotte Watershed. There are no reported discharges into the Elk Watershed.

# Appendix M

## Summary of Studying the Effects of Lowering Threshold Levels in West Virginia (Completed by CEGAS for DEP)

The State of West Virginia defines large quantity water users as “any person who withdraws over seven hundred fifty thousand gallons of water in a calendar month from the state's waters” (25,000 gallons per day (gpd) on average). The WV DEP is considering recommending lowering that threshold to 10,000 gpd. WV DEP has researched the effects of this change. During this research, WV DEP reviewed surrounding States and their large quantity user programs.

## Neighboring State Approaches

- Ohio
  - Threshold is 100,000 gpd
  - Capacity to withdraw, not actual withdrawal values
  - All regulated facilities have to report actual water use annually
- Pennsylvania
  - Separate their large quantity users into three categories
    - Public Water System
      - Require a “Water Allocation Permit” regardless of volumes
    - Non-Public water system except shale gas industry
      - Greater than and average withdrawal rate of 10,000 gpd in any 30-day period
    - Shale gas industry
      - Have to have an approved water management plan regardless of volumes
- Virginia
  - Separate their large quantity users into two categories
    - Non-irrigation users
      - Average daily withdrawal during any single month exceeding 10,000 gpd
    - Irrigation users
      - Withdrawal exceeding 1,000,000 gallons in any single month
  - All users that fall into the program are required to report withdrawals each January for the previous year
- Kentucky
  - Regulate those that withdrawal an average withdrawal rate of 10,000 gpd
  - Large quantity users in are defined as using, at a relatively constant rate, 10,000 gallons per day or more
  - Users that fall into this category are required to acquire a water withdrawal permit
  - Users are required to submit a record of their daily withdrawal at the end of each month

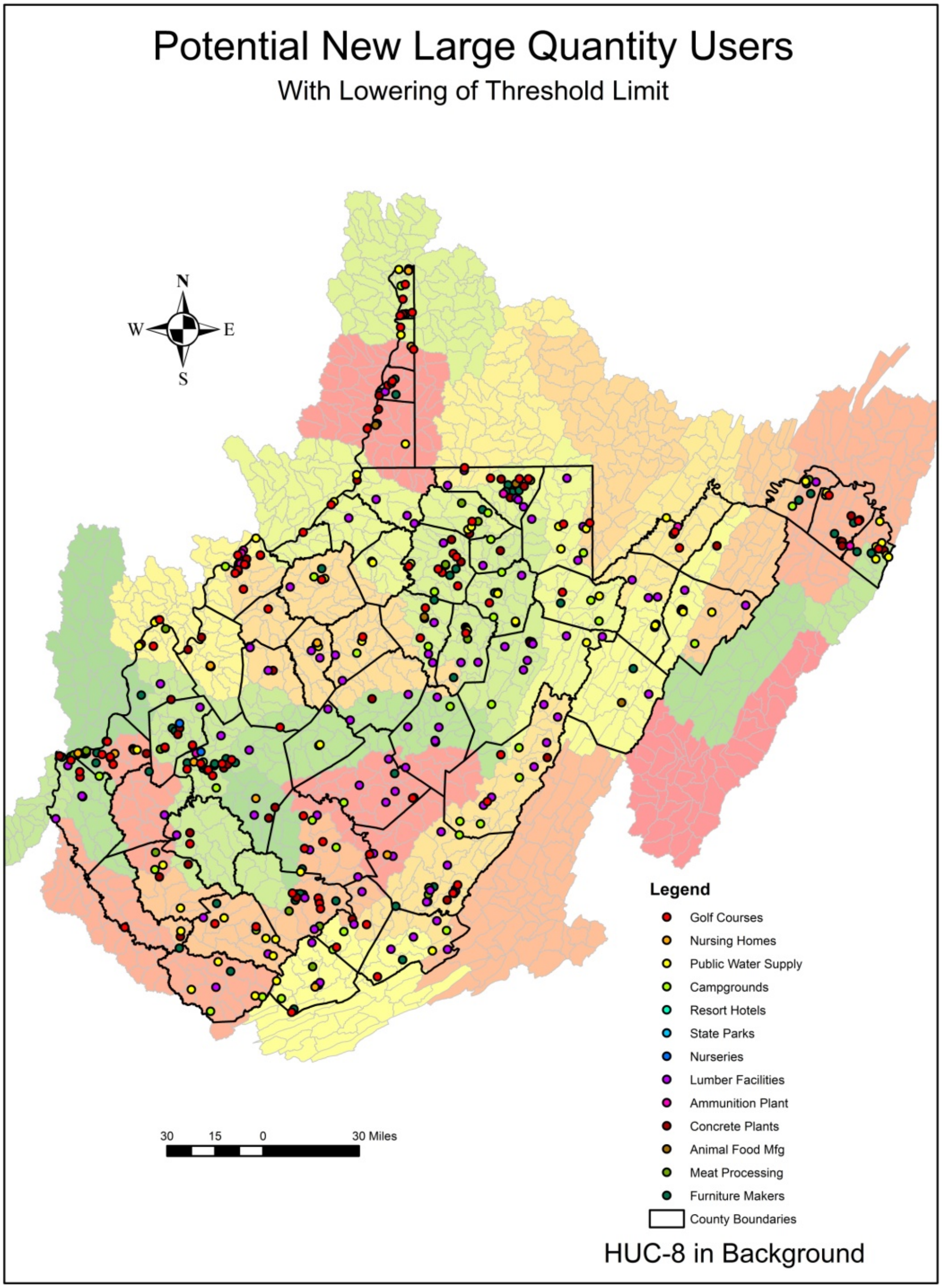
## List of Users that May Fall into New Threshold

- Golf Courses (Some or most may need to be reporting with current levels)
- Nursing homes/Retirement facilities
- Mobile home parks
- Public water supplies
- Farms (For Irrigation)
- Campgrounds

- Jails/Correction facilities
- Schools
- Resort hotels
- Parks
- Courthouses
- Cemeteries
- Nurseries
- Lumber facilities
- Chemical plants
- Paper plants
- Ammunition plants
- Concrete plants
- Pet food producers (from animal and food waste)
- Meat processors
- Industrial parks
- Furniture makers
- Highway Rest Stops

## Where are potential new users

Based on the list above, available mapping data was pulled together to visualize the potential location of new users to the LQU program.  The map below shows those results.



Potential New Large Quantity Users
With Lowering of Threshold Limit
N
W
E
S
Legend
Golf Courses
Nursing Homes
Public Water Supply
Campgrounds
Resort Hotels
State Parks
Nurseries
Lumber Facilities
Ammunition Plant
Concrete Plants
Animal Food Mfg
Meat Processing
Furniture Makers
County Boundaries
30
15
0
30 Miles
HUC-8 in Background

## What is the total water consumption of these facilities

Kentucky reported that of all of the large quantity users, 4.4% of the users fall into the 10,000-25,000 gpd range. These users accounted for .05% of water use. In Virginia, 17.8% of users fall into the new threshold range, with these users accounting for .04% of water use. In Pennsylvania, 21.5% of users fall into the new threshold range, with these users accounting for .07% of water use. The difference between the number of water users may be attributed the way each state adds users to their program. Of note is the similarity of the percentage of amount of water used. Even though the amount of water is small compared to users over 25,000 gpd, Bill Caldwell (KY Division of Water) felt that users that fall into the lower threshold are (at least in KY) located in headwater areas where small withdrawals can have large impacts if done at the wrong time.

If these numbers are applied to WV, we would anticipate approximately 80 new users (using 18% of total users) with 6 trillion gallons potentially being reported (using .05% water use). If you take out hydroelectric and thermoelectric facilities, the potential water use falls to 16.6 billion gallons, which may be a better number to use. Pennsylvania did not use hydroelectric numbers when calculating there values.

Based on available mapping data, estimated number of new users and estimated water use, the chart below shows potential water use amounts that may be reported by lowering the threshold limits.

Available mapping data was limited, dated and possibly incomplete. The following steps have been taken to estimate the number of new users and water quantities that would be added if West Virginia lowers its threshold levels to 10,000 gpb. First, if a GIS layer or layers are available, one or a combination of layers will be used to show number of potential users. If it is known that some are already listed in the current large quantity database (LQU DB), they will be deleted from the layer. These layers will be delivered to WV DEP. Second, an estimated water use quantity will be associated with users. This will be based on data from neighboring states. Finally, a chart will show results of analysis.

- Golf Courses (Some or most may need to be reporting with current levels)
  - Used GIS layer available from ESRI dataset
    - Pulled out facilities already in LQU DB
  - Assumed 10,000 gpd use
- Nursing homes/Retirement facilities
  - Used nursing home layer
  - http://wvgis.wvu.edu/data/dataset.php?ID=408
    - Assumed that most facilities are on PWS system
    - Randomly selected 5% of facilities for analysis
  - Assumed 10,000 gpd use
- Mobile home parks
  - Do not have GIS layer
- Public water supplies
  - Used layer provided by WV DEP (StateWide_Utilities_DBO_Treatment_Plant_Water)
    - Pulled out facilities already in LQU DB
  - Assumed 15,000 gpd use
- Farms (For Irrigation)
  - Do not have GIS layer

- Campgrounds
    - Could not find specific layer for campgrounds
    - Will use State Park layer
    - http://wvgis.wvu.edu/data/dataset.php?ID=203
    - Not sure if all have their own water supply but will assume that they do, since many are in rural areas
    - Assume 10,000 gpd use
- Jails/Correction facilities
    - GIS Layer available
    - No regional jails fall into this category, they all use outside pws
    - Have not been able to speak with the operations manager for prisons. Contact for prisons is Mr. Farley (304-558-3026).
- Schools
    - Have a few layers for schools
    - After discussions with Brian Carr (WV DEP), the only schools we could think of that would be have their own withdrawals may be large private schools but we don't know of any
    - Will put two in spreadsheet (not mapped)
    - Will assume 15,000 gpd
- Resort hotels
    - Created a Resort Hotel shapefile
    - Placed a point for the Greenbrier Hotel
    - Will assume 10,000 gpd
- Parks
    - Used State Park layer
    - http://wvgis.wvu.edu/data/dataset.php?ID=203
    - Assume 10,000 gpd
- Courthouses
    - After discussion with Brian Carr (WV DEP), determined that no courthouses in WV have their own PWS or are pumping from water source for irrigation.
- Cemeteries
    - After discussion with Brian Carr (WV DEP), we do not know of any cemeteries that pump for irrigation purposes. If there are any, we feel there would be a small number of them.
- Nurseries
    - Used Harris Business spreadsheet data. This spreadsheet was developed as part of a USGS water use survey in early 2000's. The percentage of respondents is unknown.
    - Assume 10,000 gpd
- Lumber facilities
    - Used Harris Business spreadsheet (Includes Logging)
    - May be a high number of facilities. Data sent from Virginia only shows one facility.
    - Assume 13,000 gpd
- Chemical plants
    - Do not have GIS layer for these facilities. Many of these are in current LQU DB.
- Paper plants
    - Do not have GIS layer for these facilities.
- Ammunition plants

  - Will use Harris Business Spreadsheet
  - Assume 10,000 gpd
- Concrete plants
  - Pulled from Harris Business Spreadsheet
  - Assume 15,000 gpd
- Pet food producers (from animal and food waste)
  - Pulled from Harris Business Spreadsheet
  - Assume 10,000 gpd
- Meat processors
  - Pulled from Harris Business Spreadsheet
  - Assume 10,000 gpd
- Industrial parks
  - After discussion with Brian Carr (WV DEP), we felt that most, if not all, industrial parks in WV use public water.
- Furniture makers
  - Pulled from Harris Business Spreadsheet
  - May be a high number of facilities. Data sent from Virginia only shows one facility.
  - Assume 10,000 gpd
- Highway Rest Stops
  - No GIS layer
  - There are 26 rest stops in WV
  - Assume 10,000 gpd

| User Type | Number | Quantity of Water (Average Per Day) | Total Annual Water |
|---|---|---|---|
| Golf Courses | 84 | 10,000 | 306,600,000 |
| Nursing Homes | 11 | 10,000 | 40,150,000 |
| Mobile Home Parks | | | |
| Public Water Supplies | 53 | 15,000 | 290,175,000 |
| Farms | | | |
| Campgrounds | 38 | 10,000 | 138,700,000 |
| Jails/Correction Facilities | | | |
| Schools | 2 | 15,000 | 10,950,000 |
| Resort Hotels | 1 | 10,000 | 3,650,000 |
| Parks | 38 | 10,000 | 138,700,000 |
| Courthouses | | | |
| Cemeteries | | | |
| Nurseries | 4 | 10,000 | 14,600,000 |
| Lumber Facilities | 116 | 13,000 | 550,420,000 |
| Chemical Plants | | | |
| Paper Plants | | | |
| Ammunition Plants | 8 | 10,000 | 29,200,000 |
| Concrete Plants | 57 | 15,000 | 312,075,000 |
| Pet Food Producers | 6 | 10,000 | 21,900,000 |
| Meat Processors | 28 | 10,000 | 102,200,000 |
| Industrial Parks | | | |
| Furniture Makers | 93 | 10,000 | 339,450,000 |
| Highway Rest Stops | 26 | 10,000 | 94,900,000 |
| | | | |
| Totals | 785 | 168,000 | 2,393,670,000 |

Estimates of Potential Users and Water Use by Lowering Threshold

The total value of 2.4 billion gallons is well below the estimated values base on .05% of current LQU water use. This may be attributed to the following reasons. One, the number of potential users and the amount of water used by these users may be low. Two, some potential users may not be listed. Finally, Surrounding states may not count users over 25,000 gpd in the same way that WV does. Therefore, their total water use may be lower than WV, which would affect the .05% number that was used.

# Appendix N

USGS Estimates of Agricultural Use in 2005

**Table 1 USGS estimates of Agriculture withdrawals related to Livestock in 2005.**

| County | Withdrawals (Mgal/yr) | County | Withdrawals (Mgal/yr) |
|---|---|---|---|
| Barbour | 29.20 | Mineral | 40.15 |
| Berkeley | 51.10 | Mingo | 0.00 |
| Boone | 0.00 | Monongalia | 25.55 |
| Braxton | 18.25 | Monroe | 80.30 |
| Brooke | 7.30 | Morgan | 7.30 |
| Cabell | 10.95 | Nicholas | 18.25 |
| Calhoun | 10.95 | Ohio | 14.60 |
| Clay | 3.65 | Pendleton | 182.50 |
| Doddridge | 14.60 | Pleasants | 7.30 |
| Fayette | 10.95 | Pocahontas | 43.80 |
| Gilmer | 18.25 | Preston | 73.00 |
| Grant | 109.50 | Putnam | 18.25 |
| Greenbrier | 127.75 | Raleigh | 10.95 |
| Hampshire | 80.30 | Randolph | 36.50 |
| Hancock | 3.65 | Ritchie | 21.90 |
| Hardy | 237.25 | Roane | 29.20 |
| Harrison | 40.15 | Summers | 25.55 |
| Jackson | 43.80 | Taylor | 21.90 |
| Jefferson | 76.65 | Tucker | 7.30 |
| Kanawha | 7.30 | Tyler | 18.25 |
| Lewis | 25.55 | Upshur | 21.90 |
| Lincoln | 7.30 | Wayne | 10.95 |
| Logan | 0.00 | Webster | 3.65 |
| Marion | 0.00 | Wetzel | 7.30 |
| Marshall | 14.60 | Wirt | 14.60 |
| Mason | 25.55 | Wood | 29.20 |
| McDowell | 58.40 | Wyoming | 0.00 |
| Mercer | 18.25 | **TOTAL** | 1,821.35 |

# Appendix O

## Annual water withdrawals related to hydraulic fracturing activities by county

| County | 2009 Total | 2010 Total | 2011 Total | Grand Total |
|---|---|---|---|---|
| Barbour | 367,080 | 17,751,678 | 32,737,488 | 50,856,246 |
| Brooke | | 72,706,958 | 96,617,600 | 169,324,558 |
| Doddridge | | 34,291,730 | 146,211,491 | 180,503,221 |
| Harrison | 7,631,275 | 62,998,608 | 97,922,011 | 168,551,894 |
| Lewis | | 12,024,684 | 36,391,324 | 48,416,008 |
| Marion | | 21,930,218 | 7,358,348 | 29,288,566 |
| Marshall | 25,097,016 | 122,057,523 | 208,315,071 | 355,469,610 |
| Monongalia | | | 57,522,662 | 57,522,662 |
| Ohio | | | 32,748,699 | 32,748,699 |
| Pleasants | | 41,274,316 | 6,219,108 | 47,493,424 |
| Preston | | 12,959,856 | 10,164,840 | 23,124,696 |
| Ritchie | | 14,613,260 | 26,548,536 | 41,161,796 |
| Taylor | | 3,125,094 | 65,419,642 | 68,544,736 |
| Tyler | | 15,120,000 | | 15,120,000 |
| Upshur | 3,273,606 | 123,437,972 | 46,083,156 | 172,794,734 |
| Webster | | | 5,912,340 | 5,912,340 |
| Wetzel | 9,658,530 | 24,308,954 | 16,614,999 | 50,582,483 |
| Out of state transfer (OH) | | 2,103,192 | | 2,103,192 |
| Out of state transfer (PA) | | | 29,995,828 | 29,995,828 |
| **Grand Total** | **46,027,507** | **580,704,043** | **922,783,143** | **1,549,514,693** |

# Appendices P - T

## Recombined Withdrawals for Consumptive Use Scenarios from Data in LQU Database

Gaps in the LQU database are filled in using the assumptions explained in Table 2. Results are shown in hundredths of billion, million, or thousands of gallons for display purposes. Withdrawals less than 0.01 billion gallons are represented in thousandths of billions of gallons in the table. Zeros (“0.00”) indicate a reported zero in the LQU database, which could occur due to closures or idle facilities. Watersheds not listed in the tables had no withdrawals in the LQU database for the period of record. There are slight differences between the watershed and county withdrawal totals due to independent rounding and other assumptions. As a result the watershed and county totals cannot be directly compared. The data is organized by recombined withdrawal category. Methods and assumptions made for recombination of use categories are discussed in Chapter 4.

# Appendix P

## Development of the Mining and Petroleum withdrawal and consumptive use scenarios

Historic withdrawals in the combined Mining and Petroleum sector (Mining and Petroleum categories from the LQU database) by watershed and by county can be found in **Table P-1** and **Table P-6**, respectively. Historic estimates of both High and Low Consumptive Use scenarios can be found by watershed and county in **Table P-2** and **Table P-7**, respectively. Results are shown in tenths of millions of gallons per year for display purposes.

## Mining and Petroleum Watershed Withdrawal and Consumptive Use Method

### Past withdrawal by HUC8

1. Sum Mining and Petroleum withdrawals by HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table P-1).

### Past employment by HUC8

2. Overlay HUC8 boundaries, county boundaries, and Mining and Petroleum withdrawal locations for each year of record in the LQU database.
3. Determine portion of HUC8 Mining and Petroleum withdrawal that occurs in each county portion of the HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011
    a. Portion of 2003 withdrawal in County 1 and HUC8 A = (2003 withdrawal in County 1 in HUC8 A)/(total County 1 withdrawal in 2003)
    b. Portion of 2003 withdrawal in County 2 and HUC8 A = (2003 withdrawal in County 2 in HUC8 A)/(total County 2 withdrawal in 2003)
    c. Etc.
4. Collect mining and petroleum employment data for each West Virginia county from Workforce WV using NAICS code 21 when no Marcellus withdrawal was reported in a given HUC8. Code 212 were used if a Marcellus withdrawal was reported in aHUC8.
    a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
5. Apportion county employment data to overlapping HUC8s based on the portion of the withdrawals in that county (from step 3) for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
6. Sum employment totals by HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table P-3).

### Per employee withdrawal rate by HUC8

7. Divide HUC8 withdrawals (from step 1) by HUC8 employment (from step 6) to obtain the per employee withdrawal rate (Table P-4).
    a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 Mining and Petroleum withdrawals.
    b. Average the per employee withdrawal rates for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 to obtain one value for each watershed to use in future projections.

### Future employment by HUC8

8. Multiply the number of employees in 2011 by a predicted rate of change by HUC8 obtained from the literature (Table P-4).
    a. High Scenario – increase 2011 HUC8 employment by 0.4% annually through 2040 (Bureau of Labor Statistics 2012)
    b. Low Scenario –decrease 2011 HUC8 employment by 1.7% annually through 2040 (WVU 2012)

### Future withdrawal by HUC8

9. Multiply HUC8 per employee withdrawal rate (from step 7) by HUC8 employment in 2020, 2030, and 2040 for the high (step 8a) and low (step 8b) scenarios (Table P-5).
10. If employment data were not for a HUC8 apply the rates of change directly to the 2011 withdrawal (Table P-5).

### Future consumptive use estimates by HUC8

11. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table P-5).
    a. High scenario – 20% (Shaffer and Runkle 2007)
12. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table P-5).
    a. Low scenario – 14% (Shaffer and Runkle 2007)

## Mining and Petroleum County Withdrawal and Consumptive Use Method

### Past withdrawal by County

1. Sum Mining and Petroleum withdrawals by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table P-6).

### Past employment by County

2. Collect mining and petroleum employment data for each West Virginia county from Workforce WV using NAICS code 21 when no Marcellus withdrawal was reported in a given HUC8. Code 212 was used if a Marcellus withdrawal was reported in a HUC8.
    a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
3. Sum employment totals by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table P-8).

### Per employee withdrawal rate by County

4. Divide county withdrawals (from step 1) by county employment (from step 3) to obtain the per employee withdrawal rate (Table P-9).
    a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 Mining and Petroleum withdrawals.
    b. Average the per employee withdrawal rates for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 to obtain one value for each county to use in future projections.

### Future employment by County

5. Multiply the number of employees in 2011 by a predicted rate of change by county obtained from the literature (Table P-8).

   a. High Scenario – increase 2011 county employment by 0.4% annually through 2040 (Bureau of Labor Statistics 2012)
   b. Low Scenario –decrease 2011 county employment by 1.7% annually through 2040 (WVU 2012)

### Future withdrawal by County

6. Multiply county per employee withdrawal rate (from step 4) by county employment in 2020, 2030, and 2040 for the high (step 5a) and low (step 5b) scenarios (Table P-10).
7. If employment data were not available for a county, apply the rate of change directly to the 2011 withdrawal (Table P-10).

### Future consumptive use estimates by County

8. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table P-10).
   a. High scenario – 20% (Shaffer and Runkle 2007)
9. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table P-10).
   a. Low scenario – 14% (Shaffer and Runkle 2007)

**The following tables provide results at the county and watershed (HUC8) levels. The results at the county scale are not comparable to the results at the watershed scale due to differences in estimation methodologies described above.**

**Table P-1  Combined Mining and Petroleum withdrawals by watershed, presented in millions of gallons per year.**

| HUC 8* | Historical Withdrawals (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Coal | 3,763.7 | 3,932.7 | 4,076.1 | 4,948.2 | 4,877.0 | 4,294.4 | 4,088.1 |
| Dunkard | 594.3 | 606.2 | 533.3 | 652.8 | 597.8 | 597.8 | 597.8 |
| Elk | 180.4 | 176.5 | 209.6 | 124.4 | 174.5 | 170.7 | 168.0 |
| Gauley | 676.5 | 666.4 | 647.2 | 795.6 | 599.6 | 552.1 | 514.8 |
| Lower Guyandotte | 169.8 | 171.5 | 170.1 | 170.4 | 170.4 | 170.4 | 170.4 |
| Lower New† | 0.0 | 0.0 | 0.0 | 147.0 | 151.0 | 165.7 | 211.6 |
| Lower Ohio | 8.9 | 10.2 | 12.5 | 4.5 | 3.5 | 1.1 | 1.1 |
| Middle Ohio North | 209.2 | 185.4 | 143.9 | 163.3 | 85.9 | 83.1 | 66.7 |
| Monongahela | 188.6 | 412.2 | 384.8 | 314.2 | 325.4 | 308.3 | 290.3 |
| Potomac Direct Drains | 407.3 | 396.8 | 360.6 | 388.2 | 388.2 | 388.2 | 388.2 |
| South Branch Potomac | 15.6 | 15.6 | 15.6 | 41.6 | 24.3 | 43.1 | 33.4 |
| Tug Fork | 1,127.3 | 1,070.6 | 1,360.7 | 1,195.1 | 989.5 | 916.2 | 753.3 |
| Twelvepole | 305.2 | 350.5 | 357.3 | 190.4 | 310.0 | 230.0 | 235.1 |
| Tygart Valley | 10.0 | 7.8 | 27.0 | 234.2 | 33.5 | 44.9 | 282.6 |
| Upper Guyandotte | 1,345.7 | 1,360.7 | 1,469.7 | 1,437.1 | 1,394.1 | 1,451.2 | 1,394.9 |
| Upper Kanawha | 958.2 | 961.7 | 965.5 | 947.7 | 1,434.2 | 3,145.5 | 3,166.6 |
| Upper Ohio North | 245.6 | 249.7 | 320.9 | 163.5 | 335.4 | 389.4 | 243.9 |
| Upper Ohio South | 1,348.2 | 1,480.0 | 1,328.5 | 1,263.5 | 1,332.6 | 1,307.4 | 1,320.0 |
| West Fork | 186.5 | 211.0 | 211.8 | 212.4 | 228.2 | 234.7 | 224.9 |
| TOTALS‡ | 11,741 | 12,265 | 12,595 | 13,394 | 13,455 | 14,494 | 14,152 |

*Big Sandy and Cheat were removed because no active withdrawals occurred in 2011, so no future projections were generated.  † There were no withdrawals in the Lower New Watershed in 2003, 2004, or 2005.  ‡Totals were rounded to whole numbers for display purposes.

**Table P-2 Combined Mining and Petroleum consumptive use scenario estimates by watershed, presented in millions of gallons per year.**

| HUC 8* | HIGH Consumptive Use (Mgal/yr) | | | | | | | LOW Consumptive Use (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Big Sandy† | 0.6 | 0.4 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.3 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cheat | 1.2 | 1.5 | 0.9 | 1.3 | 1.3 | 0.0 | 0.0 | 0.8 | 1.0 | 0.6 | 0.9 | 0.9 | 0.0 | 0.0 |
| Coal | 752.7 | 786.5 | 815.2 | 989.6 | 975.4 | 858.9 | 817.6 | 526.9 | 550.6 | 570.7 | 692.7 | 682.8 | 601.2 | 572.3 |
| Dunkard | 118.9 | 121.2 | 106.7 | 130.6 | 119.6 | 119.6 | 119.6 | 83.2 | 84.9 | 74.7 | 91.4 | 83.7 | 83.7 | 83.7 |
| Elk | 36.1 | 35.3 | 41.9 | 24.9 | 34.9 | 34.1 | 33.6 | 25.3 | 24.7 | 29.3 | 17.4 | 24.4 | 23.9 | 23.5 |
| Gauley | 135.3 | 133.3 | 129.4 | 159.1 | 119.9 | 110.4 | 103.0 | 94.7 | 93.3 | 90.6 | 111.4 | 83.9 | 77.3 | 72.1 |
| Lower Guyandotte | 34.0 | 34.3 | 34.0 | 34.1 | 34.1 | 34.1 | 34.1 | 23.8 | 24.0 | 23.8 | 23.9 | 23.9 | 23.9 | 23.9 |
| Lower New† | 0.0 | 0.0 | 0.0 | 29.4 | 30.2 | 33.2 | 42.3 | 0.0 | 0.0 | 0.0 | 20.6 | 21.1 | 23.2 | 29.6 |
| Lower Ohio | 1.8 | 2.1 | 2.5 | 0.9 | 0.7 | 0.2 | 0.2 | 1.3 | 1.4 | 1.8 | 0.6 | 0.5 | 0.2 | 0.2 |
| Middle Ohio North | 41.8 | 37.1 | 28.8 | 32.7 | 17.2 | 16.6 | 13.3 | 29.3 | 26.0 | 20.2 | 22.9 | 12.0 | 11.6 | 9.3 |
| Monongahela | 37.7 | 82.4 | 77.0 | 62.8 | 65.1 | 61.7 | 58.1 | 26.4 | 57.7 | 53.9 | 44.0 | 45.6 | 43.2 | 40.7 |
| Potomac Direct Drains | 81.5 | 79.4 | 72.1 | 77.7 | 77.7 | 77.7 | 77.7 | 57.0 | 55.6 | 50.5 | 54.4 | 54.4 | 54.4 | 54.4 |
| South Branch Potomac | 3.1 | 3.1 | 3.1 | 8.3 | 4.9 | 8.6 | 6.7 | 2.2 | 2.2 | 2.2 | 5.8 | 3.4 | 6.0 | 4.7 |
| Tug Fork | 225.5 | 214.1 | 272.1 | 239.0 | 197.9 | 183.2 | 150.7 | 157.8 | 149.9 | 190.5 | 167.3 | 138.5 | 128.3 | 105.5 |
| Twelvepole | 61.0 | 70.1 | 71.5 | 38.1 | 62.0 | 46.0 | 47.0 | 42.7 | 49.1 | 50.0 | 26.7 | 43.4 | 32.2 | 32.9 |
| Tygart Valley | 2.0 | 1.6 | 5.4 | 46.8 | 6.7 | 9.0 | 56.5 | 1.4 | 1.1 | 3.8 | 32.8 | 4.7 | 6.3 | 39.6 |
| Upper Guyandotte | 269.1 | 272.1 | 294.0 | 287.4 | 278.8 | 290.2 | 279.0 | 188.4 | 190.5 | 205.8 | 201.2 | 195.2 | 203.2 | 195.3 |
| Upper Kanawha | 191.6 | 192.3 | 193.1 | 189.5 | 286.8 | 629.1 | 633.3 | 134.1 | 134.6 | 135.2 | 132.7 | 200.8 | 440.4 | 443.3 |
| Upper Ohio North | 49.1 | 49.9 | 64.2 | 32.7 | 67.1 | 77.9 | 48.8 | 34.4 | 35.0 | 44.9 | 22.9 | 47.0 | 54.5 | 34.1 |
| Upper Ohio South | 269.6 | 296.0 | 265.7 | 252.7 | 266.5 | 261.5 | 264.0 | 188.7 | 207.2 | 186.0 | 176.9 | 186.6 | 183.0 | 184.8 |
| West Fork | 37.3 | 42.2 | 42.4 | 42.5 | 45.6 | 46.9 | 45.0 | 26.1 | 29.5 | 29.7 | 29.7 | 32.0 | 32.9 | 31.5 |
| TOTALS‡ | 2,350 | 2,455 | 2,520 | 2,680 | 2,692 | 2,899 | 2,830 | 1,645 | 1,718 | 1,764 | 1,876 | 1,885 | 2,029 | 1,981 |

*Big Sandy and Cheat were removed because no active withdrawals occurred in 2011, so no future projections were generated. † There were no withdrawals in the Lower New Watershed in 2003, 2004, or 2005. ‡Totals were rounded to whole numbers for display purposes.

**Table P-3 The past and projected number of employees in the Mining and Petroleum sector by watershed. A dash (-) indicates that data were not available. The high scenario increases employment annually by 0.4 percent (BLS 2012) and the low scenario decreases employment annually by 1.7 percent (WVU 2012).**

| HUC 8* | Employment | | | | | | | High Employment Projection | | | Low Employment Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Coal | 4,055 | 4,711 | 5,317 | 6,170 | 5,883 | 5,786 | 6,055 | 6,079 | 6,104 | 6,128 | 5,954 | 5,854 | 5,756 |
| Dunkard | 343 | 389 | 357 | 520 | 520 | 593 | 746 | 749 | 752 | 755 | 734 | 721 | 709 |
| Elk | 375 | 375 | 267 | 208 | 248 | 236 | 241 | 242 | 243 | 244 | 237 | 233 | 229 |
| Gauley | 1,005 | 1,015 | 1,209 | 1,603 | 1,653 | 1,606 | 1,750 | 1,757 | 1,764 | 1,771 | 1,721 | 1,692 | 1,664 |
| Lower Guyandotte | 172 | 196 | 195 | 192 | 180 | 208 | 229 | 230 | 231 | 232 | 225 | 221 | 218 |
| Lower New | | | | 229 | 233 | 267 | 695 | 698 | 701 | 703 | 683 | 672 | 661 |
| Lower Ohio | 56 | 46 | 60 | 31 | 8 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Middle Ohio North | 82 | 44 | 62 | 147 | 146 | 35 | 32 | 32 | 32 | 32 | 31 | 31 | 30 |
| Monongahela | 956 | 1,061 | 1,412 | 1,444 | 1,534 | 1,565 | 1,664 | 1,671 | 1,677 | 1,684 | 1,636 | 1,609 | 1,582 |
| Potomac Direct Drains | 168 | 168 | 168 | 168 | 168 | 168 | 168 | 169 | 169 | 170 | 165 | 162 | 160 |
| South Branch Potomac | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Tug Fork | 2,091 | 2,118 | 2,504 | 3,436 | 3,177 | 3,311 | 3,699 | 3,714 | 3,729 | 3,744 | 3,637 | 3,576 | 3,517 |
| Twelvepole | 423 | 494 | 520 | 728 | 824 | 834 | 882 | 886 | 889 | 893 | 867 | 853 | 839 |
| Tygart Valley | 150 | 150 | 150 | 150 | 681 | 697 | 760 | 763 | 766 | 769 | 747 | 735 | 723 |
| Upper Guyandotte | 2,770 | 2,949 | 3,219 | 3,004 | 2,718 | 2,909 | 3,545 | 3,559 | 3,573 | 3,588 | 3,486 | 3,427 | 3,370 |
| Upper Kanawha | 2,493 | 2,585 | 2,735 | 3,627 | 3,420 | 3,038 | 3,401 | 3,415 | 3,428 | 3,442 | 3,344 | 3,288 | 3,233 |
| Upper Ohio North | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Upper Ohio South | 1,114 | 1,208 | 1,366 | 1,250 | 1,251 | 1,549 | 1,689 | 1,696 | 1,703 | 1,709 | 1,661 | 1,633 | 1,606 |
| West Fork | 420 | 535 | 247 | 149 | 142 | 141 | 178 | 179 | 179 | 180 | 175 | 172 | 169 |
| TOTALS‡ | 16,673 | 18,044 | 19,788 | 23,056 | 22,786 | 22,948 | 25,738 | 25,841 | 25,944 | 26,048 | 25,308 | 24,885 | 24,469 |

*Big Sandy and Cheat were removed because no active withdrawals occurred in 2011, so no future projections were generated. Blanks indicate that no withdrawals occurred so employment data was not collected.

**Table P-4 Per Employee water use for the Mining and Petroleum water use category by watershed, presented in millions of gallons per year.**

| HUC 8* | Per Employee Withdrawal Rate (Mgal/yr) | | | | | | | Average Rate (Mgal/yr) |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | |
| Coal | 0.93 | 0.83 | 0.77 | 0.80 | 0.83 | 0.74 | 0.68 | 0.80 |
| Dunkard | 1.73 | 1.56 | 1.49 | 1.26 | 1.15 | 1.01 | 0.80 | 1.29 |
| Elk | 0.48 | 0.47 | 0.78 | 0.60 | 0.70 | 0.72 | 0.70 | 0.64 |
| Gauley | 0.67 | 0.66 | 0.54 | 0.50 | 0.36 | 0.34 | 0.29 | 0.48 |
| Lower Guyandotte | 0.99 | 0.87 | 0.87 | 0.89 | 0.95 | 0.82 | 0.74 | 0.88 |
| Lower New† | 0.00 | 0.00 | 0.00 | 0.64 | 0.65 | 0.62 | 0.30 | 0.55 |
| Lower Ohio | 0.16 | 0.22 | 0.21 | 0.15 | 0.44 | 0.21 | 0.26 | 0.24 |
| Middle Ohio North | 2.55 | 4.21 | 2.32 | 1.11 | 0.59 | 2.37 | 2.08 | 2.18 |
| Monongahela | 0.20 | 0.39 | 0.27 | 0.22 | 0.21 | 0.20 | 0.17 | 0.24 |
| Potomac Direct Drains | 2.42 | 2.36 | 2.15 | 2.31 | 2.31 | 2.31 | 2.31 | 2.31 |
| South Branch Potomac | - | - | - | - | - | - | - | - |
| Tug Fork | 0.54 | 0.51 | 0.54 | 0.35 | 0.31 | 0.28 | 0.20 | 0.39 |
| Twelvepole | 0.72 | 0.71 | 0.69 | 0.26 | 0.38 | 0.28 | 0.27 | 0.47 |
| Tygart Valley | 0.07 | 0.05 | 0.18 | 1.56 | 0.05 | 0.06 | 0.37 | 0.33 |
| Upper Guyandotte | 0.49 | 0.46 | 0.46 | 0.48 | 0.51 | 0.50 | 0.39 | 0.47 |
| Upper Kanawha | 0.38 | 0.37 | 0.35 | 0.26 | 0.42 | 1.04 | 0.93 | 0.54 |
| Upper Ohio North | - | - | - | - | - | - | - | - |
| Upper Ohio South | 1.21 | 1.23 | 0.97 | 1.01 | 1.07 | 0.84 | 0.78 | 1.02 |
| West Fork | 0.44 | 0.39 | 0.86 | 1.43 | 1.61 | 1.66 | 1.26 | 1.09 |
| TOTALS | 13.98 | 15.29 | 13.45 | 13.83 | 12.54 | 14.00 | 12.53 | 13.92 |

*Big Sandy and Cheat were removed because no active withdrawals occurred in 2011, so no future projections were generated. A dash (-) indicates that no employment data were available. † There were no withdrawals in the Lower New Watershed in 2003, 2004, or 2005.

**Table P-5 High and low scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by watershed for the Mining and Petroleum water use sector, presented in millions of gallons per year. Projections were completed for only those watersheds in which there was a 2011 withdrawal in the LQU database.**

| HUC 8* | Projected Withdrawals (Mgal/yr) | | | | | | Projected Consumptive Use (Mgal/yr) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | | | Low | | | High | | | Low | | |
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Coal | 4,844.2 | 4,863.5 | 4,883.0 | 4,744.2 | 4,664.9 | 4,586.9 | 968.8 | 972.7 | 976.6 | 664.2 | 653.1 | 642.2 |
| Dunkard | 962.9 | 966.7 | 970.6 | 943.0 | 927.3 | 911.8 | 192.6 | 193.4 | 194.1 | 132.0 | 129.8 | 127.7 |
| Elk | 154.1 | 154.7 | 155.3 | 150.9 | 148.4 | 145.9 | 30.8 | 30.9 | 31.1 | 21.1 | 20.8 | 20.4 |
| Gauley | 843.8 | 847.2 | 850.6 | 826.4 | 812.6 | 799.0 | 168.8 | 169.4 | 170.1 | 115.7 | 113.8 | 111.9 |
| Lower Guyandotte | 201.4 | 202.2 | 203.0 | 197.3 | 194.0 | 190.7 | 40.3 | 40.4 | 40.6 | 27.6 | 27.2 | 26.7 |
| Lower New | 386.4 | 388.0 | 389.5 | 378.4 | 372.1 | 365.9 | 77.3 | 77.6 | 77.9 | 53.0 | 52.1 | 51.2 |
| Lower Ohio | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 |
| Middle Ohio North | 70.0 | 70.2 | 70.5 | 68.5 | 67.4 | 66.2 | 14.0 | 14.1 | 14.1 | 9.6 | 9.4 | 9.3 |
| Monongahela | 396.1 | 397.6 | 399.2 | 387.9 | 381.4 | 375.0 | 79.2 | 79.5 | 79.9 | 54.3 | 53.4 | 52.5 |
| Potomac Direct Drains | 389.8 | 391.3 | 392.9 | 381.7 | 375.4 | 369.1 | 78.0 | 78.3 | 78.6 | 53.4 | 52.6 | 51.7 |
| South Branch Potomac† | 33.6 | 33.7 | 33.8 | 32.9 | 32.3 | 31.8 | 6.7 | 6.7 | 6.8 | 4.6 | 4.5 | 4.5 |
| Tug Fork | 1,447.1 | 1,452.9 | 1,458.7 | 1,417.3 | 1,393.6 | 1,370.3 | 289.4 | 290.6 | 291.8 | 198.4 | 195.1 | 191.8 |
| Twelvepole | 417.2 | 418.9 | 420.6 | 408.6 | 401.8 | 395.1 | 83.5 | 83.8 | 84.1 | 57.2 | 56.3 | 55.3 |
| Tygart Valley | 255.6 | 256.6 | 257.7 | 250.3 | 246.2 | 242.0 | 51.1 | 51.3 | 51.5 | 35.1 | 34.5 | 33.9 |
| Upper Guyandotte | 1,671.5 | 1,678.2 | 1,684.9 | 1,637.0 | 1,609.7 | 1,582.8 | 334.3 | 335.6 | 337.0 | 229.2 | 225.4 | 221.6 |
| Upper Kanawha | 1,832.4 | 1,839.7 | 1,847.1 | 1,794.6 | 1,764.6 | 1,735.1 | 366.5 | 368.0 | 369.4 | 251.2 | 247.0 | 242.9 |
| Upper Ohio North† | 244.8 | 245.8 | 246.8 | 239.8 | 235.8 | 231.8 | 49.0 | 49.2 | 49.4 | 33.6 | 33.0 | 32.5 |
| Upper Ohio South | 1,722.3 | 1,729.2 | 1,736.1 | 1,686.7 | 1,658.5 | 1,630.8 | 344.5 | 345.8 | 347.2 | 236.1 | 232.2 | 228.3 |
| West Fork | 195.5 | 196.3 | 197.0 | 191.4 | 188.2 | 185.1 | 39.1 | 39.3 | 39.4 | 26.8 | 26.4 | 25.9 |
| TOTALS‡ | 16,070 | 16,134 | 16,198 | 15,738 | 15,475 | 15,216 | 3,214 | 3,227 | 3,240 | 2,203 | 2,166 | 2,130 |

*Big Sandy and Cheat were removed because no active withdrawals occurred in 2011, so no future projections were generated. †No employment data were available. The rates of change in employment were applied directly to 2011 withdrawal amounts. ‡Totals were rounded to whole numbers for display purposes.

**Table P-6 Mining and Petroleum withdrawals by county, presented in millions of gallons per year.**

| County* | Historical Withdrawals (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Barbour† | 0.0 | 0.0 | 0.0 | 0.0 | 5.6 | 15.3 | 222.7 |
| Boone | 1,429.8 | 1,569.9 | 1,617.4 | 1,717.1 | 1,668.5 | 1,883.3 | 1,679.2 |
| Brooke | 82.8 | 82.8 | 82.8 | 94.9 | 86.9 | 143.0 | 99.5 |
| Fayette | 232.3 | 232.3 | 232.3 | 232.3 | 232.3 | 246.2 | 245.9 |
| Hancock | 162.7 | 166.8 | 238.0 | 68.6 | 248.5 | 246.3 | 144.4 |
| Harrison | 186.4 | 211.0 | 211.8 | 212.4 | 228.2 | 234.7 | 224.9 |
| Kanawha | 725.8 | 729.4 | 733.2 | 715.3 | 1,201.9 | 2,899.2 | 2,920.7 |
| Lincoln | 169.8 | 171.5 | 170.0 | 170.4 | 170.4 | 170.4 | 170.4 |
| Logan | 650.8 | 686.2 | 744.5 | 1,581.5 | 1,513.1 | 1,529.2 | 1,534.5 |
| Marion | 107.6 | 322.6 | 270.2 | 233.5 | 233.5 | 233.5 | 233.5 |
| Marshall | 1,348.2 | 1,480.0 | 1,328.5 | 1,263.5 | 1,332.6 | 1,307.4 | 1,320.0 |
| McDowell | 628.5 | 627.1 | 606.7 | 601.7 | 447.7 | 374.4 | 389.3 |
| Mingo | 749.9 | 709.2 | 1,061.0 | 863.5 | 814.9 | 814.9 | 637.0 |
| Monongalia | 675.3 | 695.8 | 647.8 | 739.7 | 696.0 | 672.7 | 654.7 |
| Morgan | 407.3 | 396.8 | 360.6 | 388.2 | 388.2 | 388.2 | 388.2 |
| Nicholas | 665.4 | 644.6 | 551.1 | 620.4 | 447.1 | 447.1 | 444.0 |
| Pendleton | 15.6 | 15.6 | 15.6 | 41.6 | 24.3 | 43.1 | 33.4 |
| Raleigh | 2,409.8 | 2,432.8 | 2,470.5 | 2,607.0 | 2,611.0 | 1,812.2 | 1,850.6 |
| Randolph | 10.0 | 7.8 | 27.0 | 26.7 | 23.0 | 23.5 | 25.7 |
| Upshur† | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | 6.1 | 34.3 |
| Wayne | 317.3 | 362.9 | 372.4 | 194.9 | 313.6 | 231.1 | 236.1 |
| Webster | 191.5 | 198.2 | 305.7 | 299.5 | 327.0 | 275.7 | 238.8 |
| Wetzel | 131.3 | 141.9 | 112.5 | 112.4 | 85.9 | 83.1 | 66.6 |
| Wyoming | 367.8 | 338.8 | 406.5 | 356.5 | 356.5 | 413.5 | 357.3 |
| TOTALS‡ | 11,666 | 12,224 | 12,566 | 13,142 | 13,462 | 14,494 | 14,152 |

*Pleasants and Preston counties were removed because no active withdrawals occurred in 2011, so no future projections were generated. †No related withdrawals occurred in Barbour or Upshur counties in 2003, 2004, 2005, or 2008. ‡Totals were rounded to whole numbers for display purposes.

Table P-7 Mining and Petroleum consumptive use scenarios by county, presented in millions of gallons per year.

| County* | HIGH Consumptive Use (Mgal/yr) | | | | | | | LOW Consumptive Use (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Barbour† | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 3.1 | 44.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 2.1 | 31.2 |
| Boone | 286.0 | 314.0 | 323.5 | 343.4 | 333.7 | 376.7 | 335.8 | 200.2 | 219.8 | 226.4 | 240.4 | 233.6 | 263.7 | 235.1 |
| Brooke | 16.6 | 16.6 | 16.6 | 19.0 | 17.4 | 28.6 | 19.9 | 11.6 | 11.6 | 11.6 | 13.3 | 12.2 | 20.0 | 13.9 |
| Fayette | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 49.3 | 49.2 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 34.5 | 34.4 |
| Hancock | 32.6 | 33.4 | 47.6 | 13.7 | 49.7 | 49.3 | 28.9 | 22.8 | 23.4 | 33.3 | 9.6 | 34.8 | 34.5 | 20.2 |
| Harrison | 37.3 | 42.2 | 42.4 | 42.5 | 45.6 | 46.9 | 45.0 | 26.1 | 29.5 | 29.7 | 29.7 | 32.0 | 32.9 | 31.5 |
| Kanawha | 145.2 | 145.9 | 146.6 | 143.1 | 240.4 | 579.9 | 584.1 | 101.6 | 102.1 | 102.7 | 100.2 | 168.3 | 405.9 | 408.9 |
| Lincoln | 34.0 | 34.3 | 34.0 | 34.1 | 34.1 | 34.1 | 34.1 | 23.8 | 24.0 | 23.8 | 23.9 | 23.9 | 23.9 | 23.9 |
| Logan | 130.2 | 137.3 | 148.9 | 316.3 | 302.6 | 305.8 | 306.9 | 91.1 | 96.1 | 104.2 | 221.4 | 211.8 | 214.1 | 214.8 |
| Marion | 21.5 | 64.5 | 54.0 | 46.7 | 46.7 | 46.7 | 46.7 | 15.1 | 45.2 | 37.8 | 32.7 | 32.7 | 32.7 | 32.7 |
| Marshall | 269.6 | 296.0 | 265.7 | 252.7 | 266.5 | 261.5 | 264.0 | 188.7 | 207.2 | 186.0 | 176.9 | 186.6 | 183.0 | 184.8 |
| McDowell | 125.7 | 125.4 | 121.3 | 120.4 | 89.5 | 74.9 | 77.9 | 88.0 | 87.8 | 84.9 | 84.2 | 62.7 | 52.4 | 54.5 |
| Mingo | 150.0 | 141.8 | 212.2 | 172.7 | 163.0 | 163.0 | 127.4 | 105.0 | 99.3 | 148.5 | 120.9 | 114.1 | 114.1 | 89.2 |
| Monongalia | 135.1 | 139.2 | 129.6 | 147.9 | 139.2 | 134.5 | 130.9 | 94.5 | 97.4 | 90.7 | 103.6 | 97.4 | 94.2 | 91.7 |
| Monroe | 81.5 | 79.4 | 72.1 | 77.7 | 77.7 | 77.7 | 77.7 | 57.0 | 55.6 | 50.5 | 54.4 | 54.4 | 54.4 | 54.4 |
| Nicholas | 133.1 | 128.9 | 110.2 | 124.1 | 89.4 | 89.4 | 88.8 | 93.2 | 90.3 | 77.2 | 86.9 | 62.6 | 62.6 | 62.2 |
| Pendelton | 3.1 | 3.1 | 3.1 | 8.3 | 4.9 | 8.6 | 6.7 | 2.2 | 2.2 | 2.2 | 5.8 | 3.4 | 6.0 | 4.7 |
| Raleigh | 482.0 | 486.6 | 494.1 | 521.4 | 522.2 | 362.4 | 370.1 | 337.4 | 340.6 | 345.9 | 365.0 | 365.5 | 253.7 | 259.1 |
| Randolph | 2.0 | 1.6 | 5.4 | 5.3 | 4.6 | 4.7 | 5.1 | 1.4 | 1.1 | 3.8 | 3.7 | 3.2 | 3.3 | 3.6 |
| Upshur† | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.2 | 6.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.9 | 4.8 |
| Wayne | 63.5 | 72.6 | 74.5 | 39.0 | 62.7 | 46.2 | 47.2 | 44.4 | 50.8 | 52.1 | 27.3 | 43.9 | 32.4 | 33.1 |
| Webster | 38.3 | 39.6 | 61.1 | 59.9 | 65.4 | 55.1 | 47.8 | 26.8 | 27.8 | 42.8 | 41.9 | 45.8 | 38.6 | 33.4 |
| Wetzel | 26.3 | 28.4 | 22.5 | 22.5 | 17.2 | 16.6 | 13.3 | 18.4 | 19.9 | 15.7 | 15.7 | 12.0 | 11.6 | 9.3 |
| Wyoming | 73.6 | 67.8 | 81.3 | 71.3 | 71.3 | 82.7 | 71.5 | 51.5 | 47.4 | 56.9 | 49.9 | 49.9 | 57.9 | 50.0 |
| TOTALS | 2,333.2 | 2,444.8 | 2,513.2 | 2,628.3 | 2,692.3 | 2,898.9 | 2,830.3 | 1,633.3 | 1,711.4 | 1,759.3 | 1,839.8 | 1,884.6 | 2,029.2 | 1,981.2 |

*Pleasants and Preston counties were removed because no active withdrawals occurred in 2011, so no future projections were generated. †No related withdrawals occurred in Barbour or Upshur counties in 2003, 2004, 2005, or 2008.

Table P-8 Number of employees by county in the WorkForce West Virginia NAICS category 21 or 212. A dash (-) indicates that data were not available. The high scenario increases employment annually by 0.4 percent (BLS 2012) and the low scenario decreases employment annually by 1.7 percent (WVU 2012).

| County* | Employment | | | | | | | High Employment Projection | | | Low Employment Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Barbour | 47 | 42 | 48 | 348 | 348 | 348 | 348 | 349 | 351 | 352 | 342 | 336 | 331 |
| Boone | 3,256 | 3,745 | 3,864 | 3,972 | 3,712 | 3,625 | 3,716 | 3,731 | 3,746 | 3,761 | 3,654 | 3,593 | 3,533 |
| Brooke | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Fayette | 431 | 422 | 416 | 739 | 698 | 668 | 835 | 838 | 842 | 845 | 821 | 807 | 794 |
| Hancock | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Harrison | 420 | 535 | 247 | 149 | 142 | 141 | 178 | 179 | 179 | 180 | 175 | 172 | 169 |
| Kanawha | 2,191 | 2,297 | 2,499 | 3,057 | 2,823 | 2,409 | 2,607 | 2,617 | 2,628 | 2,638 | 2,563 | 2,521 | 2,478 |
| Lincoln | 159 | 197 | 374 | 415 | 453 | 470 | 498 | 500 | 502 | 504 | 490 | 481 | 473 |
| Logan | 1,195 | 1,329 | 1,449 | 1,668 | 1,652 | 1,719 | 2,253 | 2,262 | 2,271 | 2,280 | 2,215 | 2,178 | 2,142 |
| Marion | 967 | 1,113 | 1,418 | 1,482 | 1,557 | 1,599 | 1,707 | 1,714 | 1,721 | 1,728 | 1,678 | 1,650 | 1,623 |
| Marshall | 1,114 | 1,208 | 1,366 | 1,250 | 1,251 | 1,549 | 1,689 | 1,696 | 1,703 | 1,709 | 1,661 | 1,633 | 1,606 |
| McDowell | 738 | 838 | 906 | 1,501 | 1,400 | 1,552 | 1,958 | 1,966 | 1,974 | 1,982 | 1,925 | 1,893 | 1,861 |
| Mingo | 1,648 | 1,591 | 1,879 | 2,739 | 2,341 | 2,303 | 2,447 | 2,457 | 2,467 | 2,476 | 2,406 | 2,366 | 2,326 |
| Monongalia | 332 | 337 | 351 | 486 | 501 | 559 | 703 | 706 | 709 | 711 | 691 | 680 | 668 |
| Morgan | 168 | 168 | 168 | 168 | 168 | 168 | 168 | 169 | 169 | 170 | 165 | 162 | 160 |
| Nicholas | 631 | 611 | 649 | 964 | 1,024 | 1,115 | 1,248 | 1,253 | 1,258 | 1,263 | 1,227 | 1,207 | 1,186 |
| Pendleton | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Raleigh | 1,184 | 1,385 | 1,750 | 1,909 | 1,943 | 2,053 | 2,528 | 2,538 | 2,548 | 2,558 | 2,486 | 2,444 | 2,403 |
| Randolph | 150 | 150 | 150 | 150 | 150 | 201 | 254 | 255 | 256 | 257 | 250 | 246 | 241 |
| Upshur | 183 | 133 | 116 | 216 | 183 | 148 | 158 | 159 | 159 | 160 | 155 | 153 | 150 |
| Wayne | 484 | 544 | 585 | 759 | 837 | 844 | 886 | 890 | 893 | 897 | 871 | 857 | 842 |
| Webster | - | 375 | 393 | 385 | 386 | 353 | 321 | 322 | 324 | 325 | 316 | 310 | 305 |
| Wetzel | 21 | 21 | 21 | 29 | 29 | 35 | 32 | 32 | 32 | 32 | 31 | 31 | 30 |
| Wyoming | 938 | 952 | 1,207 | 1,072 | 1,042 | 1,192 | 1,280 | 1,285 | 1,290 | 1,295 | 1,259 | 1,238 | 1,217 |
| TOTALS | 16,257 | 17,993 | 19,856 | 23,458 | 22,640 | 23,051 | 25,814 | 25,917 | 26,021 | 26,125 | 25,382 | 24,958 | 24,541 |

*Pleasants and Preston counties were removed because no active withdrawals occurred in 2011, so no future projections were generated.

**Table P-9 Per Employee water use for the Mining and Petroleum water use category by county, presented in millions of gallons per year.**

| County* | Per Employee Withdrawal Rate (Mgal/yr) | | | | | | | Average Rate (Mgal/yr) |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | |
| Barbour† | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.04 | 0.64 | 0.10 |
| Boone | 0.44 | 0.42 | 0.42 | 0.43 | 0.45 | 0.52 | 0.45 | 0.45 |
| Brooke | - | - | - | - | - | - | - | - |
| Fayette | 0.54 | 0.55 | 0.56 | 0.31 | 0.33 | 0.37 | 0.29 | 0.42 |
| Hancock | - | - | - | - | - | - | - | - |
| Harrison | 0.44 | 0.39 | 0.86 | 1.43 | 1.61 | 1.66 | 1.26 | 1.09 |
| Kanawha | 0.33 | 0.32 | 0.29 | 0.23 | 0.43 | 1.20 | 1.12 | 0.56 |
| Lincoln | 1.07 | 0.87 | 0.45 | 0.41 | 0.38 | 0.36 | 0.34 | 0.55 |
| Logan | 0.54 | 0.52 | 0.51 | 0.95 | 0.92 | 0.89 | 0.68 | 0.72 |
| Marion | 0.11 | 0.29 | 0.19 | 0.16 | 0.15 | 0.15 | 0.14 | 0.17 |
| Marshall | 1.21 | 1.23 | 0.97 | 1.01 | 1.07 | 0.84 | 0.78 | 1.02 |
| McDowell | 0.85 | 0.75 | 0.67 | 0.40 | 0.32 | 0.24 | 0.20 | 0.49 |
| Mingo | 0.46 | 0.45 | 0.56 | 0.32 | 0.35 | 0.35 | 0.26 | 0.39 |
| Monongalia | 2.03 | 2.06 | 1.85 | 1.52 | 1.39 | 1.20 | 0.93 | 1.57 |
| Morgan | 2.42 | 2.36 | 2.15 | 2.31 | 2.31 | 2.31 | 2.31 | 2.31 |
| Nicholas | 1.05 | 1.06 | 0.85 | 0.64 | 0.44 | 0.40 | 0.36 | 0.69 |
| Pendleton | - | - | - | - | - | - | - | - |
| Raleigh | 2.04 | 1.76 | 1.41 | 1.37 | 1.34 | 0.88 | 0.73 | 1.36 |
| Randolph | 0.07 | 0.05 | 0.18 | 0.18 | 0.15 | 0.12 | 0.10 | 0.12 |
| Upshur† | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.04 | 0.22 | 0.04 |
| Wayne | 0.66 | 0.67 | 0.64 | 0.26 | 0.37 | 0.27 | 0.27 | 0.45 |
| Webster | - | 0.53 | 0.78 | 0.78 | 0.85 | 0.78 | 0.74 | 0.74 |
| Wetzel | 6.25 | 6.76 | 5.35 | 3.87 | 2.96 | 2.37 | 2.08 | 4.24 |
| Wyoming | 0.39 | 0.36 | 0.34 | 0.33 | 0.34 | 0.35 | 0.28 | 0.34 |
| TOTALS | 20.90 | 21.40 | 19.03 | 16.91 | 16.21 | 15.34 | 14.18 | 17.82 |

*Pleasants and Preston counties were removed because no active withdrawals occurred in 2011, so no future projections were generated. A dash (-) indicates that no employment data were available. †No related withdrawals occurred in Barbour or Upshur counties in 2003, 2004, 2005, or 2008.

**Table P-10 High and low scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by county for the Mining and Petroleum water use sector, presented in millions of gallons per year. Projections were completed for only those counties in which there was a 2011 withdrawal in the LQU database.**

| County* | Projected Withdrawals (Mgal/yr) | | | | | | Projected Consumptive Use (Mgal/yr) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | | | Low | | | High | | | Low | | |
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Barbour | 34.9 | 35.1 | 35.2 | 34.2 | 33.7 | 33.1 | 7.0 | 7.0 | 7.0 | 4.8 | 4.7 | 4.6 |
| Boone | 1,668.3 | 1,675.0 | 1,681.7 | 1,633.9 | 1,606.6 | 1,579.7 | 333.7 | 335.0 | 336.3 | 228.7 | 224.9 | 221.2 |
| Brooke† | 99.9 | 100.3 | 100.7 | 97.8 | 96.2 | 94.6 | 20.0 | 20.1 | 20.1 | 13.7 | 13.5 | 13.2 |
| Fayette | 354.3 | 355.7 | 357.1 | 347.0 | 341.2 | 335.5 | 70.9 | 71.1 | 71.4 | 48.6 | 47.8 | 47.0 |
| Hancock† | 145.0 | 145.6 | 146.1 | 142.0 | 139.6 | 137.3 | 29.0 | 29.1 | 29.2 | 19.9 | 19.6 | 19.2 |
| Harrison | 195.5 | 196.3 | 197.0 | 191.4 | 188.2 | 185.1 | 39.1 | 39.3 | 39.4 | 26.8 | 26.4 | 25.9 |
| Kanawha | 1,467.9 | 1,473.8 | 1,479.7 | 1,437.6 | 1,413.6 | 1,390.0 | 293.6 | 294.8 | 295.9 | 201.3 | 197.9 | 194.6 |
| Lincoln | 277.5 | 278.6 | 279.7 | 271.7 | 267.2 | 262.7 | 55.5 | 55.7 | 55.9 | 38.0 | 37.4 | 36.8 |
| Logan | 1,618.8 | 1,625.3 | 1,631.8 | 1,585.4 | 1,558.9 | 1,532.9 | 323.8 | 325.1 | 326.4 | 222.0 | 218.3 | 214.6 |
| Marion | 289.4 | 290.5 | 291.7 | 283.4 | 278.7 | 274.0 | 57.9 | 58.1 | 58.3 | 39.7 | 39.0 | 38.4 |
| Marshall | 1,722.3 | 1,729.2 | 1,736.1 | 1,686.7 | 1,658.5 | 1,630.8 | 344.5 | 345.8 | 347.2 | 236.1 | 232.2 | 228.3 |
| McDowell | 963.3 | 967.2 | 971.0 | 943.4 | 927.7 | 912.2 | 192.7 | 193.4 | 194.2 | 132.1 | 129.9 | 127.7 |
| Mingo | 962.7 | 966.5 | 970.4 | 942.8 | 927.1 | 911.6 | 192.5 | 193.3 | 194.1 | 132.0 | 129.8 | 127.6 |
| Monongalia | 1,108.1 | 1,112.6 | 1,117.0 | 1,085.3 | 1,067.1 | 1,049.3 | 221.6 | 222.5 | 223.4 | 151.9 | 149.4 | 146.9 |
| Morgan | 389.8 | 391.3 | 392.9 | 381.7 | 375.4 | 369.1 | 78.0 | 78.3 | 78.6 | 53.4 | 52.6 | 51.7 |
| Nicholas | 858.4 | 861.8 | 865.3 | 840.7 | 826.6 | 812.8 | 171.7 | 172.4 | 173.1 | 117.7 | 115.7 | 113.8 |
| Pendleton† | 33.6 | 33.7 | 33.8 | 32.9 | 32.3 | 31.8 | 6.7 | 6.7 | 6.8 | 4.6 | 4.5 | 4.5 |
| Raleigh | 3,454.7 | 3,468.5 | 3,482.3 | 3,383.4 | 3,326.8 | 3,271.2 | 690.9 | 693.7 | 696.5 | 473.7 | 465.8 | 458.0 |
| Randolph | 30.9 | 31.0 | 31.1 | 30.2 | 29.7 | 29.2 | 6.2 | 6.2 | 6.2 | 4.2 | 4.2 | 4.1 |
| Upshur | 6.5 | 6.5 | 6.5 | 6.3 | 6.2 | 6.1 | 1.3 | 1.3 | 1.3 | 0.9 | 0.9 | 0.9 |
| Wayne | 397.9 | 399.5 | 401.1 | 389.7 | 383.2 | 376.8 | 79.6 | 79.9 | 80.2 | 54.6 | 53.6 | 52.8 |
| Webster | 239.4 | 240.3 | 241.3 | 234.4 | 230.5 | 226.7 | 47.9 | 48.1 | 48.3 | 32.8 | 32.3 | 31.7 |
| Wetzel | 136.1 | 136.7 | 137.2 | 133.3 | 131.1 | 128.9 | 27.2 | 27.3 | 27.5 | 18.7 | 18.4 | 18.1 |
| Wyoming | 437.9 | 439.7 | 441.4 | 428.9 | 421.7 | 414.7 | 87.6 | 87.9 | 88.3 | 60.0 | 59.0 | 58.1 |
| TOTALS‡ | 16,893 | 16,960 | 17,028 | 16,544 | 16,268 | 15,996 | 3,379 | 3,392 | 3,406 | 2,316 | 2,277 | 2,239 |

*Pleasants and Preston counties were removed because no active withdrawals occurred in 2011, so no future projections were generated. †No employment data were available. The rates of change in employment were applied directly to 2011 withdrawal amounts. ‡Totals were rounded to whole numbers for display purposes.

# Appendix Q

## Development of the Manufacturing withdrawal and consumptive use scenarios

Historic Manufacturing withdrawals in the combined Manufacturing sector (Chemical, Industrial, and Timber categories from the LQU database) by watershed and by county can be found in **Table Q-1** and **Table Q-6**, respectively. Historic estimates of both High and Low Consumptive Use scenarios can be found by watershed and county in **Table Q-2** and **Table Q-7**, respectively. Results are shown in hundredths of billion gallons for display purposes.

## Manufacturing Watershed Withdrawal and Consumptive Use Method

### Past withdrawal by HUC8

1. Sum Industrial, Chemical, and Timber withdrawals in the LQU by HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table Q-1).

### Past employment by HUC8

2. Overlay HUC8 boundaries onto county boundaries and manufacturing withdrawal locations for each year of record in the LQU database.
3. Determine portion of HUC8 Manufacturing withdrawal that occurs in each county portion of the HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
    a. Portion of 2003 withdrawal in County 1 and HUC8 A = (2003 withdrawal in County 1 in HUC8 A)/ (total County 1 withdrawal in 2003)
    b. Portion of 2003 withdrawal in County 2 and HUC8 A = (2003 withdrawal in County 2 in HUC8 A)/ (total County 2 withdrawal in 2003)
    c. Etc.
4. Collect manufacturing employment data for each West Virginia county from Workforce WV using NAICS codes 31-33 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
5. Apportion county employment data to overlapping HUC8s based on the portion of the withdrawals in that county (from step 3) for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
6. Sum employment totals by HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table Q-3).

### Per employee withdrawal rate by HUC8

7. Divide HUC8 withdrawals (from step 1) by HUC8 employment (from step 6) to obtain the per employee withdrawal rate (Table Q-4).
    a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 Manufacturing withdrawals.
    b. Average the per employee withdrawal rates for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 to obtain one value for each watershed to use in future projections.

### Future employment by HUC8

8. Multiply the number of employees in 2011 by a predicted rate of change by HUC8 obtained from the literature (Table Q-3).
    a. High Scenario – increase 2011 HUC8 employment by 1.5% annually through 2040 (WVU 2012)
    b. Low Scenario – decrease 2011 HUC8 employment by 0.1% annually through 2040 (Bureau of Labor Statistics 2012)

### Future withdrawal by HUC8

9. Multiply HUC8 per employee withdrawal rate (from step 7) by HUC8 employment in 2020, 2030, and 2040 for the high (step 8a) and low (step 8b) scenarios (Table Q-5).

10. If employment data were not available for a HUC8, apply the rate of change directly to the 2011 withdrawal (Table Q-5).

### Future consumptive use estimates by HUC8

11. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table Q-5).
    a. High scenario – 13% (Shaffer and Runkle 2007)
12. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table Q-5).
    a. Low scenario – 10% (Shaffer and Runkle 2007)

## Manufacturing County Withdrawal and Consumptive Use Method

### Past withdrawal by county

1. Sum Industrial, Chemical, and Timber withdrawals in the LQU by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table Q-6).

### Past employment by county

2. Collect manufacturing employment data for each West Virginia county from Workforce WV using NAICS codes 31-33 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
3. Sum employment totals for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table Q-8).

### Per employee withdrawal rate by county

4. Divide county withdrawals (from step 1) by county employment (from step 3) to obtain the per employee withdrawal rate (Table Q-9).
    a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 LQU database Manufacturing withdrawals.
    b. Average the per employee withdrawal rates for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 to obtain one value for each county to use in future projections.

### Future employment by county

5. Multiply the number of employees in 2011 by a predicted rate of change for each county obtained from the literature (Table Q-8).
    a. High Scenario – increase 2011 county employment by 1.5% annually through 2040 (WVU 2012)
    b. Low Scenario – decrease 2011 county employment by 0.1% annually through 2040 (Bureau of Labor Statistics 2012)

### Future withdrawal by county

6. Multiply county per employee withdrawal rate (from step 4) by county employment in 2020, 2030, and 2040 for the high (step 5a) and low (step 5b) scenarios (Table Q-9).
7. If employment data were not available for a county, apply the rate of change directly to the 2011 withdrawal (Table Q-9).

### Future consumptive use estimates by county

8. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table Q-9).
    a. High scenario – 13% (Shaffer and Runkle 2007)
9. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table Q-9).
    a. Low scenario – 10% (Shaffer and Runkle 2007)

**The following tables provide results at the county and watershed (HUC8) levels. The results at the county scale are not comparable to the results at the watershed scale due to differences in the estimation methodologies described above.**

**Table Q-1 Manufacturing withdrawals by watershed, presented in billions of gallons per year.**

| HUC 8* | Historical Withdrawals (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Big Sandy | 0.16 | 0.09 | 0.10 | 0.08 | 0.09 | 0.06 | 0.07 |
| Cheat | 0.16 | 0.16 | 0.16 | 0.02 | 0.02 | 0.02 | 0.03 |
| Lower Guyandotte | 0.27 | 0.24 | 0.25 | 0.28 | 0.25 | 0.26 | 0.30 |
| Lower Kanawha | 66.82 | 69.72 | 65.60 | 67.29 | 62.13 | 67.62 | 61.15 |
| Lower Ohio | 0.37 | 0.35 | 0.38 | 0.31 | 0.26 | 0.29 | 0.29 |
| Middle Ohio North | 59.80 | 59.65 | 59.42 | 58.19 | 45.58 | 45.90 | 49.72 |
| Middle Ohio South | 17.74 | 17.78 | 20.42 | 18.81 | 17.80 | 17.93 | 17.77 |
| Monongahela | 1.19 | 1.21 | 1.13 | 1.16 | 1.17 | 1.17 | 1.17 |
| North Branch Potomac | 0.05 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| Potomac Direct Drains | 3.79 | 3.81 | 3.85 | 3.70 | 3.70 | 1.37 | 2.93 |
| Shenandoah Jefferson | 0.04 | 0.04 | 0.05 | 0.04 | 0.06 | 0.04 | 0.04 |
| Upper Kanawha | 45.23 | 45.33 | 45.33 | 46.91 | 39.53 | 39.52 | 39.52 |
| Upper New | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Upper Ohio North | 55.89 | 55.80 | 44.64 | 14.91 | 16.18 | 12.47 | 14.27 |
| Upper Ohio South | 0.47 | 0.37 | 0.36 | 0.23 | 0.23 | 0.20 | 0.15 |
| TOTALS | 252.00 | 254.64 | 241.78 | 212.02 | 187.09 | 186.94 | 187.50 |

*Greenbrier was removed because no active withdrawals occurred in 2011, so no future projections were generated.

**Table Q-2 Manufacturing consumptive use scenarios by watershed, presented in billions of gallons per year.**

| HUC 8* | HIGH Consumptive Use (Bgal/yr) | | | | | | | LOW Consumptive Use (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Big Sandy | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Cheat† | 0.02 | 0.02 | 0.02 | 0.002 | 0.002 | 0.003 | 0.004 | 0.02 | 0.02 | 0.02 | 0.002 | 0.002 | 0.002 | 0.003 |
| Lower Guyandotte | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 |
| Lower Kanawha | 8.69 | 9.06 | 8.53 | 8.75 | 8.08 | 8.79 | 7.95 | 6.68 | 6.97 | 6.56 | 6.73 | 6.21 | 6.76 | 6.12 |
| Lower Ohio | 0.05 | 0.05 | 0.05 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 |
| Middle Ohio North | 7.77 | 7.75 | 7.72 | 7.56 | 5.92 | 5.97 | 6.46 | 5.98 | 5.96 | 5.94 | 5.82 | 4.56 | 4.59 | 4.97 |
| Middle Ohio South | 2.31 | 2.31 | 2.65 | 2.44 | 2.31 | 2.33 | 2.31 | 1.77 | 1.78 | 2.04 | 1.88 | 1.78 | 1.79 | 1.78 |
| Monongahela | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.12 | 0.12 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 |
| North Branch Potomac | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Potomac Direct Drains | 0.49 | 0.50 | 0.50 | 0.48 | 0.48 | 0.18 | 0.38 | 0.38 | 0.38 | 0.39 | 0.37 | 0.37 | 0.14 | 0.29 |
| Shenandoah Jefferson† | 0.005 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.005 | 0.004 | 0.004 | 0.005 | 0.004 | 0.01 | 0.004 | 0.004 |
| Upper Kanawha | 5.88 | 5.89 | 5.89 | 6.10 | 5.14 | 5.14 | 5.14 | 4.52 | 4.53 | 4.53 | 4.69 | 3.95 | 3.95 | 3.95 |
| Upper New† | 0.002 | 0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Upper Ohio North | 7.27 | 7.25 | 5.80 | 1.94 | 2.10 | 1.62 | 1.86 | 5.59 | 5.58 | 4.46 | 1.49 | 1.62 | 1.25 | 1.43 |
| Upper Ohio South | 0.06 | 0.05 | 0.05 | 0.03 | 0.03 | 0.03 | 0.02 | 0.05 | 0.04 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 |
| TOTALS | 32.77 | 33.10 | 31.42 | 27.56 | 24.30 | 24.32 | 24.38 | 25.22 | 25.47 | 24.18 | 21.21 | 18.72 | 18.71 | 18.77 |

*Greenbrier was removed because no active withdrawals occurred in 2011, so no future projections were generated. † Results rounded to additional decimal places when value was less than 0.01 billion gallons.

**Table Q-3 The past and projected number of employees in the Manufacturing sector by watershed. A dash (-) indicates that data were not available. The high scenario increases employment annually by 1.5 percent (WVU 2012) and the low scenario decreases employment annually by 0.1 percent (BLS 2012).**

| HUC 8* | Employment | | | | | | | High Employment Projection | | | Low Employment Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Big Sandy | 707 | 758 | 741 | 672 | 565 | 553 | 554 | 562 | 571 | 579 | 553 | 553 | 552 |
| Cheat | 302 | 287 | 286 | 257 | 241 | 247 | 251 | 255 | 259 | 262 | 251 | 250 | 250 |
| Lower Guyandotte | 4,884 | 4,948 | 5,071 | 5,120 | 4,685 | 4,592 | 4,705 | 4,776 | 4,847 | 4,920 | 4,700 | 4,696 | 4,691 |
| Lower Kanawha | 3,631 | 3,496 | 3,016 | 2,509 | 2,192 | 2,126 | 2,060 | 2,091 | 2,122 | 2,154 | 2,058 | 2,056 | 2,054 |
| Lower Ohio | 606 | 548 | 589 | 657 | 619 | 649 | 666 | 676 | 686 | 696 | 665 | 665 | 664 |
| Middle Ohio North | 3,249 | 3,078 | 3,023 | 2,686 | 2,326 | 2,197 | 2,150 | 2,182 | 2,215 | 2,248 | 2,148 | 2,146 | 2,144 |
| Middle Ohio South | 7,439 | 7,164 | 6,567 | 5,819 | 4,954 | 4,517 | 4,404 | 4,470 | 4,537 | 4,605 | 4,400 | 4,395 | 4,391 |
| Monongahela | 1,455 | 1,388 | 1,360 | 1,470 | 1,253 | 1,140 | 1,209 | 1,227 | 1,246 | 1,264 | 1,208 | 1,207 | 1,205 |
| North Branch Potomac | 1,280 | 1,308 | 1,386 | 1,804 | 1,994 | 1,919 | 1,898 | 1,926 | 1,955 | 1,985 | 1,896 | 1,894 | 1,892 |
| Potomac Direct Drains | 960 | 864 | 811 | 237 | 106 | 124 | 226 | 229 | 233 | 236 | 226 | 226 | 225 |
| Shenandoah Jefferson | 383 | 288 | 247 | 737 | 724 | 700 | 630 | 639 | 649 | 659 | 629 | 629 | 628 |
| Upper Kanawha | 2,654 | 2,462 | 2,273 | 2,011 | 1,859 | 1,709 | 1,682 | 1,707 | 1,733 | 1,759 | 1,680 | 1,679 | 1,677 |
| Upper New | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Upper Ohio North | 7,231 | 6,516 | 6,172 | 4,910 | 4,486 | 4,674 | 4,740 | 4,811 | 4,883 | 4,957 | 4,735 | 4,731 | 4,726 |
| Upper Ohio South | 305 | 250 | 266 | 80 | 267 | 127 | 80 | 81 | 82 | 84 | 80 | 80 | 80 |
| TOTALS | 35,086 | 33,355 | 31,808 | 28,969 | 26,271 | 25,274 | 25,255 | 25,634 | 26,018 | 26,409 | 25,230 | 25,205 | 25,179 |

*Greenbrier was removed because no active withdrawals occurred in 2011, so no future projections were generated.

**Table Q-4 Per Employee water use for the Manufacturing water use category by watershed, presented in millions of gallons per year.**

| HUC 8 | Per Employee Withdrawal Rate (Mgal/yr) | | | | | | | Average Rate (Mgal/yr) |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | |
| Big Sandy | 0.22 | 0.12 | 0.13 | 0.12 | 0.16 | 0.10 | 0.13 | 0.14 |
| Cheat | 0.52 | 0.55 | 0.55 | 0.07 | 0.07 | 0.09 | 0.11 | 0.28 |
| Lower Guyandotte | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.05 |
| Lower Kanawha | 18.40 | 19.94 | 21.75 | 26.82 | 28.35 | 31.81 | 29.69 | 25.25 |
| Lower Ohio | 0.61 | 0.64 | 0.64 | 0.48 | 0.42 | 0.44 | 0.44 | 0.52 |
| Middle Ohio North | 18.41 | 19.38 | 19.65 | 21.66 | 19.59 | 20.89 | 23.13 | 20.39 |
| Middle Ohio South | 2.39 | 2.48 | 3.11 | 3.23 | 3.59 | 3.97 | 4.04 | 3.26 |
| Monongahela | 0.82 | 0.87 | 0.83 | 0.79 | 0.93 | 1.03 | 0.97 | 0.89 |
| North Branch Potomac | 0.04 | 0.06 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Potomac Direct Drains | 3.94 | 4.41 | 4.75 | 15.63 | 34.89 | 11.04 | 12.95 | 12.52 |
| Shenandoah Jefferson | 0.10 | 0.14 | 0.20 | 0.06 | 0.08 | 0.06 | 0.06 | 0.10 |
| Upper Kanawha | 17.04 | 18.41 | 19.94 | 23.33 | 21.27 | 23.13 | 23.50 | 20.94 |
| Upper New | - | - | - | - | - | - | - | - |
| Upper Ohio North | 7.73 | 8.56 | 7.23 | 3.04 | 3.61 | 2.67 | 3.01 | 5.12 |
| Upper Ohio South | 1.53 | 1.48 | 1.36 | 2.89 | 0.87 | 1.55 | 1.92 | 1.66 |
| TOTALS | 71.80 | 77.09 | 80.24 | 98.21 | 113.92 | 96.88 | 100.05 | 91.16 |

*Greenbrier was removed because no active withdrawals occurred in 2011, so no future projections were generated. A dash (-) indicates that no employment data were available.

Table Q-5 High and low scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by watershed for the Manufacturing water use sector, presented in billions of gallons per year. Projections were completed for only those watersheds in which there was a 2011 withdrawal in the LQU database.

| HUC 8 | Projected Withdrawals (Bgal/yr) | | | | | | Projected Consumptive Use (Bgal/yr) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | | | Low | | | High | | | Low | | |
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Big Sandy | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Cheat | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Lower Guyandotte | 0.26 | 0.26 | 0.27 | 0.26 | 0.26 | 0.25 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Lower Kanawha | 52.80 | 53.59 | 54.39 | 51.97 | 51.91 | 51.86 | 6.86 | 6.97 | 7.07 | 5.20 | 5.19 | 5.19 |
| Lower Ohio | 0.35 | 0.36 | 0.36 | 0.35 | 0.35 | 0.35 | 0.05 | 0.05 | 0.05 | 0.03 | 0.03 | 0.03 |
| Middle Ohio North | 44.49 | 45.16 | 45.84 | 43.79 | 43.75 | 43.70 | 5.78 | 5.87 | 5.96 | 4.38 | 4.37 | 4.37 |
| Middle Ohio South | 14.56 | 14.78 | 15.00 | 14.33 | 14.32 | 14.31 | 1.89 | 1.92 | 1.95 | 1.43 | 1.43 | 1.43 |
| Monongahela | 1.09 | 1.11 | 1.13 | 1.08 | 1.08 | 1.07 | 0.14 | 0.14 | 0.15 | 0.11 | 0.11 | 0.11 |
| North Branch Potomac | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Potomac Direct Drains | 2.87 | 2.91 | 2.96 | 2.83 | 2.82 | 2.82 | 0.37 | 0.38 | 0.38 | 0.28 | 0.28 | 0.28 |
| Shenandoah Jefferson | 0.06 | 0.06 | 0.07 | 0.06 | 0.06 | 0.06 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Upper Kanawha | 35.76 | 36.29 | 36.84 | 35.19 | 35.16 | 35.12 | 4.65 | 4.72 | 4.79 | 3.52 | 3.52 | 3.51 |
| Upper New*† | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.003 | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 |
| Upper Ohio North | 24.64 | 25.01 | 25.39 | 24.25 | 24.23 | 24.20 | 3.20 | 3.25 | 3.30 | 2.43 | 2.42 | 2.42 |
| Upper Ohio South | 0.13 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| TOTALS | 177.26 | 179.92 | 182.64 | 174.49 | 174.32 | 174.12 | 23.03 | 23.39 | 23.74 | 17.46 | 17.43 | 17.42 |

*No employment data were available. The rates of change in employment were applied directly to 2011 withdrawal amounts. † Results rounded to additional decimal places when value was less than 0.01 billion gallons.

Table Q-6 Manufacturing withdrawals by county, presented in billions of gallons per year.

| County* | Historical Withdrawals (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Berkeley | 3.69 | 3.69 | 3.69 | 3.69 | 3.69 | 1.36 | 2.91 |
| Brooke | 2.52 | 2.48 | 2.20 | 5.84 | 1.54 | 1.78 | 3.00 |
| Cabell | 0.27 | 0.24 | 0.25 | 0.28 | 0.25 | 0.26 | 0.30 |
| Fayette | 9.49 | 9.49 | 9.49 | 9.49 | 2.22 | 2.20 | 2.21 |
| Hancock | 53.69 | 53.60 | 42.72 | 9.28 | 14.85 | 10.81 | 11.39 |
| Jackson | 0.77 | 0.81 | 0.89 | 0.98 | 0.23 | 0.17 | 0.10 |
| Jefferson | 0.13 | 0.16 | 0.21 | 0.06 | 0.06 | 0.06 | 0.05 |
| Kanawha | 102.56 | 105.56 | 101.44 | 104.71 | 99.45 | 104.94 | 98.47 |
| Marion | 1.19 | 1.21 | 1.13 | 1.16 | 1.17 | 1.17 | 1.17 |
| Marshall | 55.57 | 55.49 | 55.40 | 55.01 | 42.10 | 42.42 | 46.53 |
| Mason | 0.37 | 0.35 | 0.38 | 0.31 | 0.26 | 0.29 | 0.29 |
| Mineral | 0.05 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| Monroe | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Pleasants | 1.83 | 2.02 | 1.96 | 1.22 | 1.32 | 1.50 | 1.33 |
| Tucker | 0.16 | 0.16 | 0.16 | 0.02 | 0.02 | 0.02 | 0.03 |
| Tyler | 2.44 | 2.11 | 1.97 | 1.98 | 2.18 | 2.07 | 1.91 |
| Wayne | 0.16 | 0.09 | 0.10 | 0.08 | 0.09 | 0.06 | 0.07 |
| Wood | 16.98 | 16.98 | 19.53 | 17.83 | 17.56 | 17.76 | 17.68 |
| TOTALS | 251.89 | 254.53 | 241.61 | 212.03 | 187.08 | 186.96 | 187.53 |

*Greenbrier was removed because no active withdrawals occurred in 2011, so no future projections were generated.

Table Q-7 Manufacturing consumptive use scenarios by county, presented in billions of gallons per year.

| County* | HIGH Consumptive Use (Bgal/yr) | | | | | | | LOW Consumptive Use (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Berkeley | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.18 | 0.38 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.14 | 0.29 |
| Brooke | 0.33 | 0.32 | 0.29 | 0.76 | 0.20 | 0.23 | 0.39 | 0.25 | 0.25 | 0.22 | 0.58 | 0.15 | 0.18 | 0.30 |
| Cabell | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 |
| Fayette | 1.23 | 1.23 | 1.23 | 1.23 | 0.29 | 0.29 | 0.29 | 0.95 | 0.95 | 0.95 | 0.95 | 0.22 | 0.22 | 0.22 |
| Hancock | 6.98 | 6.97 | 5.55 | 1.21 | 1.93 | 1.41 | 1.48 | 5.37 | 5.36 | 4.27 | 0.93 | 1.49 | 1.08 | 1.14 |
| Jackson | 0.10 | 0.10 | 0.12 | 0.13 | 0.03 | 0.02 | 0.01 | 0.08 | 0.08 | 0.09 | 0.10 | 0.02 | 0.02 | 0.01 |
| Jefferson† | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.005 |
| Kanawha | 13.33 | 13.72 | 13.19 | 13.61 | 12.93 | 13.64 | 12.80 | 10.26 | 10.56 | 10.14 | 10.47 | 9.95 | 10.49 | 9.85 |
| Marion | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.12 | 0.12 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 |
| Marshall | 7.22 | 7.21 | 7.20 | 7.15 | 5.47 | 5.51 | 6.05 | 5.56 | 5.55 | 5.54 | 5.50 | 4.21 | 4.24 | 4.65 |
| Mason | 0.05 | 0.05 | 0.05 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 |
| Mineral | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Monroe† | 0.002 | 0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Pleasants | 0.24 | 0.26 | 0.26 | 0.16 | 0.17 | 0.19 | 0.17 | 0.18 | 0.20 | 0.20 | 0.12 | 0.13 | 0.15 | 0.13 |
| Tucker† | 0.02 | 0.02 | 0.02 | 0.002 | 0.002 | 0.003 | 0.004 | 0.02 | 0.02 | 0.02 | 0.002 | 0.002 | 0.002 | 0.003 |
| Tyler | 0.32 | 0.27 | 0.26 | 0.26 | 0.28 | 0.27 | 0.25 | 0.24 | 0.21 | 0.20 | 0.20 | 0.22 | 0.21 | 0.19 |
| Wayne | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Wood | 2.21 | 2.21 | 2.54 | 2.32 | 2.28 | 2.31 | 2.30 | 1.70 | 1.70 | 1.95 | 1.78 | 1.76 | 1.78 | 1.77 |
| TOTALS | 32.75 | 33.07 | 31.42 | 27.57 | 24.30 | 24.31 | 24.39 | 25.21 | 25.47 | 24.16 | 21.21 | 18.73 | 18.72 | 18.76 |

*Greenbrier was removed because no active withdrawals occurred in 2011, so no future projections were generated. †Results rounded to additional decimal places when value was less than 0.01 billion gallons.

**Table Q-8 The past and projected number of employees in the Manufacturing sector by county. A dash (-) indicates that data were not available. The high scenario increases employment annually by 1.5 percent (WVU 2012) and the low scenario decreases employment annually by 0.1 percent (BLS 2012).**

| County* | Employment | | | | | | | High Employment Projection | | | Low Employment Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Berkeley | 2,570 | 2,403 | 2,589 | 1,893 | 1,446 | 1,366 | 1,393 | 1,414 | 1,435 | 1,457 | 1,392 | 1,390 | 1,389 |
| Brooke | 2,344 | 2,184 | 2,137 | 2,118 | 1,920 | 1,960 | 2,010 | 2,040 | 2,071 | 2,102 | 2,008 | 2,006 | 2,004 |
| Cabell | 4,884 | 4,948 | 5,071 | 5,120 | 4,685 | 4,592 | 4,705 | 4,776 | 4,847 | 4,920 | 4,700 | 4,696 | 4,691 |
| Fayette | 712 | 665 | 626 | 616 | 543 | 536 | 494 | 501 | 509 | 517 | 494 | 493 | 493 |
| Hancock | 5,187 | 4,579 | 4,298 | 2,869 | 2,830 | 2,839 | 2,808 | 2,850 | 2,893 | 2,936 | 2,805 | 2,802 | 2,800 |
| Jackson | 2,069 | 2,148 | 2,164 | 2,175 | 1,488 | 1,273 | 1,242 | 1,261 | 1,280 | 1,299 | 1,241 | 1,240 | 1,238 |
| Jefferson | 1,343 | 1,152 | 1,058 | 974 | 830 | 824 | 856 | 869 | 882 | 895 | 855 | 854 | 853 |
| Kanawha | 5,573 | 5,293 | 4,663 | 3,904 | 3,508 | 3,299 | 3,248 | 3,297 | 3,346 | 3,396 | 3,245 | 3,242 | 3,238 |
| Marion | 1,455 | 1,388 | 1,360 | 1,470 | 1,253 | 1,140 | 1,209 | 1,227 | 1,246 | 1,264 | 1,208 | 1,207 | 1,205 |
| Marshall | 1,913 | 1,847 | 1,759 | 1,518 | 1,326 | 1,218 | 1,217 | 1,235 | 1,254 | 1,273 | 1,216 | 1,215 | 1,213 |
| Mason | 606 | 548 | 589 | 657 | 619 | 649 | 666 | 676 | 686 | 696 | 665 | 665 | 664 |
| Mineral | 1,280 | 1,308 | 1,386 | 1,804 | 1,994 | 1,919 | 1,898 | 1,926 | 1,955 | 1,985 | 1,896 | 1,894 | 1,892 |
| Monroe | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Pleasants | 561 | 545 | 571 | 502 | 397 | 394 | 391 | 397 | 403 | 409 | 391 | 390 | 390 |
| Tucker | 302 | 287 | 286 | 257 | 241 | 247 | 251 | 255 | 259 | 262 | 251 | 250 | 250 |
| Tyler | 780 | 689 | 696 | 669 | 606 | 587 | 544 | 552 | 560 | 569 | 543 | 543 | 542 |
| Wayne | 707 | 758 | 741 | 672 | 565 | 553 | 554 | 562 | 571 | 579 | 553 | 553 | 552 |
| Wood | 5,370 | 5,016 | 4,403 | 3,644 | 3,466 | 3,244 | 3,162 | 3,209 | 3,258 | 3,306 | 3,159 | 3,156 | 3,153 |
| TOTALS | 37,656 | 35,758 | 34,397 | 30,862 | 27,717 | 26,640 | 26,648 | 27,048 | 27,453 | 27,865 | 26,621 | 26,595 | 26,568 |

*Greenbrier was removed because no active withdrawals occurred in 2011, so no future projections were generated.

**Table Q-9 Per Employee water use for the Manufacturing water use category by county, presented in millions of gallons per year.**

| County* | Per Employee Withdrawal Rate (Mgal/yr) | | | | | | | Average Rate (Mgal/yr) |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | |
| Berkeley | 1.44 | 1.54 | 1.43 | 1.95 | 2.55 | 0.99 | 2.09 | 1.71 |
| Brooke | 1.08 | 1.14 | 1.03 | 2.76 | 0.80 | 0.91 | 1.49 | 1.31 |
| Cabell | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.05 |
| Fayette | 13.33 | 14.27 | 15.16 | 15.41 | 4.08 | 4.11 | 4.46 | 10.12 |
| Hancock | 10.35 | 11.71 | 9.94 | 3.23 | 5.25 | 3.81 | 4.06 | 6.91 |
| Jackson | 0.37 | 0.38 | 0.41 | 0.45 | 0.16 | 0.13 | 0.08 | 0.28 |
| Jefferson | 0.10 | 0.14 | 0.20 | 0.06 | 0.08 | 0.07 | 0.06 | 0.10 |
| Kanawha | 18.40 | 19.94 | 21.75 | 26.82 | 28.35 | 31.81 | 30.32 | 25.34 |
| Marion | 0.82 | 0.87 | 0.83 | 0.79 | 0.93 | 1.03 | 0.97 | 0.89 |
| Marshall | 29.05 | 30.04 | 31.49 | 36.24 | 31.75 | 34.83 | 38.23 | 33.09 |
| Mason | 0.61 | 0.64 | 0.64 | 0.48 | 0.42 | 0.44 | 0.44 | 0.52 |
| Mineral | 0.04 | 0.06 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Monroe | - | - | - | - | - | - | - | - |
| Pleasants | 3.26 | 3.71 | 3.44 | 2.43 | 3.31 | 3.80 | 3.39 | 3.34 |
| Tucker | 0.52 | 0.55 | 0.55 | 0.07 | 0.07 | 0.09 | 0.11 | 0.28 |
| Tyler | 3.12 | 3.06 | 2.84 | 2.95 | 3.59 | 3.53 | 3.51 | 3.23 |
| Wayne | 0.22 | 0.12 | 0.13 | 0.12 | 0.16 | 0.10 | 0.13 | 0.14 |
| Wood | 3.16 | 3.38 | 4.44 | 4.89 | 5.07 | 5.47 | 5.59 | 4.57 |
| TOTALS | 85.92 | 91.60 | 94.38 | 98.74 | 86.66 | 91.22 | 95.03 | 91.92 |

*Greenbrier was removed because no active withdrawals occurred in 2011, so no future projections were generated. A dash (-) indicates that no employment data were available.

**Table Q-10 High and low scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by county for the Manufacturing water use sector, presented in billions of gallons per year. Projections were completed for only those watersheds in which there was a 2011 withdrawal in the LQU database.**

| County | Projected Withdrawals (Bgal/yr) | | | | | | Projected Consumptive Use (Bgal/yr) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | | | Low | | | High | | | Low | | |
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Berkeley | 2.42 | 2.46 | 2.49 | 2.38 | 2.38 | 2.38 | 0.31 | 0.32 | 0.32 | 0.24 | 0.24 | 0.24 |
| Brooke | 2.68 | 2.72 | 2.76 | 2.64 | 2.64 | 2.63 | 0.35 | 0.35 | 0.36 | 0.26 | 0.26 | 0.26 |
| Cabell | 0.26 | 0.26 | 0.27 | 0.26 | 0.26 | 0.25 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Fayette | 5.07 | 5.15 | 5.23 | 4.99 | 4.99 | 4.98 | 0.66 | 0.67 | 0.68 | 0.50 | 0.50 | 0.50 |
| Hancock | 19.68 | 19.98 | 20.28 | 19.37 | 19.35 | 19.33 | 2.56 | 2.60 | 2.64 | 1.94 | 1.94 | 1.93 |
| Jackson | 0.36 | 0.36 | 0.37 | 0.35 | 0.35 | 0.35 | 0.05 | 0.05 | 0.05 | 0.03 | 0.03 | 0.03 |
| Jefferson | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Kanawha | 83.55 | 84.80 | 86.07 | 82.23 | 82.15 | 82.07 | 10.86 | 11.02 | 11.19 | 8.22 | 8.21 | 8.21 |
| Marion | 1.09 | 1.11 | 1.13 | 1.08 | 1.08 | 1.07 | 0.14 | 0.14 | 0.15 | 0.11 | 0.11 | 0.11 |
| Marshall | 40.88 | 41.49 | 42.11 | 40.23 | 40.19 | 40.15 | 5.31 | 5.39 | 5.47 | 4.02 | 4.02 | 4.02 |
| Mason | 0.35 | 0.36 | 0.36 | 0.35 | 0.35 | 0.35 | 0.05 | 0.05 | 0.05 | 0.03 | 0.03 | 0.03 |
| Mineral | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Monroe*† | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.003 | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 |
| Pleasants | 1.32 | 1.34 | 1.36 | 1.30 | 1.30 | 1.30 | 0.17 | 0.17 | 0.18 | 0.13 | 0.13 | 0.13 |
| Tucker | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Tyler | 1.78 | 1.81 | 1.84 | 1.75 | 1.75 | 1.75 | 0.23 | 0.24 | 0.24 | 0.18 | 0.18 | 0.18 |
| Wayne | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Wood | 14.67 | 14.89 | 15.12 | 14.44 | 14.43 | 14.41 | 1.91 | 1.94 | 1.97 | 1.44 | 1.44 | 1.44 |
| TOTALS | 174.45 | 177.07 | 179.73 | 171.71 | 171.56 | 171.36 | 22.67 | 23.01 | 23.37 | 17.17 | 17.16 | 17.15 |

*No employment data were available. The rates of change in employment were applied directly to 2011 withdrawal amounts. †Results rounded to additional decimal places when value was less than 0.01 billion gallons.

# Appendix R

## Development of the Recreation withdrawal and consumptive use scenarios

Historic Recreation withdrawals in the combined Recreation sector (Recreation SIC category from the LQU database) by watershed and by county can be found in **Table R-1** and **Table R-6**, respectively. Historic estimates of both High and Low Consumptive Use scenarios can be found by watershed and county in **Table R-2** and **Table R-7**, respectively. Results are shown in hundredths of million gallons for display purposes.

## Recreation Watershed Withdrawal and Consumptive Use Method

### Past withdrawal by HUC8

1. Sum Recreation withdrawals by HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table R-1).

### Past employment by HUC8

2. Overlay HUC8 boundaries, county boundaries, and Recreation withdrawal locations for each year of record in the LQU database.
3. Determine portion of HUC8 Recreation withdrawal that occurs in each county portion of the HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
    a. Portion of 2003 withdrawal in County 1 and HUC8 A = (withdrawal in County 1 in HUC8 A)/ (total County 1 withdrawal)
    b. Portion of 2003 withdrawal in County 2 and HUC8 A = (withdrawal in County 2 in HUC8 A)/ (total County 2 withdrawal)
    c. Etc.
4. Collect recreation employment data for each West Virginia county from Workforce WV using NAICS codes 71 and 72 (removing any obvious non-recreation employment like restaurants and bars when the information was available) for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
5. Apportion county employment data to overlapping HUC8s based on the portion of the withdrawals in that county (from step 3) for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
6. Sum employment totals by HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table R-3).

### Per employee withdrawal rate by HUC8

7. Divide HUC8 withdrawals (from step 1) by HUC8 employment (from step 6) to obtain the per employee withdrawal rate (Table R-4).
    a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 LQU database Recreation withdrawals.
    b. Average the per employee withdrawal rates for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 to obtain one value for each watershed to use in future projections.

### Future employment by HUC8

8. Multiply the number of employees in 2011 by a predicted rate of change by HUC8 obtained from the literature (Table R-4).
    a. High Scenario – change 2011 HUC8 employment by 1.0% annually through 2040

(Bureau of Labor Statistics 2012)

b. Low Scenario – change 2011 HUC8 employment by 0% annually through 2040 (WVU 2012)

### Future withdrawal by HUC8

9. Multiply HUC8 per employee withdrawal rate (from step 7) by HUC8 employment in 2020, 2030, and 2040 for the high (step 8a) and low (step 8b) scenarios (Table R-5).

### Future consumptive use estimates by HUC8

10. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table R-5).
    a. High scenario – 56.5% , the average of 75th percentile industrial and irrigation coefficients (Shaffer and Runkle 2007)
11. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table R-5).
    a. Low scenario – 55%, the average of median industrial and irrigation coefficients (Shaffer and Runkle 2007)

## Recreation County Withdrawal and Consumptive Use Method

### Past withdrawal by county

1. Sum Recreation withdrawals by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table R-6).

### Past employment by county

2. Collect recreation employment data for each West Virginia county from Workforce WV using NAICS codes 71 and 72 (removing any obvious non-recreation employment like restaurants and bars when the information was available) for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.
3. Sum employment totals by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table R-8).

### Per employee withdrawal rate by county

4. Divide county withdrawals (from step 1) by county employment (from step 3) to obtain the per employee withdrawal rate (Table R-9).
    a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 LQU database Recreation withdrawals.
    b. Average the per employee withdrawal rates for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 to obtain one value for each county to use in future projections.

### Future employment by county

5. Multiply the number of employees in 2011 by a predicted rate of change by county obtained from the literature (Table R-8).
    a. High Scenario – change 2011 county employment by 1.0% annually through 2040 (Bureau of Labor Statistics 2012)
    b. Low Scenario – change 2011 county employment by 0% annually through 2040 (WVU 2012)

### Future withdrawal by county

6. Multiply county per employee withdrawal rate (from step 4) by county employment in 2020, 2030, and 2040 for the high (step 5a) and low (step 5b) scenarios (Table R-10)

### Future consumptive use estimates by county

7. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table R-10).
    a. High scenario – 56.5% , the average of 75th percentile industrial and irrigation coefficients (Shaffer and Runkle 2007)
8. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients (Table R-10).
    a. Low scenario – 55%, the average of median industrial and irrigation coefficients (Shaffer and Runkle 2007)

**The following tables provide results at the county and watershed (HUC8) levels. The results at the county scale are not comparable to the results at the watershed scale due to differences in the estimation methodologies described above.**

**Table R-1 Recreation withdrawals by watershed, presented in millions of gallons per year.**

| HUC 8 | Historical Withdrawals (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Cacapon | 6.99 | 7.15 | 8.79 | 7.64 | 7.64 | 7.64 | 7.64 |
| Cheat | 437.92 | 445.78 | 513.78 | 458.29 | 493.86 | 494.94 | 376.18 |
| Elk | 7.52 | 7.70 | 9.09 | 8.10 | 8.74 | 8.76 | 6.63 |
| Greenbrier | 860.77 | 862.12 | 870.98 | 864.62 | 683.23 | 699.33 | 644.45 |
| Lower Kanawha | 12.35 | 12.35 | 12.35 | 12.35 | 12.35 | 12.35 | 12.35 |
| Lower New | 111.30 | 116.19 | 172.53 | 206.98 | 170.42 | 179.34 | 171.75 |
| Middle Ohio South | 3.70 | 5.60 | 11.70 | 7.00 | 7.00 | 7.00 | 7.00 |
| Monongahela* | 0.00 | 0.00 | 0.00 | 19.18 | 20.19 | 19.68 | 4.79 |
| Potomac Direct Drains | 60.57 | 56.34 | 31.17 | 43.80 | 44.19 | 44.19 | 44.19 |
| Shenandoah Jefferson* | 0.00 | 18.00 | 72.00 | 45.00 | 41.73 | 43.91 | 43.91 |
| South Branch Potomac | 6.59 | 6.65 | 11.32 | 8.19 | 8.19 | 8.19 | 8.19 |
| Tug Fork | 2.78 | 2.63 | 2.75 | 2.72 | 2.72 | 2.72 | 2.72 |
| Upper Ohio North | 69.18 | 70.89 | 78.09 | 112.48 | 87.15 | 87.15 | 87.15 |
| West Fork | 20.82 | 34.45 | 39.64 | 39.16 | 37.75 | 37.75 | 27.31 |
| TOTALS† | 1,600 | 1,646 | 1,834 | 1,836 | 1,625 | 1,653 | 1,444 |

* There were no withdrawals in the Monongahela Watershed in 2003, 2004, or 2005 or the Shenandoah Jefferson Watershed in 2003. ‡Totals were rounded to whole numbers for display purposes.

**Table R-2 Recreation consumptive use scenario estimates by watershed, presented in millions of gallons per year.**

| HUC 8 | HIGH Consumptive Use (Mgal/yr) | | | | | | | LOW Consumptive Use (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Cacapon | 3.95 | 4.04 | 4.96 | 4.32 | 4.32 | 4.32 | 4.32 | 3.85 | 3.93 | 4.83 | 4.20 | 4.20 | 4.20 | 4.20 |
| Cheat | 247.42 | 251.86 | 290.29 | 258.93 | 279.03 | 279.64 | 212.54 | 240.86 | 245.18 | 282.58 | 252.06 | 271.62 | 272.22 | 206.90 |
| Elk | 4.25 | 4.35 | 5.13 | 4.58 | 4.94 | 4.95 | 3.75 | 4.14 | 4.24 | 5.00 | 4.46 | 4.81 | 4.82 | 3.65 |
| Greenbrier | 486.34 | 487.10 | 492.10 | 488.51 | 386.03 | 395.12 | 364.12 | 473.42 | 474.17 | 479.04 | 475.54 | 375.78 | 384.63 | 354.45 |
| Lower Kanawha | 6.98 | 6.98 | 6.98 | 6.98 | 6.98 | 6.98 | 6.98 | 6.79 | 6.79 | 6.79 | 6.79 | 6.79 | 6.79 | 6.79 |
| Lower New | 62.88 | 65.65 | 97.48 | 116.95 | 96.29 | 101.33 | 97.04 | 61.22 | 63.91 | 94.89 | 113.84 | 93.73 | 98.64 | 94.47 |
| Middle Ohio South | 2.09 | 3.16 | 6.61 | 3.95 | 3.95 | 3.95 | 3.95 | 2.03 | 3.08 | 6.44 | 3.85 | 3.85 | 3.85 | 3.85 |
| Monongahela* | 0.00 | 0.00 | 0.00 | 10.84 | 11.41 | 11.12 | 2.70 | 0.00 | 0.00 | 0.00 | 10.55 | 11.10 | 10.83 | 2.63 |
| Potomac Direct Drains | 34.22 | 31.83 | 17.61 | 24.75 | 24.97 | 24.97 | 24.97 | 33.31 | 30.99 | 17.14 | 24.09 | 24.31 | 24.31 | 24.31 |
| Shenandoah Jefferson* | 0.00 | 10.17 | 40.68 | 25.43 | 23.58 | 24.81 | 24.81 | 0.00 | 9.90 | 39.60 | 24.75 | 22.95 | 24.15 | 24.15 |
| South Branch Potomac | 3.73 | 3.76 | 6.39 | 4.63 | 4.63 | 4.63 | 4.63 | 3.63 | 3.66 | 6.22 | 4.50 | 4.50 | 4.50 | 4.50 |
| Tug Fork | 1.57 | 1.49 | 1.55 | 1.54 | 1.54 | 1.54 | 1.54 | 1.53 | 1.45 | 1.51 | 1.50 | 1.50 | 1.50 | 1.50 |
| Upper Ohio North | 39.09 | 40.05 | 44.12 | 63.55 | 49.24 | 49.24 | 49.24 | 38.05 | 38.99 | 42.95 | 61.86 | 47.93 | 47.93 | 47.93 |
| West Fork | 11.77 | 19.47 | 22.40 | 22.13 | 21.33 | 21.33 | 15.43 | 11.45 | 18.95 | 21.80 | 21.54 | 20.76 | 20.76 | 15.02 |
| TOTALS† | 904 | 930 | 1,036 | 1,037 | 918 | 934 | 816 | 880 | 905 | 1,009 | 1,010 | 894 | 909 | 794 |

* There were no withdrawals in the Monongahela Watershed in 2003, 2004, or 2005 or the Shenandoah Jefferson Watershed in 2003. †Totals were rounded to whole numbers for display purposes.

**Table R-3 The past and projected number of employees in the Recreation sector by watershed. The high scenario increases employment annually by 1 percent (BLS 2012) and the low scenario did not change employment into the future (WVU 2012).**

| HUC 8 | Employment | | | | | | | High Employment Projection | | | Low Employment Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Cacapon | 157 | 159 | 151 | 189 | 172 | 189 | 189 | 191 | 193 | 195 | 189 | 189 | 189 |
| Cheat | 148 | 180 | 194 | 154 | 137 | 135 | 169 | 171 | 172 | 174 | 169 | 169 | 169 |
| Elk† | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Greenbrier | 1,910 | 1,881 | 1,852 | 1,632 | 1,410 | 1,889 | 2,929 | 2,958 | 2,988 | 3,018 | 2,929 | 2,929 | 2,929 |
| Lower Kanawha | 2,518 | 2,475 | 2,558 | 2,643 | 2,762 | 2,683 | 2,611 | 2,637 | 2,663 | 2,690 | 2,611 | 2,611 | 2,611 |
| Lower New | 1,002 | 984 | 992 | 817 | 781 | 767 | 938 | 947 | 957 | 966 | 938 | 938 | 938 |
| Middle Ohio South | 651 | 735 | 813 | 805 | 797 | 770 | 799 | 807 | 815 | 823 | 799 | 799 | 799 |
| Monongahela* | - | - | - | 1,210 | 1,222 | 1,294 | 1,341 | 1,354 | 1,368 | 1,382 | 1,341 | 1,341 | 1,341 |
| Potomac Direct Drains | 2,409 | 1,477 | 861 | 1,154 | 1,160 | 1,190 | 800 | 808 | 816 | 824 | 800 | 800 | 800 |
| Shenandoah Jefferson* | - | 1,100 | 1,687 | 1,597 | 1,473 | 1,744 | 546 | 551 | 557 | 563 | 546 | 546 | 546 |
| South Branch Potomac | 57 | 84 | 94 | 71 | 53 | 67 | 50 | 51 | 51 | 52 | 50 | 50 | 50 |
| Tug Fork | 83 | 85 | 67 | 76 | 76 | 72 | 75 | 76 | 77 | 77 | 75 | 75 | 75 |
| Upper Ohio North | 1,720 | 1,747 | 1,796 | 346 | 328 | 328 | 308 | 311 | 314 | 317 | 308 | 308 | 308 |
| West Fork | 309 | 342 | 354 | 380 | 338 | 334 | 354 | 358 | 361 | 365 | 354 | 354 | 354 |
| TOTALS | 10,965 | 11,250 | 11,420 | 11,075 | 10,710 | 11,463 | 11,110 | 11,221 | 11,333 | 11,447 | 11,110 | 11,110 | 11,110 |

* There were no withdrawals in the Monongahela Watershed in 2003, 2004, or 2005 or the Shenandoah Jefferson Watershed in 2003 so no employment data needed to be collected. †Employment in Elk watershed was rounded up to a whole number to ensure the withdrawal was represented.

**Table R-4 Per Employee water use for the Recreation water use category by watershed, presented in millions of gallons per year.**

| HUC 8 | Per Employee Withdrawal Rate (Mgal/yr) | | | | | | | Average Rate (Mgal/yr) |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | |
| Cacapon | 0.04 | 0.04 | 0.06 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Cheat | 2.96 | 2.48 | 2.65 | 2.98 | 3.60 | 3.67 | 2.23 | 2.94 |
| Elk | 7.52 | 7.70 | 9.09 | 8.10 | 8.74 | 8.76 | 6.63 | 8.08 |
| Greenbrier | 0.45 | 0.46 | 0.47 | 0.53 | 0.48 | 0.37 | 0.22 | 0.43 |
| Lower Kanawha† | 0.01 | 0.01 | 0.01 | 0.01 | 0.004 | 0.01 | 0.01 | 0.01 |
| Lower New | 0.11 | 0.12 | 0.17 | 0.25 | 0.22 | 0.23 | 0.18 | 0.18 |
| Middle Ohio South | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Monongahela*† | - | - | - | 0.02 | 0.02 | 0.02 | 0.004 | 0.01 |
| Potomac Direct Drains | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.06 | 0.04 |
| Shenandoah Jefferson* | - | 0.02 | 0.04 | 0.03 | 0.03 | 0.03 | 0.08 | 0.04 |
| South Branch Potomac | 0.12 | 0.08 | 0.12 | 0.12 | 0.15 | 0.12 | 0.16 | 0.12 |
| Tug Fork | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Upper Ohio North | 0.04 | 0.04 | 0.04 | 0.33 | 0.27 | 0.27 | 0.28 | 0.18 |
| West Fork | 0.07 | 0.10 | 0.11 | 0.10 | 0.11 | 0.11 | 0.08 | 0.10 |
| TOTALS | 11.39 | 11.13 | 12.85 | 12.60 | 13.75 | 13.72 | 10.02 | 12.22 |

* There were no withdrawals in the Monongahela Watershed in 2003, 2004, or 2005 or the Shenandoah Jefferson Watershed in 2003 so calculating a withdrawal rate was not necessary. † Results rounded to additional decimal places when value was less than 0.01 million gallons.

**Table R-5 High and low scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by watershed for the Recreation water use sector, presented in millions of gallons per year. Projections were completed for only those watersheds in which there was a 2011 withdrawal in the LQU database.**

| HUC 8 | Projected Withdrawals (Mgal/yr) | | | | | | Projected Consumptive Use (Mgal/yr) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | | | Low | | | High | | | Low | | |
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Cacapon | 8.55 | 8.63 | 8.72 | 8.46 | 8.46 | 8.46 | 4.83 | 4.88 | 4.93 | 4.65 | 4.65 | 4.65 |
| Cheat | 501.26 | 506.27 | 511.34 | 496.30 | 496.30 | 496.30 | 283.21 | 286.04 | 288.91 | 272.96 | 272.96 | 272.96 |
| Elk‡ | 8.16 | 8.24 | 8.32 | 8.08 | 8.08 | 8.08 | 4.61 | 4.66 | 4.70 | 4.44 | 4.44 | 4.44 |
| Greenbrier | 650.90 | 657.41 | 663.98 | 644.45 | 644.45 | 644.45 | 367.76 | 371.43 | 375.15 | 354.45 | 354.45 | 354.45 |
| Lower Kanawha | 12.51 | 12.63 | 12.76 | 12.38 | 12.38 | 12.38 | 7.07 | 7.14 | 7.21 | 6.81 | 6.81 | 6.81 |
| Lower New | 173.47 | 175.21 | 176.96 | 171.75 | 171.75 | 171.75 | 98.01 | 98.99 | 99.98 | 94.47 | 94.47 | 94.47 |
| Middle Ohio South | 7.26 | 7.34 | 7.41 | 7.19 | 7.19 | 7.19 | 4.10 | 4.15 | 4.19 | 3.96 | 3.96 | 3.96 |
| Monongahela | 17.32 | 17.49 | 17.67 | 17.15 | 17.15 | 17.15 | 9.79 | 9.88 | 9.98 | 9.43 | 9.43 | 9.43 |
| Potomac Direct Drains | 30.93 | 31.24 | 31.55 | 30.62 | 30.62 | 30.62 | 17.47 | 17.65 | 17.82 | 16.84 | 16.84 | 16.84 |
| Shenandoah Jefferson | 20.33 | 20.53 | 20.73 | 20.12 | 20.12 | 20.12 | 11.48 | 11.60 | 11.72 | 11.07 | 11.07 | 11.07 |
| South Branch Potomac | 6.28 | 6.35 | 6.41 | 6.22 | 6.22 | 6.22 | 3.55 | 3.59 | 3.62 | 3.42 | 3.42 | 3.42 |
| Tug Fork | 2.72 | 2.74 | 2.77 | 2.69 | 2.69 | 2.69 | 1.53 | 1.55 | 1.57 | 1.48 | 1.48 | 1.48 |
| Upper Ohio North | 56.16 | 56.72 | 57.29 | 55.61 | 55.61 | 55.61 | 31.73 | 32.05 | 32.37 | 30.58 | 30.58 | 30.58 |
| West Fork | 34.99 | 35.34 | 35.69 | 34.64 | 34.64 | 34.64 | 19.77 | 19.97 | 20.17 | 19.05 | 19.05 | 19.05 |
| TOTALS† | 1,531 | 1,546 | 1,562 | 1,516 | 1,516 | 1,516 | 865 | 874 | 882 | 834 | 834 | 834 |

†Totals were rounded to whole numbers for display purposes.

**Table R-6 Recreation withdrawals by county, presented in millions of gallons per year.**

| County | Historical Withdrawals (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Berkeley | 45.57 | 41.34 | 19.97 | 30.07 | 30.46 | 30.46 | 30.46 |
| Greenbrier | 860.77 | 862.12 | 870.98 | 864.62 | 683.23 | 699.33 | 644.45 |
| Hampshire | 6.99 | 7.15 | 8.79 | 7.64 | 7.64 | 7.64 | 7.64 |
| Hancock | 69.18 | 70.89 | 78.09 | 112.48 | 87.15 | 87.15 | 87.15 |
| Hardy | 6.59 | 6.65 | 11.32 | 8.19 | 8.19 | 8.19 | 8.19 |
| Jefferson | 15.00 | 33.00 | 83.21 | 58.74 | 55.47 | 57.65 | 57.65 |
| Kanawha | 12.35 | 12.35 | 12.35 | 12.35 | 12.35 | 12.35 | 12.35 |
| Lewis | 20.82 | 34.45 | 39.64 | 39.16 | 37.75 | 37.75 | 27.31 |
| Mingo | 2.78 | 2.63 | 2.75 | 2.72 | 2.72 | 2.72 | 2.72 |
| Monongalia* | 0.00 | 0.00 | 0.00 | 19.18 | 20.19 | 19.68 | 4.79 |
| Pocahontas | 442.22 | 450.30 | 519.29 | 463.07 | 499.27 | 500.37 | 378.86 |
| Preston | 3.22 | 3.18 | 3.58 | 3.33 | 3.33 | 3.33 | 3.95 |
| Raleigh | 111.30 | 116.19 | 172.53 | 206.98 | 170.42 | 179.34 | 171.75 |
| Wood | 3.70 | 5.60 | 11.70 | 7.00 | 7.00 | 7.00 | 7.00 |
| TOTALS† | 1,600 | 1,646 | 1,834 | 1,836 | 1,625 | 1,653 | 1,444 |

* There were no withdrawals in Monongalia County in 2003, 2004, or 2005. † Totals were rounded to whole numbers for display purposes.

**Table R-7 Recreation consumptive use scenario estimates by county, presented in millions of gallons per year.**

| County | HIGH Consumptive Use (Mgal/yr) | | | | | | | LOW Consumptive Use (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Berkeley | 25.75 | 23.36 | 11.28 | 16.99 | 17.21 | 17.21 | 17.21 | 25.06 | 22.74 | 10.98 | 16.54 | 16.75 | 16.75 | 16.75 |
| Greenbrier | 486.34 | 487.10 | 492.10 | 488.51 | 386.03 | 395.12 | 364.12 | 473.42 | 474.17 | 479.04 | 475.54 | 375.78 | 384.63 | 354.45 |
| Hampshire | 3.95 | 4.04 | 4.96 | 4.32 | 4.32 | 4.32 | 4.32 | 3.85 | 3.93 | 4.83 | 4.20 | 4.20 | 4.20 | 4.20 |
| Hancock | 39.09 | 40.05 | 44.12 | 63.55 | 49.24 | 49.24 | 49.24 | 38.05 | 38.99 | 42.95 | 61.86 | 47.93 | 47.93 | 47.93 |
| Hardy | 3.73 | 3.76 | 6.39 | 4.63 | 4.63 | 4.63 | 4.63 | 3.63 | 3.66 | 6.22 | 4.50 | 4.50 | 4.50 | 4.50 |
| Jefferson | 8.48 | 18.65 | 47.01 | 33.19 | 31.34 | 32.57 | 32.57 | 8.25 | 18.15 | 45.76 | 32.30 | 30.51 | 31.71 | 31.71 |
| Kanawha | 6.98 | 6.98 | 6.98 | 6.98 | 6.98 | 6.98 | 6.98 | 6.79 | 6.79 | 6.79 | 6.79 | 6.79 | 6.79 | 6.79 |
| Lewis | 11.77 | 19.47 | 22.40 | 22.13 | 21.33 | 21.33 | 15.43 | 11.45 | 18.95 | 21.80 | 21.54 | 20.76 | 20.76 | 15.02 |
| Mingo | 1.57 | 1.49 | 1.55 | 1.54 | 1.54 | 1.54 | 1.54 | 1.53 | 1.45 | 1.51 | 1.50 | 1.50 | 1.50 | 1.50 |
| Monongalia* | 0.00 | 0.00 | 0.00 | 10.84 | 11.41 | 11.12 | 2.70 | 0.00 | 0.00 | 0.00 | 10.55 | 11.10 | 10.83 | 2.63 |
| Pocahontas | 249.86 | 254.42 | 293.40 | 261.63 | 282.09 | 282.71 | 214.06 | 243.22 | 247.67 | 285.61 | 254.69 | 274.60 | 275.20 | 208.37 |
| Preston | 1.82 | 1.80 | 2.02 | 1.88 | 1.88 | 1.88 | 2.23 | 1.77 | 1.75 | 1.97 | 1.83 | 1.83 | 1.83 | 2.17 |
| Raleigh | 62.88 | 65.65 | 97.48 | 116.95 | 96.29 | 101.33 | 97.04 | 61.22 | 63.91 | 94.89 | 113.84 | 93.73 | 98.64 | 94.47 |
| Wood | 2.09 | 3.16 | 6.61 | 3.95 | 3.95 | 3.95 | 3.95 | 2.03 | 3.08 | 6.44 | 3.85 | 3.85 | 3.85 | 3.85 |
| TOTALS | 904.31 | 929.93 | 1,036.30 | 1,037.09 | 918.24 | 933.93 | 816.02 | 880.27 | 905.24 | 1,008.79 | 1,009.53 | 893.83 | 909.12 | 794.34 |

* There were no withdrawals in Monongalia County in 2003, 2004, or 2005.

Table R-8 The past and projected number of employees in the Recreation sector by county. The high scenario increases employment annually by 1 percent (BLS 2012) and the low scenario did not change employment into the future (WVU 2012).

| County | Employment | | | | | | | High Employment Projection | | | Low Employment Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Berkeley | 544 | 561 | 599 | 666 | 675 | 616 | 620 | 626 | 632 | 639 | 620 | 620 | 620 |
| Greenbrier | 1,910 | 1,881 | 1,852 | 1,632 | 1,410 | 1,889 | 2,929 | 2,958 | 2,988 | 3,018 | 2,929 | 2,929 | 2,929 |
| Hampshire | 157 | 159 | 151 | 189 | 172 | 189 | 189 | 191 | 193 | 195 | 189 | 189 | 189 |
| Hancock | 1,720 | 1,747 | 1,796 | 346 | 328 | 328 | 308 | 311 | 314 | 317 | 308 | 308 | 308 |
| Hardy | 57 | 84 | 94 | 71 | 53 | 67 | 50 | 51 | 51 | 52 | 50 | 50 | 50 |
| Jefferson | 1,865 | 2,016 | 1,949 | 2,085 | 1,958 | 2,318 | 726 | 733 | 741 | 748 | 726 | 726 | 726 |
| Kanawha | 2,518 | 2,475 | 2,558 | 2,643 | 2,762 | 2,683 | 2,611 | 2,637 | 2,663 | 2,690 | 2,611 | 2,611 | 2,611 |
| Lewis | 309 | 342 | 354 | 380 | 338 | 334 | 354 | 358 | 361 | 365 | 354 | 354 | 354 |
| Mingo | 83 | 85 | 67 | 76 | 76 | 72 | 75 | 76 | 77 | 77 | 75 | 75 | 75 |
| Monongalia | 841 | 1,135 | 1,220 | 1,210 | 1,222 | 1,294 | 1,341 | 1,354 | 1,368 | 1,382 | 1,341 | 1,341 | 1,341 |
| Pocahontas | 2 | 3 | 19 | 3 | 5 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Preston | 146 | 177 | 175 | 151 | 132 | 128 | 161 | 163 | 164 | 166 | 161 | 161 | 161 |
| Raleigh | 1,002 | 984 | 992 | 817 | 781 | 767 | 938 | 947 | 957 | 966 | 938 | 938 | 938 |
| Wood | 651 | 735 | 813 | 805 | 797 | 770 | 799 | 807 | 815 | 823 | 799 | 799 | 799 |
| TOTALS | 11,805 | 12,384 | 12,639 | 11,074 | 10,709 | 11,462 | 11,109 | 11,220 | 11,332 | 11,446 | 11,109 | 11,109 | 11,109 |

Table R-9 Per Employee water use for the Recreation water use category by county, presented in millions of gallons per year.

| County | Per Employee Withdrawal Rate (Mgal/yr) | | | | | | | Average Rate (Mgal/yr) |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | |
| Berkeley | 0.08 | 0.07 | 0.03 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Greenbrier | 0.45 | 0.46 | 0.47 | 0.53 | 0.48 | 0.37 | 0.22 | 0.43 |
| Hampshire | 0.04 | 0.04 | 0.06 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Hancock | 0.04 | 0.04 | 0.04 | 0.33 | 0.27 | 0.27 | 0.28 | 0.18 |
| Hardy | 0.12 | 0.08 | 0.12 | 0.12 | 0.15 | 0.12 | 0.16 | 0.12 |
| Jefferson | 0.01 | 0.02 | 0.04 | 0.03 | 0.03 | 0.02 | 0.08 | 0.03 |
| Kanawha | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Lewis | 0.07 | 0.10 | 0.11 | 0.10 | 0.11 | 0.11 | 0.08 | 0.10 |
| Mingo | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Monongalia*† | - | - | - | 0.02 | 0.02 | 0.02 | 0.004 | 0.01 |
| Pocahontas | 221.11 | 150.10 | 27.33 | 154.36 | 99.85 | 71.48 | 47.36 | 110.23 |
| Preston | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 | 0.02 |
| Raleigh | 0.11 | 0.12 | 0.17 | 0.25 | 0.22 | 0.23 | 0.18 | 0.18 |
| Wood | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| TOTALS | 222.09 | 151.09 | 28.44 | 155.90 | 101.30 | 72.79 | 48.52 | 111.44 |

* There were no withdrawals in the Monongahela Watershed in 2003, 2004, or 2005 so no employment data needed to be collected or withdrawal rate calculated. †Results rounded to additional decimal places when value was less than 0.01 million gallons.

**Table R-10 High and low scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by county for the Recreation water use sector, presented in millions of gallons per year. Projections were completed for only those counties in which there was a 2011 withdrawal in the LQU database.**

| County | Projected Withdrawals (Mgal/yr) | | | | | | Projected Consumptive Use (Mgal/yr) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | | | Low | | | High | | | Low | | |
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Berkeley | 33.96 | 34.30 | 34.64 | 33.62 | 33.62 | 33.62 | 19.19 | 19.38 | 19.57 | 18.49 | 18.49 | 18.49 |
| Greenbrier | 1,261.03 | 1,273.64 | 1,286.37 | 1,248.54 | 1,248.54 | 1,248.54 | 712.48 | 719.60 | 726.80 | 686.70 | 686.70 | 686.70 |
| Hampshire | 8.55 | 8.63 | 8.72 | 8.46 | 8.46 | 8.46 | 4.83 | 4.88 | 4.93 | 4.65 | 4.65 | 4.65 |
| Hancock | 56.16 | 56.72 | 57.29 | 55.61 | 55.61 | 55.61 | 31.73 | 32.05 | 32.37 | 30.58 | 30.58 | 30.58 |
| Hardy | 6.28 | 6.35 | 6.41 | 6.22 | 6.22 | 6.22 | 3.55 | 3.59 | 3.62 | 3.42 | 3.42 | 3.42 |
| Jefferson | 23.87 | 24.11 | 24.35 | 23.63 | 23.63 | 23.63 | 13.49 | 13.62 | 13.76 | 13.00 | 13.00 | 13.00 |
| Kanawha | 12.51 | 12.63 | 12.76 | 12.38 | 12.38 | 12.38 | 7.07 | 7.14 | 7.21 | 6.81 | 6.81 | 6.81 |
| Lewis | 34.99 | 35.34 | 35.69 | 34.64 | 34.64 | 34.64 | 19.77 | 19.97 | 20.17 | 19.05 | 19.05 | 19.05 |
| Mingo | 2.72 | 2.74 | 2.77 | 2.69 | 2.69 | 2.69 | 1.53 | 1.55 | 1.57 | 1.48 | 1.48 | 1.48 |
| Monongalia | 9.90 | 10.00 | 10.10 | 9.80 | 9.80 | 9.80 | 5.59 | 5.65 | 5.70 | 5.39 | 5.39 | 5.39 |
| Pocahontas | 890.64 | 899.54 | 908.54 | 881.82 | 881.82 | 881.82 | 503.21 | 508.24 | 513.33 | 485.00 | 485.00 | 485.00 |
| Preston | 3.68 | 3.71 | 3.75 | 3.64 | 3.64 | 3.64 | 2.08 | 2.10 | 2.12 | 2.00 | 2.00 | 2.00 |
| Raleigh | 174.80 | 176.55 | 178.31 | 173.07 | 173.07 | 173.07 | 98.76 | 99.75 | 100.75 | 95.19 | 95.19 | 95.19 |
| Wood | 7.26 | 7.34 | 7.41 | 7.19 | 7.19 | 7.19 | 4.10 | 4.15 | 4.19 | 3.96 | 3.96 | 3.96 |
| TOTALS* | 2,526 | 2,552 | 2,577 | 2,501 | 2,501 | 2,501 | 1,427 | 1,442 | 1,456 | 1,376 | 1,376 | 1,376 |

*Totals were rounded to whole numbers for display purposes.

# Appendix S

## Development of the Public Water Supply withdrawal and consumptive use scenarios

Historic Public Water Supply withdrawals in the combined Public Water Supply sector (Public Water Supply SIC category from the LQU database) by watershed and by county can be found in **Table S-1** and **Table S-6**, respectively. Historic estimates of both High and Low Consumptive Use scenarios can be found by watershed and county in **Table S-2** and **Table S-7**, respectively. Results are shown in tenths or hundredths of billion or million gallons for display purposes.

## Public Water Supply Watershed Withdrawal and Consumptive Use Method

### Past withdrawal by HUC8

1. Sum withdrawals by HUC8.

   Note: There are no Public Water Supply withdrawals for Shenandoah Hardy, James, and Dunkard HUC8s.

### Past population by HUC8

2. Sum 2000 U.S. Census block data by HUC8.

   Note: The boundaries of the block and watershed geospatial files are not identical, creating boundary slivers. Census blocks that fall outside of a watershed boundary were manually attributed to the appropriate HUC. Census blocks that cross HUC8 boundaries were area weighted to divide populations between HUC8s.

3. Sum 2010 block data by HUC8.

   Note: DEP watershed assignments were used for the census blocks. These watershed assignments were developed using different assumptions than described in step 2 above.

4. Interpolate between 2000 and 2010 HUC8 population data to get population estimates for 2003, 2004, 2005, 2008, 2009 (corresponding to years for which withdrawal data is available in the LQU database).
   a. Population2003 = Population2000+(2003-2000)*((Population2010 -Population2000) /(2010-2000))
5. Extrapolate from the 2000 and 2010 population data to get a block population estimate for 2011. a. Population2011 = Population2000+(2011-2000)*((Population2010-Population2000)/(2010-2000))

### Per capita withdrawal rate by HUC8

6. Divide HUC8 withdrawals by HUC8 population to obtain the per capita withdrawal by HUC8.
   a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011, using each year's corresponding withdrawal and population data (estimation methods described above).
   b. Average the per capita withdrawal for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 to obtain one value for each watershed.

### Future population by HUC8

7. Calculate change rate in county population projections for 2020 and 2030 (Cristiadi 2011).

   Note: The rate of change was calculated to 4 decimal places so that counties with small population changes would not appear to have a 0 rate of change.

   a. (2020-2010)/2010

b. (2030-2020)/2020

8. Extrapolate county change rate in 2020 and 2030 for 2040.

   Note: The rate of change was calculated to 4 decimal places so that counties with small population changes would not appear to have a 0 rate of change.

   a. (2030-2020)+2030
9. Apply these county rates of change to the 2010 block data to get population projections in 2020, 2030, and 2040 by block.
10. Sum the projected block populations by HUC8 for 2020, 2030, and 2040 using the DEP watershed designations for the blocks.

### Future withdrawal by HUC8

11. Multiply average HUC8 per capita withdrawal rate (from step 6b) by HUC8 population in 2020, 2030, and 2040 (from step 10).

### Future consumptive use estimates by HUC8

12. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficient.
    a. High scenario – 20% (Shaffer and Runkle 2007)
13. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficient.
    a. Low scenario – 15% (Shaffer and Runkle 2007)

## Public Water Supply County Withdrawal and Consumptive Use Method

### Past withdrawal by county

1. Sum withdrawals by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.

   Note: There is no Public Water Supply withdrawal for Wirt County.

### Past population by county

2. Interpolate between 2000 and 2010 county population data to get population estimates for 2003, 2004, 2005, 2008, 2009 (corresponding to years for which withdrawal data is available in the LQU database)
   a. Population2003 = Population2000+(2003-2000)*((Population2010- Population2000)/(2010-2000))
3. Extrapolate from the 2000 and 2010 population data to get a county population estimate for 2011
   a. Population2011 = Population2000+ (2011-2000) * ((Population2010 - Population2000) / (2010-2000))

### Per capita withdrawal rate by County

4. Divide county withdrawals by county population to obtain the per capita withdrawal by county. a. Do for 2003, 2004, 2005, 2008, 2009, 2010, and 2011, using each year's corresponding
   withdrawal and population data (estimation methods described above).
   b. Average the per capita withdrawal for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 to obtain one value for each county.

### Future population by county

5. Calculate change rate in county population projections for 2020 and 2030 (Cristiadi 2011).
   Note: The rate of change was calculated to 4 decimal places so that counties with small population changes would not appear to have a 0 rate of change.
   a. (2020-2010)/2010
   b. (2030-2020)/2
6. Extrapolate county change rate in 2020 and 2030 for 2040
   Note: The rate of change was calculated to 4 decimal places so that counties with small population changes would not appear to have a 0 rate of change.
   a. (2030-2020)+2030
   b. (2030-2020)+2030
7. Apply these county rates of change to the 2010 census data to get population projections in 2020, 2030, and 2040 by county.

### Future withdrawal by county

8. Multiply average county per capita withdrawal rate (from step 4b) by county population in 2020, 2030, and 2040 (from step 7)

### Future consumptive use estimates by county

9. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by the consumptive use coefficients.
   a. High scenario – 20% (Shaffer and Runkle 2007)
10. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by the consumptive use coefficients.
   a. Low scenario – 15% (Shaffer and Runkle 2007)

**The following tables provide results at the county and watershed (HUC8) levels. The results at the county scale are not comparable to the results at the watershed scale due to differences in the estimation methodologies described above.**

**Table S-1 Public Water Supply withdrawals by watershed, presented in billions of gallons per year.**

| HUC 8* | Historical Withdrawals (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Big Sandy | 0.83 | 0.92 | 0.96 | 0.90 | 0.76 | 0.88 | 0.88 |
| Cacapon | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.06 |
| Cheat | 0.62 | 0.65 | 0.69 | 0.78 | 0.74 | 0.74 | 0.75 |
| Coal | 0.36 | 0.61 | 0.68 | 0.63 | 0.63 | 0.67 | 0.65 |
| Elk | 12.12 | 12.03 | 11.96 | 11.97 | 11.98 | 11.96 | 11.97 |
| Gauley | 1.14 | 1.08 | 1.19 | 1.17 | 1.13 | 1.13 | 1.15 |
| Greenbrier | 1.09 | 1.12 | 1.25 | 1.18 | 1.06 | 1.20 | 1.27 |
| Little Kanawha | 1.07 | 1.14 | 1.14 | 1.14 | 1.21 | 1.21 | 1.22 |
| Lower Guyandotte | 0.83 | 0.91 | 0.89 | 1.65 | 1.07 | 1.07 | 1.04 |
| Lower Kanawha | 0.90 | 0.81 | 0.85 | 0.98 | 0.88 | 0.88 | 0.88 |
| Lower New | 4.23 | 4.28 | 4.38 | 4.42 | 4.32 | 4.42 | 4.39 |
| Lower Ohio | 4.86 | 4.78 | 5.01 | 4.91 | 4.93 | 4.95 | 4.96 |
| Middle Ohio North | 1.40 | 1.45 | 1.49 | 1.46 | 1.44 | 1.38 | 1.39 |
| Middle Ohio South | 3.54 | 3.57 | 3.45 | 3.26 | 3.28 | 3.40 | 8.10 |
| Monongahela | 7.60 | 7.45 | 7.47 | 7.51 | 3.82 | 3.74 | 3.73 |
| North Branch Potomac | 0.52 | 0.52 | 0.55 | 0.74 | 0.68 | 0.74 | 0.73 |
| Potomac Direct Drains | 4.26 | 5.20 | 4.09 | 4.81 | 4.49 | 3.40 | 3.45 |
| Shenandoah Jefferson | 0.56 | 0.62 | 0.65 | 0.69 | 0.69 | 0.75 | 0.71 |
| South Branch Potomac | 1.82 | 2.00 | 2.05 | 1.98 | 1.92 | 1.95 | 1.94 |
| Tug Fork | 2.60 | 2.49 | 2.63 | 2.75 | 2.17 | 2.65 | 2.63 |
| Twelvepole | 0.19 | 0.20 | 0.22 | 0.21 | 0.21 | 0.21 | 0.21 |
| Tygart Valley | 5.55 | 6.10 | 5.86 | 6.25 | 5.80 | 6.19 | 6.21 |
| Upper Guyandotte | 1.43 | 1.44 | 1.41 | 1.26 | 1.32 | 1.34 | 1.34 |
| Upper Kanawha | 1.25 | 1.30 | 1.26 | 1.27 | 1.27 | 1.27 | 1.25 |
| Upper New | 2.46 | 2.48 | 2.66 | 2.66 | 2.57 | 2.64 | 2.51 |
| Upper Ohio North | 1.75 | 2.03 | 1.94 | 1.92 | 1.93 | 2.00 | 2.03 |
| Upepr Ohio South | 3.90 | 3.86 | 3.98 | 3.84 | 3.85 | 3.87 | 3.92 |
| West Fork | 3.14 | 3.18 | 3.05 | 3.14 | 3.13 | 3.11 | 3.08 |
| Youghiogheny | 0.10 | 0.12 | 0.12 | 0.10 | 0.10 | 0.10 | 0.07 |
| TOTALS | 70.18 | 72.40 | 71.94 | 73.64 | 67.44 | 67.92 | 72.52 |

* Watersheds with no Public Water Supply withdrawals recorded in the LQU database are not listed (Dunkard, James, and Shenandoah Hardy Watersheds).

**Table S-2 Public Water Supply consumptive use scenario estimates by watershed, presented in millions of gallons per year.**

| HUC 8* | HIGH Consumptive Use (Mgal/yr) | | | | | | | LOW Consumptive Use (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Big Sandy | 166.42 | 183.39 | 191.57 | 180.46 | 152.26 | 175.74 | 175.74 | 124.81 | 137.55 | 143.68 | 135.35 | 114.19 | 131.81 | 131.81 |
| Cacapon | 12.65 | 11.76 | 11.32 | 12.53 | 12.59 | 13.32 | 12.81 | 9.49 | 8.82 | 8.49 | 9.40 | 9.44 | 9.99 | 9.61 |
| Cheat | 124.55 | 130.86 | 137.58 | 155.16 | 148.80 | 148.88 | 149.09 | 93.42 | 98.15 | 103.19 | 116.37 | 111.60 | 111.66 | 111.82 |
| Coal | 71.89 | 121.82 | 136.65 | 125.85 | 126.41 | 134.73 | 130.29 | 53.92 | 91.37 | 102.49 | 94.38 | 94.81 | 101.05 | 97.72 |
| Elk | 2,424.80 | 2,405.86 | 2,392.10 | 2,393.72 | 2,396.14 | 2,392.62 | 2,393.81 | 1,818.60 | 1,804.39 | 1,794.08 | 1,795.29 | 1,797.10 | 1,794.46 | 1,795.36 |
| Gauley | 228.22 | 215.19 | 237.03 | 234.33 | 225.94 | 225.55 | 229.14 | 171.17 | 161.39 | 177.77 | 175.75 | 169.45 | 169.16 | 171.86 |
| Greenbrier | 218.72 | 224.81 | 249.78 | 236.74 | 211.99 | 240.49 | 254.72 | 164.04 | 168.61 | 187.33 | 177.55 | 159.00 | 180.37 | 191.04 |
| Little Kanawha | 213.45 | 228.00 | 228.66 | 228.72 | 242.66 | 241.91 | 244.96 | 160.09 | 171.00 | 171.50 | 171.54 | 182.00 | 181.43 | 183.72 |
| Lower Guyandotte | 165.58 | 182.74 | 178.62 | 329.45 | 213.21 | 213.21 | 208.65 | 124.18 | 137.06 | 133.96 | 247.09 | 159.90 | 159.90 | 156.49 |
| Lower Kanawha | 179.74 | 162.49 | 170.83 | 195.93 | 175.35 | 175.35 | 175.35 | 134.81 | 121.87 | 128.12 | 146.94 | 131.51 | 131.51 | 131.51 |
| Lower New | 845.64 | 855.22 | 876.39 | 883.73 | 864.31 | 883.42 | 878.87 | 634.23 | 641.41 | 657.30 | 662.79 | 648.24 | 662.56 | 659.15 |
| Lower Ohio | 971.15 | 956.48 | 1,002.80 | 982.31 | 986.73 | 989.40 | 992.44 | 728.36 | 717.36 | 752.10 | 736.73 | 740.05 | 742.05 | 744.33 |
| Middle Ohio North | 280.59 | 290.95 | 297.81 | 292.04 | 287.25 | 275.90 | 277.97 | 210.44 | 218.21 | 223.36 | 219.03 | 215.44 | 206.92 | 208.48 |
| Middle Ohio South | 708.79 | 713.81 | 690.05 | 651.65 | 655.95 | 680.82 | 1,619.52 | 531.59 | 535.36 | 517.54 | 488.74 | 491.97 | 510.61 | 1,214.64 |
| Monongahela | 1,520.10 | 1,489.49 | 1,493.68 | 1,501.09 | 764.97 | 748.18 | 746.33 | 1,140.07 | 1,117.12 | 1,120.26 | 1,125.82 | 573.73 | 561.13 | 559.75 |
| North Branch Potomac | 104.56 | 103.38 | 109.53 | 148.90 | 135.56 | 148.56 | 146.65 | 78.42 | 77.53 | 82.15 | 111.68 | 101.67 | 111.42 | 109.99 |
| Potomac Direct Drains | 852.25 | 1,041.00 | 817.36 | 961.68 | 897.39 | 679.77 | 690.01 | 639.19 | 780.75 | 613.02 | 721.26 | 673.04 | 509.82 | 517.51 |
| Shenandoah Jefferson | 112.71 | 124.28 | 130.84 | 138.48 | 138.46 | 150.54 | 142.93 | 84.53 | 93.21 | 98.13 | 103.86 | 103.85 | 112.90 | 107.20 |
| South Branch Potomac | 364.65 | 399.38 | 410.41 | 395.52 | 383.22 | 390.15 | 387.07 | 273.49 | 299.54 | 307.80 | 296.64 | 287.41 | 292.61 | 290.30 |
| Tug Fork | 519.18 | 498.52 | 526.53 | 549.58 | 433.45 | 529.65 | 526.70 | 389.38 | 373.89 | 394.90 | 412.19 | 325.09 | 397.23 | 395.02 |
| Twelvepole | 38.73 | 40.96 | 44.99 | 41.56 | 41.56 | 41.56 | 41.56 | 29.05 | 30.72 | 33.75 | 31.17 | 31.17 | 31.17 | 31.17 |
| Tygart Valley | 1,109.03 | 1,220.99 | 1,172.37 | 1,250.00 | 1,159.84 | 1,238.99 | 1,242.44 | 831.77 | 915.74 | 879.28 | 937.50 | 869.88 | 929.25 | 931.83 |
| Upper Guyandotte | 285.45 | 288.31 | 281.67 | 251.73 | 264.15 | 267.57 | 267.16 | 214.09 | 216.23 | 211.25 | 188.80 | 198.12 | 200.68 | 200.37 |
| Upper Kanawha | 249.56 | 260.21 | 251.45 | 254.17 | 253.31 | 253.73 | 250.96 | 187.17 | 195.16 | 188.59 | 190.63 | 189.98 | 190.30 | 188.22 |
| Upper New | 491.73 | 495.97 | 531.06 | 532.99 | 514.99 | 528.77 | 502.72 | 368.80 | 371.98 | 398.29 | 399.75 | 386.24 | 396.58 | 377.04 |
| Upper Ohio North | 350.26 | 406.08 | 388.91 | 384.97 | 386.70 | 399.65 | 406.59 | 262.70 | 304.56 | 291.69 | 288.73 | 290.03 | 299.74 | 304.94 |
| Upper Ohio South | 779.08 | 772.22 | 795.55 | 767.70 | 770.34 | 773.35 | 783.11 | 584.31 | 579.16 | 596.66 | 575.77 | 577.76 | 580.01 | 587.33 |
| West Fork | 628.08 | 636.70 | 610.76 | 628.35 | 626.51 | 621.41 | 615.93 | 471.06 | 477.53 | 458.07 | 471.27 | 469.88 | 466.06 | 461.94 |
| Youghiogheny | 20.85 | 23.69 | 24.49 | 19.42 | 20.96 | 19.80 | 14.61 | 15.64 | 17.77 | 18.37 | 14.57 | 15.72 | 14.85 | 10.96 |
| TOTALS† | 14,038 | 14,485 | 14,391 | 14,729 | 13,491 | 13,583 | 14,508 | 10,529 | 10,863 | 10,793 | 11,047 | 10,118 | 10,187 | 10,881 |

* Watersheds with no Public Water Supply withdrawals recorded in the LQU database are not listed (Dunkard, James, and Shenandoah Hardy Watersheds). † Totals were rounded to whole numbers for display purposes.

**Table S-3 The past and projected population by watershed. Note that the totals between the county and watershed population tables are slightly different due to assumptions made to apportion population numbers.**

| HUC 8* | Population | | | | | | | Population Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 |
| Big Sandy | 6,825 | 6,838 | 6,850 | 6,887 | 6,900 | 6,912 | 6,924 | 6,757 | 6,398 | 5,860 |
| Cacapon | 21,997 | 22,376 | 22,755 | 23,891 | 24,270 | 24,649 | 25,028 | 27,216 | 28,599 | 28,529 |
| Cheat | 35,032 | 35,516 | 36,000 | 37,452 | 37,936 | 38,420 | 38,904 | 39,917 | 40,765 | 41,071 |
| Coal | 58,067 | 57,927 | 57,788 | 57,368 | 57,229 | 57,089 | 56,949 | 56,122 | 53,952 | 50,699 |
| Elk | 59,752 | 59,505 | 59,259 | 58,520 | 58,273 | 58,027 | 57,781 | 56,382 | 53,925 | 50,738 |
| Gauley | 42,617 | 42,510 | 42,403 | 42,082 | 41,975 | 41,868 | 41,761 | 41,970 | 40,936 | 38,804 |
| Greenbrier | 43,564 | 43,627 | 43,690 | 43,878 | 43,941 | 44,004 | 44,067 | 44,575 | 43,498 | 40,827 |
| Little Kanawha | 100,942 | 100,983 | 101,024 | 101,146 | 101,187 | 101,228 | 101,269 | 101,051 | 98,023 | 92,351 |
| Lower Guyandotte | 85,984 | 86,156 | 86,328 | 86,843 | 87,014 | 87,186 | 87,358 | 86,134 | 83,922 | 80,708 |
| Lower Kanawha | 161,361 | 161,481 | 161,602 | 161,964 | 162,084 | 162,205 | 162,326 | 163,928 | 161,885 | 156,035 |
| Lower New | 93,586 | 93,743 | 93,901 | 94,373 | 94,531 | 94,688 | 94,846 | 94,595 | 92,150 | 87,471 |
| Lower Ohio | 55,728 | 55,490 | 55,253 | 54,539 | 54,301 | 54,063 | 53,825 | 53,947 | 53,477 | 52,673 |
| Middle Ohio North | 41,827 | 41,791 | 41,756 | 41,648 | 41,612 | 41,576 | 41,540 | 39,672 | 36,333 | 31,875 |
| Middle Ohio South | 76,795 | 76,918 | 77,042 | 77,411 | 77,535 | 77,658 | 77,781 | 79,401 | 79,097 | 76,703 |
| Monongahela | 112,630 | 113,892 | 115,155 | 118,942 | 120,205 | 121,467 | 122,730 | 131,294 | 142,568 | 155,815 |
| North Branch Potomac | 30,789 | 30,918 | 31,047 | 31,434 | 31,563 | 31,692 | 31,821 | 32,709 | 32,689 | 31,602 |
| Potomac Direct Drains | 116,838 | 120,258 | 123,678 | 133,939 | 137,359 | 140,779 | 144,199 | 170,595 | 202,136 | 234,314 |
| Shenandoah Jefferson | 26,392 | 27,119 | 27,846 | 30,027 | 30,754 | 31,481 | 32,208 | 36,864 | 41,875 | 46,096 |
| South Branch Potomac | 30,624 | 30,775 | 30,927 | 31,380 | 31,531 | 31,682 | 31,833 | 33,022 | 33,116 | 31,866 |
| Tug Fork | 53,154 | 52,488 | 51,822 | 49,823 | 49,157 | 48,491 | 47,825 | 45,321 | 41,277 | 36,598 |
| Twelvepole | 30,141 | 30,127 | 30,113 | 30,070 | 30,056 | 30,042 | 30,028 | 29,341 | 27,799 | 25,530 |
| Tygart Valley | 86,406 | 86,797 | 87,188 | 88,362 | 88,753 | 89,144 | 89,535 | 92,142 | 92,373 | 89,745 |
| Upper Guyandotte | 54,712 | 54,292 | 53,872 | 52,612 | 52,192 | 51,772 | 51,352 | 49,087 | 45,208 | 40,403 |
| Upper Kanawha | 65,833 | 65,324 | 64,816 | 63,289 | 62,781 | 62,272 | 61,763 | 61,527 | 59,687 | 56,833 |
| Upper New | 75,699 | 75,692 | 75,685 | 75,663 | 75,656 | 75,649 | 75,642 | 74,573 | 72,188 | 68,593 |
| Upper Ohio North | 46,969 | 46,696 | 46,424 | 45,605 | 45,332 | 45,059 | 44,786 | 42,660 | 39,340 | 35,312 |
| Upepr Ohio South | 93,772 | 93,142 | 92,513 | 90,624 | 89,995 | 89,365 | 88,736 | 85,092 | 79,536 | 72,994 |
| West Fork | 103,280 | 103,425 | 103,571 | 104,008 | 104,153 | 104,299 | 104,445 | 106,039 | 105,759 | 103,415 |
| Youghiogheny | 3,771 | 3,795 | 3,820 | 3,893 | 3,918 | 3,942 | 3,967 | 4,014 | 3,970 | 3,810 |
| TOTALS | 1,815,087 | 1,819,601 | 1,824,128 | 1,837,673 | 1,842,193 | 1,846,709 | 1,851,229 | 1,885,947 | 1,892,481 | 1,867,270 |

* Watersheds with no Public Water Supply withdrawals recorded in the LQU database are not listed (Dunkard, James, and Shenandoah Hardy Watersheds).

**Table S-4 Per capita Public Water Supply withdrawal by watershed. Results rounded to the hundredths of thousand gallons for display purposes.**

| HUC 8* | Per Capita Withdrawal Rate (kgal/yr) | | | | | | | Average Rate (kgal/yr) |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | |
| Big Sandy | 121.92 | 134.10 | 139.83 | 131.02 | 110.33 | 127.13 | 126.91 | 127.32 |
| Cacapon | 2.88 | 2.63 | 2.49 | 2.62 | 2.59 | 2.70 | 2.56 | 2.64 |
| Cheat | 17.78 | 18.42 | 19.11 | 20.71 | 19.61 | 19.38 | 19.16 | 19.17 |
| Coal | 6.19 | 10.52 | 11.82 | 10.97 | 11.04 | 11.80 | 11.44 | 10.54 |
| Elk | 202.90 | 202.16 | 201.83 | 204.52 | 205.60 | 206.16 | 207.15 | 204.33 |
| Gauley | 26.78 | 25.31 | 27.95 | 27.84 | 26.91 | 26.94 | 27.44 | 27.02 |
| Greenbrier | 25.10 | 25.76 | 28.59 | 26.98 | 24.12 | 27.33 | 28.90 | 26.68 |
| Little Kanawha | 10.57 | 11.29 | 11.32 | 11.31 | 11.99 | 11.95 | 12.09 | 11.50 |
| Lower Guyandotte | 9.63 | 10.61 | 10.35 | 18.97 | 12.25 | 12.23 | 11.94 | 12.28 |
| Lower Kanawha | 5.57 | 5.03 | 5.29 | 6.05 | 5.41 | 5.41 | 5.40 | 5.45 |
| Lower New | 45.18 | 45.61 | 46.67 | 46.82 | 45.72 | 46.65 | 46.33 | 46.14 |
| Lower Ohio | 87.13 | 86.19 | 90.75 | 90.06 | 90.86 | 91.50 | 92.19 | 89.81 |
| Middle Ohio North | 33.54 | 34.81 | 35.66 | 35.06 | 34.52 | 33.18 | 33.46 | 34.32 |
| Middle Ohio South | 46.15 | 46.40 | 44.78 | 42.09 | 42.30 | 43.83 | 104.11 | 52.81 |
| Monongahela | 67.48 | 65.39 | 64.86 | 63.10 | 31.82 | 30.80 | 30.41 | 50.55 |
| North Branch Potomac | 16.98 | 16.72 | 17.64 | 23.68 | 21.47 | 23.44 | 23.04 | 20.43 |
| Potomac Direct Drains | 36.47 | 43.28 | 33.04 | 35.90 | 32.67 | 24.14 | 23.93 | 32.78 |
| Shenandoah Jefferson | 21.35 | 22.91 | 23.49 | 23.06 | 22.51 | 23.91 | 22.19 | 22.78 |
| South Branch Potomac | 59.54 | 64.89 | 66.35 | 63.02 | 60.77 | 61.57 | 60.80 | 62.42 |
| Tug Fork | 48.84 | 47.49 | 50.80 | 55.15 | 44.09 | 54.61 | 55.06 | 50.86 |
| Twelvepole | 6.43 | 6.80 | 7.47 | 6.91 | 6.91 | 6.92 | 6.92 | 6.91 |
| Tygart Valley | 64.18 | 70.34 | 67.23 | 70.73 | 65.34 | 69.49 | 69.38 | 68.10 |
| Upper Guyandotte | 26.09 | 26.55 | 26.14 | 23.92 | 25.31 | 25.84 | 26.01 | 25.69 |
| Upper Kanawha | 18.95 | 19.92 | 19.40 | 20.08 | 20.17 | 20.37 | 20.32 | 19.89 |
| Upper New | 32.48 | 32.76 | 35.08 | 35.22 | 34.03 | 34.95 | 33.23 | 33.97 |
| Upper Ohio North | 37.29 | 43.48 | 41.89 | 42.21 | 42.65 | 44.35 | 45.39 | 42.46 |
| Upepr Ohio South | 41.54 | 41.45 | 43.00 | 42.36 | 42.80 | 43.27 | 44.13 | 42.65 |
| West Fork | 30.41 | 30.78 | 29.49 | 30.21 | 30.08 | 29.79 | 29.49 | 30.03 |
| Youghiogheny | 27.64 | 31.22 | 32.06 | 24.94 | 26.74 | 25.12 | 18.42 | 26.59 |
| TOTALS† | 1,177 | 1,223 | 1,234 | 1,236 | 1,151 | 1,185 | 1,238 | 1,206 |

* Watersheds with no Public Water Supply withdrawals recorded in the LQU database are not listed (Dunkard, James, and Shenandoah Hardy Watersheds). † Totals were rounded to whole numbers for display purposes.

**Table S-5 Projected withdrawals and high and low consumptive use estimates by watershed in 2020, 2030, and 2040 for the Public Water Supply water use sector. Results are shown in hundredths of billion gallons for display purposes.**

| HUC 8* | Withdrawal (Bgal/yr) | | | HIGH Consumptive Use Scenario (Bgal/yr) | | | LOW Consumptive Use Scenario (Bgal/yr) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Big Sandy | 0.86 | 0.81 | 0.75 | 0.17 | 0.16 | 0.15 | 0.13 | 0.12 | 0.11 |
| Cacapon | 0.07 | 0.08 | 0.08 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| Cheat | 0.77 | 0.78 | 0.79 | 0.15 | 0.16 | 0.16 | 0.11 | 0.12 | 0.12 |
| Coal | 0.59 | 0.57 | 0.53 | 0.12 | 0.11 | 0.11 | 0.09 | 0.09 | 0.08 |
| Elk | 11.52 | 11.02 | 10.37 | 2.30 | 2.20 | 2.07 | 1.73 | 1.65 | 1.56 |
| Gauley | 1.13 | 1.11 | 1.05 | 0.23 | 0.22 | 0.21 | 0.17 | 0.17 | 0.16 |
| Greenbrier | 1.19 | 1.16 | 1.09 | 0.24 | 0.23 | 0.22 | 0.18 | 0.17 | 0.16 |
| Little Kanawha | 1.16 | 1.13 | 1.06 | 0.23 | 0.23 | 0.21 | 0.17 | 0.17 | 0.16 |
| Lower Guyandotte | 1.06 | 1.03 | 0.99 | 0.21 | 0.21 | 0.20 | 0.16 | 0.15 | 0.15 |
| Lower Kanawha | 0.89 | 0.88 | 0.85 | 0.18 | 0.18 | 0.17 | 0.13 | 0.13 | 0.13 |
| Lower New | 4.36 | 4.25 | 4.04 | 0.87 | 0.85 | 0.81 | 0.65 | 0.64 | 0.61 |
| Lower Ohio | 4.84 | 4.80 | 4.73 | 0.97 | 0.96 | 0.95 | 0.73 | 0.72 | 0.71 |
| Middle Ohio North | 1.36 | 1.25 | 1.09 | 0.27 | 0.25 | 0.22 | 0.20 | 0.19 | 0.16 |
| Middle Ohio South | 4.19 | 4.18 | 4.05 | 0.84 | 0.84 | 0.81 | 0.63 | 0.63 | 0.61 |
| Monongahela | 6.64 | 7.21 | 7.88 | 1.33 | 1.44 | 1.58 | 1.00 | 1.08 | 1.18 |
| North Branch Potomac | 0.67 | 0.67 | 0.65 | 0.13 | 0.13 | 0.13 | 0.10 | 0.10 | 0.10 |
| Potomac Direct Drains | 5.59 | 6.63 | 7.68 | 1.12 | 1.33 | 1.54 | 0.84 | 0.99 | 1.15 |
| Shenandoah Jefferson | 0.84 | 0.95 | 1.05 | 0.17 | 0.19 | 0.21 | 0.13 | 0.14 | 0.16 |
| South Branch Potomac | 2.06 | 2.07 | 1.99 | 0.41 | 0.41 | 0.40 | 0.31 | 0.31 | 0.30 |
| Tug Fork | 2.31 | 2.10 | 1.86 | 0.46 | 0.42 | 0.37 | 0.35 | 0.31 | 0.28 |
| Twelvepole | 0.20 | 0.19 | 0.18 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| Tygart Valley | 6.27 | 6.29 | 6.11 | 1.25 | 1.26 | 1.22 | 0.94 | 0.94 | 0.92 |
| Upper Guyandotte | 1.26 | 1.16 | 1.04 | 0.25 | 0.23 | 0.21 | 0.19 | 0.17 | 0.16 |
| Upper Kanawha | 1.22 | 1.19 | 1.13 | 0.24 | 0.24 | 0.23 | 0.18 | 0.18 | 0.17 |
| Upper New | 2.53 | 2.45 | 2.33 | 0.51 | 0.49 | 0.47 | 0.38 | 0.37 | 0.35 |
| Upper Ohio North | 1.81 | 1.67 | 1.50 | 0.36 | 0.33 | 0.30 | 0.27 | 0.25 | 0.22 |
| Upper Ohio South | 3.63 | 3.39 | 3.11 | 0.73 | 0.68 | 0.62 | 0.54 | 0.51 | 0.47 |
| West Fork | 3.18 | 3.18 | 3.11 | 0.64 | 0.64 | 0.62 | 0.48 | 0.48 | 0.47 |
| Youghiogheny | 0.11 | 0.11 | 0.10 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| TOTALS | 72.31 | 72.31 | 71.19 | 14.45 | 14.47 | 14.27 | 10.85 | 10.84 | 10.71 |

* Watersheds with no Public Water Supply withdrawals recorded in the LQU database are not listed (Dunkard, James, and Shenandoah Hardy Watersheds).

**Table S-6 Public Water Supply withdrawals by county, presented in billions of gallons per year.**

| County* | Historical Withdrawals (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Barbour | 0.40 | 0.35 | 0.42 | 0.47 | 0.50 | 0.49 | 0.49 |
| Berkeley | 3.69 | 4.54 | 3.41 | 4.14 | 3.88 | 2.99 | 3.07 |
| Boone | 0.07 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 |
| Braxton | 0.35 | 0.34 | 0.35 | 0.37 | 0.38 | 0.38 | 0.38 |
| Brooke | 1.77 | 2.02 | 1.95 | 1.91 | 1.92 | 1.98 | 1.99 |
| Cabell | 4.82 | 4.76 | 4.96 | 4.85 | 4.85 | 4.85 | 4.85 |
| Calhoun | 0.11 | 0.11 | 0.10 | 0.11 | 0.12 | 0.13 | 0.12 |
| Clay | 0.15 | 0.12 | 0.14 | 0.17 | 0.18 | 0.17 | 0.17 |
| Doddridge | 0.06 | 0.05 | 0.06 | 0.05 | 0.05 | 0.05 | 0.06 |
| Fayette | 1.89 | 1.93 | 1.91 | 2.04 | 1.94 | 2.02 | 2.01 |
| Gilmer | 0.14 | 0.20 | 0.22 | 0.19 | 0.22 | 0.24 | 0.22 |
| Grant | 0.40 | 0.39 | 0.39 | 0.39 | 0.36 | 0.38 | 0.38 |
| Greenbrier | 0.94 | 0.96 | 1.08 | 1.05 | 0.92 | 1.07 | 1.15 |
| Hampshire | 0.21 | 0.19 | 0.21 | 0.23 | 0.21 | 0.22 | 0.21 |
| Hancock | 0.30 | 0.31 | 0.31 | 0.32 | 0.31 | 0.31 | 0.34 |
| Hardy | 1.22 | 1.38 | 1.45 | 1.35 | 1.35 | 1.35 | 1.35 |
| Harrison | 2.68 | 2.69 | 2.57 | 2.65 | 2.65 | 2.65 | 2.65 |
| Jackson | 0.60 | 0.62 | 0.63 | 0.62 | 0.66 | 0.68 | 0.65 |
| Jefferson | 0.92 | 1.02 | 1.12 | 1.11 | 1.10 | 0.98 | 0.94 |
| Kanawha | 12.19 | 12.41 | 12.34 | 12.27 | 12.27 | 12.32 | 12.27 |
| Lewis | 0.46 | 0.49 | 0.48 | 0.49 | 0.48 | 0.46 | 0.43 |
| Lincoln | 0.13 | 0.13 | 0.14 | 0.13 | 0.13 | 0.13 | 0.11 |
| Logan | 1.19 | 1.28 | 1.18 | 1.98 | 1.47 | 1.40 | 1.40 |
| Marion | 2.79 | 2.74 | 2.83 | 3.24 | 2.85 | 3.07 | 3.08 |
| Marshall | 1.05 | 1.08 | 1.17 | 1.05 | 1.06 | 1.08 | 1.12 |
| Mason | 0.80 | 0.83 | 0.85 | 0.87 | 0.90 | 0.94 | 0.91 |
| McDowell† | 0.89 | 0.86 | 0.96 | 0.93 | 0.95 | 0.97 | 0.96 |
| Mercer | 1.48 | 1.44 | 1.62 | 1.56 | 1.47 | 1.54 | 1.41 |
| Mineral‡ | 0.43 | 0.41 | 0.43 | 0.61 | 0.54 | 0.63 | 0.64 |
| Mingo | 1.36 | 1.34 | 1.36 | 1.57 | 0.96 | 1.42 | 1.44 |
| Monongalia | 7.34 | 7.18 | 7.19 | 7.24 | 3.62 | 3.62 | 3.62 |
| Monroe | 0.29 | 0.28 | 0.30 | 0.29 | 0.30 | 0.30 | 0.30 |
| Morgan | 0.23 | 0.29 | 0.22 | 0.26 | 0.21 | 0.20 | 0.17 |
| Nicholas | 0.89 | 0.84 | 0.94 | 0.89 | 0.85 | 0.85 | 0.87 |
| Ohio | 2.49 | 2.45 | 2.48 | 2.47 | 2.47 | 2.47 | 2.47 |

**Table S-6, cont. Public Water Supply withdrawals by county, presented in billions of gallons per year.**

| County*, cont. | Historical Withdrawals (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Pendleton | 0.14 | 0.16 | 0.13 | 0.14 | 0.13 | 0.12 | 0.11 |
| Pleasants | 0.24 | 0.30 | 0.29 | 0.27 | 0.27 | 0.27 | 0.27 |
| Pocahontas | 0.13 | 0.12 | 0.13 | 0.14 | 0.14 | 0.14 | 0.13 |
| Preston | 0.57 | 0.63 | 0.67 | 0.71 | 0.65 | 0.65 | 0.63 |
| Putnam | 0.85 | 0.77 | 0.81 | 0.93 | 0.83 | 0.83 | 0.83 |
| Raleigh | 3.34 | 3.39 | 3.50 | 3.40 | 3.40 | 3.41 | 3.39 |
| Randolph | 1.00 | 1.67 | 1.26 | 1.19 | 1.09 | 1.19 | 1.19 |
| Ritchie | 0.14 | 0.16 | 0.15 | 0.15 | 0.16 | 0.15 | 0.19 |
| Roane | 0.25 | 0.25 | 0.24 | 0.27 | 0.29 | 0.27 | 0.27 |
| Summers | 0.99 | 1.06 | 1.05 | 1.01 | 1.01 | 1.01 | 1.01 |
| Taylor | 0.71 | 0.72 | 0.70 | 0.71 | 0.71 | 0.69 | 0.70 |
| Tucker | 0.26 | 0.26 | 0.26 | 0.28 | 0.26 | 0.27 | 0.27 |
| Tyler | 0.16 | 0.16 | 0.21 | 0.20 | 0.19 | 0.15 | 0.14 |
| Upshur | 0.77 | 0.77 | 0.80 | 0.78 | 0.78 | 0.78 | 0.78 |
| Wayne | 1.12 | 1.19 | 1.26 | 1.21 | 1.06 | 1.19 | 1.20 |
| Webster | 0.16 | 0.16 | 0.16 | 0.17 | 0.17 | 0.17 | 0.17 |
| Wetzel | 0.65 | 0.62 | 0.63 | 0.62 | 0.62 | 0.62 | 0.62 |
| Wood | 3.15 | 3.16 | 3.01 | 2.83 | 2.79 | 2.83 | 7.63 |
| Wyoming | 0.67 | 0.65 | 0.71 | 0.51 | 0.50 | 0.59 | 0.60 |
| TOTALS | 70.03 | 72.28 | 71.79 | 73.45 | 67.24 | 67.73 | 72.42 |

*Counties with no Public Water Supply withdrawals in the LQU database are not listed (Wirt). †Several McDowell County PSD withdrawals (Bartley, Big Four, and Kimball-Carswell) were excluded because withdrawals reportedly occurred in Virginia. ‡Piedmont Municipal Water Works' withdrawals were not included because the actual withdrawals reportedly occur in Garrett County, Maryland.

Table S-7 Public Water Supply consumptive use scenario estimates by county, presented in millions of gallons per year.

| County* | HIGH Consumptive Use (Mgal/yr) | | | | | | | LOW Consumptive Use (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Barbour | 80.09 | 70.34 | 83.46 | 93.95 | 99.25 | 98.95 | 97.38 | 60.07 | 52.76 | 62.6 | 70.46 | 74.44 | 74.21 | 73.04 |
| Berkeley | 737.7 | 907.3 | 681.5 | 828.7 | 775.5 | 597.6 | 613.2 | 553.2 | 680.5 | 511.1 | 621.5 | 581.6 | 448.2 | 459.9 |
| Boone | 13.3 | 10.0 | 10.9 | 11.4 | 12.8 | 11.2 | 11.2 | 10.0 | 7.5 | 8.1 | 8.5 | 9.6 | 8.4 | 8.4 |
| Braxton | 70.5 | 67.1 | 70.4 | 74.4 | 75.3 | 75.2 | 76.0 | 52.9 | 50.3 | 52.8 | 55.8 | 56.5 | 56.4 | 57.0 |
| Brooke | 353.4 | 403.4 | 389.7 | 381.4 | 383.5 | 396.6 | 398.5 | 265.0 | 302.5 | 292.2 | 286.0 | 287.6 | 297.4 | 298.9 |
| Cabell | 963.7 | 952.9 | 992.9 | 969.8 | 969.8 | 969.8 | 969.8 | 722.8 | 714.6 | 744.7 | 727.4 | 727.4 | 727.4 | 727.4 |
| Calhoun | 22.5 | 21.9 | 20.9 | 21.8 | 23.6 | 26.1 | 23.5 | 16.8 | 16.5 | 15.7 | 16.3 | 17.7 | 19.6 | 17.7 |
| Clay | 30.7 | 23.7 | 29.0 | 34.9 | 36.1 | 33.3 | 33.3 | 23.0 | 17.8 | 21.8 | 26.2 | 27.1 | 25.0 | 25.0 |
| Doddridge | 11.2 | 10.0 | 11.5 | 10.9 | 10.9 | 10.9 | 12.3 | 8.4 | 7.5 | 8.6 | 8.2 | 8.2 | 8.2 | 9.3 |
| Fayette | 378.9 | 386.0 | 381.3 | 408.0 | 388.0 | 404.7 | 402.7 | 284.1 | 289.5 | 286.0 | 306.0 | 291.0 | 303.5 | 302.0 |
| Gilmer | 28.8 | 40.8 | 43.2 | 37.6 | 44.0 | 47.8 | 45.0 | 21.6 | 30.6 | 32.4 | 28.2 | 33.0 | 35.9 | 33.7 |
| Grant | 79.0 | 77.8 | 77.4 | 78.1 | 71.9 | 75.9 | 76.7 | 59.3 | 58.3 | 58.1 | 58.6 | 54.0 | 57.0 | 57.5 |
| Greenbrier | 187.6 | 192.5 | 215.7 | 209.3 | 184.3 | 213.3 | 229.7 | 140.7 | 144.4 | 161.8 | 157.0 | 138.2 | 160.0 | 172.3 |
| Hampshire | 42.0 | 38.9 | 42.1 | 45.6 | 43.0 | 44.9 | 42.0 | 31.5 | 29.1 | 31.6 | 34.2 | 32.2 | 33.6 | 31.5 |
| Hancock | 60.1 | 62.9 | 61.9 | 63.0 | 62.4 | 62.5 | 67.8 | 45.1 | 47.1 | 46.4 | 47.3 | 46.8 | 46.8 | 50.8 |
| Hardy | 244.6 | 275.8 | 290.1 | 270.2 | 270.2 | 270.2 | 270.2 | 183.5 | 206.8 | 217.6 | 202.6 | 202.6 | 202.6 | 202.6 |
| Harrison | 536.6 | 538.3 | 513.9 | 529.6 | 529.6 | 529.6 | 529.6 | 402.5 | 403.7 | 385.4 | 397.2 | 397.2 | 397.2 | 397.2 |
| Jackson | 120.3 | 124.0 | 125.7 | 123.3 | 131.8 | 135.5 | 130.4 | 90.2 | 93.0 | 94.3 | 92.5 | 98.9 | 101.7 | 97.8 |
| Jefferson | 183.2 | 203.1 | 224.5 | 221.9 | 220.1 | 195.4 | 188.1 | 137.4 | 152.3 | 168.4 | 166.4 | 165.1 | 146.6 | 141.1 |
| Kanawha | 2,438.5 | 2,482.6 | 2,468.9 | 2,454.5 | 2,454.7 | 2,463.5 | 2,455.0 | 1,828.9 | 1,861.9 | 1,851.7 | 1,840.9 | 1,841.0 | 1,847.6 | 1,841.3 |
| Lewis | 91.5 | 98.5 | 96.9 | 98.8 | 96.9 | 91.8 | 86.4 | 68.6 | 73.8 | 72.7 | 74.1 | 72.7 | 68.9 | 64.8 |
| Lincoln | 26.0 | 25.8 | 28.5 | 26.8 | 26.8 | 26.8 | 22.2 | 19.5 | 19.3 | 21.4 | 20.1 | 20.1 | 20.1 | 16.7 |
| Logan | 237.6 | 256.3 | 235.1 | 396.3 | 293.7 | 279.2 | 279.2 | 178.2 | 192.3 | 176.3 | 297.2 | 220.2 | 209.4 | 209.4 |

Table S-7, cont.  Public Water Supply consumptive use scenario estimates by county, presented in millions of gallons per year.

| County*, cont. | HIGH Consumptive Use (Mgal/yr) | | | | | | | LOW Consumptive Use (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Marion | 558.8 | 547.6 | 566.3 | 648.7 | 570.9 | 614.2 | 616.6 | 419.1 | 410.7 | 424.7 | 486.6 | 428.2 | 460.7 | 462.5 |
| Marshall | 210.5 | 215.3 | 233.1 | 209.4 | 212.5 | 215.2 | 224.6 | 157.9 | 161.5 | 174.8 | 157.1 | 159.4 | 161.4 | 168.4 |
| Mason | 114.8 | 119.3 | 125.1 | 128.2 | 126.8 | 127.4 | 114.3 | 86.1 | 89.5 | 93.8 | 96.1 | 95.1 | 95.6 | 85.7 |
| McDowell† | 178.6 | 171.9 | 192.4 | 185.5 | 190.7 | 194.9 | 191.1 | 133.9 | 128.9 | 144.3 | 139.1 | 143.0 | 146.2 | 143.3 |
| Mercer | 296.4 | 288.8 | 323.0 | 312.8 | 293.1 | 307.7 | 281.7 | 222.3 | 216.6 | 242.3 | 234.6 | 219.8 | 230.8 | 211.3 |
| Mineral†† | 86.5 | 82.4 | 86.2 | 122.6 | 108.6 | 126.6 | 128.1 | 64.9 | 61.8 | 64.7 | 92.0 | 81.5 | 94.9 | 96.0 |
| Mingo | 272.5 | 268.3 | 272.8 | 313.9 | 192.0 | 284.0 | 288.9 | 204.4 | 201.3 | 204.6 | 235.4 | 144.0 | 213.0 | 216.7 |
| Monongalia | 1,468.9 | 1,436.0 | 1,437.1 | 1,447.3 | 723.7 | 723.7 | 723.7 | 1,101.7 | 1,077.0 | 1,077.8 | 1,085.5 | 542.8 | 542.8 | 542.8 |
| Monroe | 57.2 | 55.8 | 60.2 | 58.6 | 60.3 | 59.5 | 59.5 | 42.9 | 41.8 | 45.1 | 44.0 | 45.2 | 44.6 | 44.6 |
| Morgan | 46.8 | 57.5 | 44.8 | 52.3 | 42.9 | 39.9 | 34.3 | 35.1 | 43.1 | 33.6 | 39.2 | 32.2 | 29.9 | 25.7 |
| Nicholas | 178.6 | 167.0 | 187.5 | 178.1 | 170.7 | 169.6 | 173.0 | 134.0 | 125.3 | 140.6 | 133.5 | 128.0 | 127.2 | 129.8 |
| Ohio | 498.7 | 490.1 | 495.8 | 494.9 | 494.9 | 494.9 | 494.9 | 374.0 | 367.6 | 371.8 | 371.1 | 371.1 | 371.1 | 371.1 |
| Pendleton | 27.0 | 31.9 | 26.4 | 28.4 | 25.9 | 23.6 | 23.0 | 20.3 | 23.9 | 19.8 | 21.3 | 19.5 | 17.7 | 17.2 |
| Pleasants | 48.7 | 60.3 | 57.5 | 54.2 | 53.1 | 53.9 | 53.1 | 36.5 | 45.2 | 43.1 | 40.7 | 39.8 | 40.4 | 39.8 |
| Pocahontas | 26.2 | 24.7 | 25.6 | 28.7 | 28.0 | 28.7 | 25.5 | 19.6 | 18.5 | 19.2 | 21.5 | 21.0 | 21.5 | 19.2 |
| Preston | 114.5 | 126.0 | 134.6 | 141.3 | 130.2 | 130.9 | 125.5 | 85.8 | 94.5 | 100.9 | 105.9 | 97.6 | 98.1 | 94.2 |
| Putnam | 170.5 | 153.2 | 161.0 | 186.5 | 165.9 | 165.9 | 165.9 | 127.9 | 114.9 | 120.8 | 139.9 | 124.4 | 124.4 | 124.4 |
| Raleigh | 667.4 | 678.0 | 699.3 | 679.6 | 680.3 | 681.5 | 678.9 | 500.5 | 508.5 | 524.5 | 509.7 | 510.2 | 511.1 | 509.2 |
| Randolph | 200.2 | 333.5 | 251.8 | 237.2 | 217.0 | 238.2 | 237.5 | 150.1 | 250.1 | 188.9 | 177.9 | 162.8 | 178.6 | 178.2 |
| Ritchie | 27.0 | 31.4 | 29.2 | 29.2 | 32.1 | 30.9 | 38.1 | 20.3 | 23.6 | 21.9 | 21.9 | 24.1 | 23.2 | 28.5 |
| Roane | 49.3 | 49.4 | 47.7 | 54.2 | 57.8 | 53.1 | 53.1 | 37.0 | 37.1 | 35.8 | 40.6 | 43.4 | 39.9 | 39.9 |
| Summers | 197.5 | 211.0 | 209.4 | 202.7 | 202.1 | 202.5 | 202.4 | 148.1 | 158.3 | 157.1 | 152.0 | 151.6 | 151.9 | 151.8 |

Table S-7, cont. Public Water Supply consumptive use scenario estimates by county, presented in millions of gallons per year.

| County*, cont. | HIGH Consumptive Use (Mgal/yr) | | | | | | | LOW Consumptive Use (Mgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Taylor | 142.95 | 143.34 | 141 | 142.43 | 142.43 | 137.84 | 140.73 | 107.21 | 107.51 | 105.75 | 106.82 | 106.82 | 103.38 | 105.55 |
| Tucker | 52.3 | 51.6 | 51.8 | 56.3 | 52.9 | 54.0 | 53.7 | 39.2 | 38.7 | 38.9 | 42.2 | 39.7 | 40.5 | 40.3 |
| Tyler | 31.2 | 32.5 | 43.0 | 39.1 | 37.9 | 30.3 | 28.5 | 23.4 | 24.4 | 32.2 | 29.3 | 28.4 | 22.8 | 21.4 |
| Upshur | 154.2 | 154.1 | 160.5 | 156.3 | 156.3 | 156.3 | 156.3 | 115.7 | 115.6 | 120.4 | 117.2 | 117.2 | 117.2 | 117.2 |
| Wayne | 224.3 | 238.3 | 251.2 | 241.3 | 212.2 | 237.3 | 239.0 | 168.2 | 178.8 | 188.4 | 181.0 | 159.2 | 178.0 | 179.3 |
| Webster | 32.0 | 31.1 | 31.7 | 34.1 | 33.8 | 33.2 | 33.2 | 24.0 | 23.4 | 23.8 | 25.6 | 25.4 | 24.9 | 24.9 |
| Wetzel | 129.4 | 123.1 | 125.8 | 124.3 | 124.1 | 124.3 | 124.3 | 97.0 | 92.3 | 94.3 | 93.2 | 93.1 | 93.2 | 93.2 |
| Wood | 630.6 | 631.6 | 602.3 | 566.0 | 557.2 | 566.1 | 1,525.2 | 472.9 | 473.7 | 451.7 | 424.5 | 417.9 | 424.6 | 1,143.9 |
| Wyoming | 134.2 | 129.8 | 141.0 | 101.4 | 99.6 | 118.6 | 119.6 | 100.7 | 97.3 | 105.8 | 76.0 | 74.7 | 89.0 | 89.7 |
| TOTALS‡ | 11,034 | 11,143 | 11,225 | 11,271 | 10,214 | 10,444 | 11,376 | 9,277 | 9,359 | 9,421 | 9,458 | 8,665 | 8,838 | 9,537 |

*Counties with no Public Water Supply withdrawals in the LQU database are not listed (Wirt). †Several McDowell County PSD withdrawals (Bartley, Big Four, and Kimball-Carswell) were excluded because withdrawals reportedly occurred in Virginia. ††Piedmont Municipal Water Works' withdrawals were not included because the actual withdrawals reportedly occur in Garrett County, Maryland. ‡Totals were rounded to whole numbers for display purposes.

Table S-8 The past and projected population by county.  Note that the totals between the county and watershed population tables are slightly different due to assumptions made to apportion population numbers.

| County* | Population | | | | | | | Population Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 |
| Barbour | 15,867 | 15,970 | 16,073 | 16,383 | 16,486 | 16,589 | 16,692 | 17,779 | 18,517 | 19,590 |
| Berkeley | 84,384 | 87,211 | 90,037 | 98,516 | 101,343 | 104,169 | 106,995 | 128,550 | 155,566 | 180,663 |
| Boone | 25,263 | 25,173 | 25,082 | 24,810 | 24,720 | 24,629 | 24,538 | 23,804 | 22,492 | 21,550 |
| Braxton | 14,648 | 14,630 | 14,613 | 14,559 | 14,541 | 14,523 | 14,505 | 14,308 | 13,932 | 13,722 |
| Brooke | 25,034 | 24,896 | 24,758 | 24,345 | 24,207 | 24,069 | 23,931 | 22,834 | 20,964 | 19,570 |
| Cabell | 96,645 | 96,598 | 96,552 | 96,412 | 96,366 | 96,319 | 96,273 | 96,081 | 95,722 | 95,380 |
| Calhoun | 7,596 | 7,600 | 7,605 | 7,618 | 7,623 | 7,627 | 7,632 | 7,702 | 7,429 | 7,410 |
| Clay | 10,047 | 9,952 | 9,858 | 9,575 | 9,480 | 9,386 | 9,292 | 8,328 | 7,359 | 6,320 |
| Doddridge | 7,643 | 7,723 | 7,803 | 8,042 | 8,122 | 8,202 | 8,282 | 7,962 | 7,314 | 6,978 |
| Fayette | 47,117 | 46,963 | 46,809 | 46,347 | 46,193 | 46,039 | 45,885 | 44,916 | 42,749 | 41,377 |
| Gilmer | 7,620 | 7,773 | 7,927 | 8,386 | 8,540 | 8,693 | 8,846 | 8,567 | 8,310 | 8,208 |
| Grant | 11,490 | 11,554 | 11,618 | 11,809 | 11,873 | 11,937 | 12,001 | 12,256 | 12,027 | 12,220 |
| Greenbrier | 34,761 | 34,864 | 34,967 | 35,275 | 35,377 | 35,480 | 35,583 | 36,981 | 37,064 | 38,195 |
| Hampshire | 21,331 | 21,707 | 22,084 | 23,212 | 23,588 | 23,964 | 24,340 | 26,404 | 27,621 | 29,774 |
| Hancock | 32,070 | 31,871 | 31,672 | 31,074 | 30,875 | 30,676 | 30,477 | 28,997 | 26,797 | 24,979 |
| Hardy | 13,076 | 13,211 | 13,347 | 13,754 | 13,889 | 14,025 | 14,161 | 15,465 | 16,372 | 17,698 |
| Harrison | 68,786 | 68,831 | 68,876 | 69,010 | 69,054 | 69,099 | 69,144 | 70,459 | 70,528 | 71,571 |
| Jackson | 28,363 | 28,484 | 28,606 | 28,969 | 29,090 | 29,211 | 29,332 | 30,799 | 31,531 | 32,901 |
| Jefferson | 45,582 | 46,713 | 47,844 | 51,236 | 52,367 | 53,498 | 54,629 | 62,691 | 71,208 | 80,291 |
| Kanawha | 197,970 | 197,269 | 196,568 | 194,465 | 193,764 | 193,063 | 192,362 | 190,884 | 185,722 | 182,724 |
| Lewis | 16,755 | 16,700 | 16,646 | 16,481 | 16,427 | 16,372 | 16,317 | 16,089 | 15,497 | 15,127 |
| Lincoln | 21,992 | 21,953 | 21,914 | 21,798 | 21,759 | 21,720 | 21,681 | 21,092 | 19,822 | 19,019 |
| Logan | 37,420 | 37,323 | 37,227 | 36,936 | 36,840 | 36,743 | 36,646 | 35,273 | 32,702 | 30,927 |
| Marion | 56,544 | 56,526 | 56,508 | 56,454 | 56,436 | 56,418 | 56,400 | 56,788 | 56,328 | 56,526 |
| Marshall | 34,795 | 34,554 | 34,313 | 33,589 | 33,348 | 33,107 | 32,866 | 30,900 | 28,092 | 25,772 |
| Mason | 26,367 | 26,504 | 26,641 | 27,051 | 27,187 | 27,324 | 27,461 | 27,692 | 27,252 | 27,365 |

Table S-8, cont. The past and projected population by county. Note that the totals between the county and watershed population tables are slightly different due to assumptions made to apportion population numbers.

| County*, cont. | Population | | | | | | | Population Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 |
| McDowell | 25,764 | 25,243 | 24,721 | 23,156 | 22,635 | 22,113 | 21,591 | 20,159 | 18,046 | 16,017 |
| Mercer | 62,765 | 62,694 | 62,622 | 62,407 | 62,336 | 62,264 | 62,192 | 61,759 | 60,112 | 59,306 |
| Mineral | 27,418 | 27,532 | 27,645 | 27,985 | 28,099 | 28,212 | 28,325 | 29,107 | 29,123 | 29,823 |
| Mingo | 27,829 | 27,687 | 27,546 | 27,122 | 26,980 | 26,839 | 26,698 | 25,421 | 23,318 | 21,691 |
| Monongalia | 86,163 | 87,595 | 89,028 | 93,324 | 94,757 | 96,189 | 97,621 | 107,780 | 121,820 | 133,978 |
| Monroe | 14,259 | 14,151 | 14,043 | 13,718 | 13,610 | 13,502 | 13,394 | 12,916 | 12,211 | 11,609 |
| Morgan | 15,722 | 15,982 | 16,242 | 17,021 | 17,281 | 17,541 | 17,801 | 19,737 | 21,032 | 23,018 |
| Nicholas | 26,463 | 26,430 | 26,398 | 26,299 | 26,266 | 26,233 | 26,200 | 26,158 | 25,451 | 25,243 |
| Ohio | 46,532 | 46,233 | 45,935 | 45,040 | 44,741 | 44,443 | 44,145 | 43,005 | 41,184 | 39,598 |
| Pendleton | 8,046 | 7,996 | 7,946 | 7,795 | 7,745 | 7,695 | 7,645 | 7,262 | 6,649 | 6,183 |
| Pleasants | 7,541 | 7,550 | 7,560 | 7,587 | 7,596 | 7,605 | 7,614 | 7,506 | 6,954 | 6,731 |
| Pocahontas | 9,007 | 8,966 | 8,925 | 8,801 | 8,760 | 8,719 | 8,678 | 8,515 | 7,849 | 7,526 |
| Preston | 30,590 | 31,008 | 31,427 | 32,683 | 33,101 | 33,520 | 33,939 | 34,124 | 33,750 | 34,165 |
| Putnam | 52,758 | 53,148 | 53,538 | 54,707 | 55,096 | 55,486 | 55,876 | 58,400 | 59,295 | 61,640 |
| Raleigh | 79,112 | 79,076 | 79,040 | 78,931 | 78,895 | 78,859 | 78,823 | 79,969 | 78,989 | 79,635 |
| Randolph | 28,605 | 28,719 | 28,834 | 29,176 | 29,291 | 29,405 | 29,519 | 29,404 | 28,359 | 28,145 |
| Ritchie | 10,375 | 10,385 | 10,396 | 10,428 | 10,438 | 10,449 | 10,460 | 10,651 | 10,442 | 10,586 |
| Roane | 15,290 | 15,238 | 15,186 | 15,030 | 14,978 | 14,926 | 14,874 | 14,487 | 13,415 | 12,818 |
| Summers | 13,277 | 13,370 | 13,463 | 13,741 | 13,834 | 13,927 | 14,020 | 13,364 | 12,524 | 11,840 |
| Taylor | 16,331 | 16,411 | 16,492 | 16,734 | 16,814 | 16,895 | 16,976 | 18,254 | 18,905 | 20,155 |
| Tucker | 7,267 | 7,249 | 7,231 | 7,177 | 7,159 | 7,141 | 7,123 | 7,074 | 6,722 | 6,587 |
| Tyler | 9,477 | 9,438 | 9,400 | 9,285 | 9,246 | 9,208 | 9,170 | 8,536 | 7,585 | 6,839 |
| Upshur | 23,659 | 23,744 | 23,829 | 24,084 | 24,169 | 24,254 | 24,339 | 25,060 | 25,085 | 25,688 |

**Table S-8, cont. The past and projected population by county. Note that the totals between the county and watershed population tables are slightly different due to assumptions made to apportion population numbers.**

| County*, cont. | Population | | | | | | | Population Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2020 | 2030 | 2040 |
| Wayne | 42,776 | 42,734 | 42,692 | 42,565 | 42,523 | 42,481 | 42,439 | 41,530 | 39,320 | 38,037 |
| Webster | 9,550 | 9,493 | 9,437 | 9,267 | 9,211 | 9,154 | 9,098 | 8,980 | 8,578 | 8,353 |
| Wetzel | 17,360 | 17,249 | 17,138 | 16,805 | 16,694 | 16,583 | 16,472 | 15,509 | 14,133 | 12,984 |
| Wood | 87,677 | 87,574 | 87,471 | 87,162 | 87,059 | 86,956 | 86,853 | 87,197 | 85,495 | 85,225 |
| Wyoming | 25,134 | 24,943 | 24,752 | 24,178 | 23,987 | 23,796 | 23,605 | 22,094 | 20,010 | 18,211 |
| TOTALS | 1,815,913 | 1,820,391 | 1,824,885 | 1,838,314 | 1,842,796 | 1,847,277 | 1,851,761 | 1,887,559 | 1,895,273 | 1,927,488 |

*Counties with no Public Water Supply withdrawals in the LQU database are not listed (Wirt).

**Table S-9 Per capita Public Water Supply withdrawal by county. Results rounded to the hundredths of thousand gallons for display purposes.**

| County* | Per Capita Withdrawal Rate (kgal/yr) | | | | | | | Average Rate (kgal/yr) |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | |
| Barbour | 25.24 | 22.02 | 25.96 | 28.67 | 30.10 | 29.82 | 29.17 | 27.28 |
| Berkeley | 43.71 | 52.02 | 37.85 | 42.06 | 38.26 | 28.69 | 28.65 | 38.75 |
| Boone | 2.63 | 1.98 | 2.16 | 2.29 | 2.60 | 2.28 | 2.29 | 2.32 |
| Braxton | 24.05 | 22.94 | 24.08 | 25.55 | 25.88 | 25.88 | 26.21 | 24.94 |
| Brooke | 70.58 | 81.01 | 78.69 | 78.32 | 79.21 | 82.38 | 83.27 | 79.07 |
| Cabell | 49.86 | 49.32 | 51.42 | 50.30 | 50.32 | 50.34 | 50.37 | 50.27 |
| Calhoun | 14.78 | 14.43 | 13.73 | 14.28 | 15.49 | 17.12 | 15.42 | 15.04 |
| Clay | 15.26 | 11.92 | 14.71 | 18.23 | 19.03 | 17.76 | 17.94 | 16.41 |
| Doddridge | 7.34 | 6.47 | 7.34 | 6.77 | 6.70 | 6.64 | 7.45 | 6.96 |
| Fayette | 40.20 | 41.10 | 40.73 | 44.02 | 42.00 | 43.95 | 43.88 | 42.27 |
| Gilmer | 18.88 | 26.26 | 27.26 | 22.42 | 25.74 | 27.49 | 25.43 | 24.78 |
| Grant | 34.39 | 33.66 | 33.32 | 33.06 | 30.29 | 31.81 | 31.96 | 32.64 |
| Greenbrier | 26.99 | 27.61 | 30.85 | 29.67 | 26.05 | 30.06 | 32.28 | 29.07 |
| Hampshire | 9.83 | 8.95 | 9.54 | 9.83 | 9.11 | 9.36 | 8.62 | 9.32 |
| Hancock | 9.37 | 9.86 | 9.76 | 10.14 | 10.10 | 10.18 | 11.12 | 10.08 |
| Hardy | 93.53 | 104.36 | 108.67 | 98.21 | 97.25 | 96.31 | 95.38 | 99.10 |
| Harrison | 39.01 | 39.10 | 37.30 | 38.37 | 38.34 | 38.32 | 38.29 | 38.39 |
| Jackson | 21.20 | 21.77 | 21.98 | 21.29 | 22.66 | 23.20 | 22.23 | 22.05 |
| Jefferson | 20.09 | 21.74 | 23.46 | 21.65 | 21.02 | 18.27 | 17.22 | 20.49 |
| Kanawha | 61.59 | 62.92 | 62.80 | 63.11 | 63.34 | 63.80 | 63.81 | 63.05 |
| Lewis | 27.30 | 29.48 | 29.11 | 29.97 | 29.51 | 28.05 | 26.46 | 28.55 |
| Lincoln | 5.92 | 5.87 | 6.51 | 6.14 | 6.15 | 6.16 | 5.12 | 5.98 |
| Logan | 31.75 | 34.34 | 31.58 | 53.64 | 39.85 | 38.00 | 38.10 | 38.18 |
| Marion | 49.42 | 48.44 | 50.11 | 57.46 | 50.58 | 54.44 | 54.67 | 52.16 |
| Marshall | 30.25 | 31.15 | 33.97 | 31.17 | 31.86 | 32.50 | 34.17 | 32.15 |
| Mason | 30.42 | 31.17 | 31.95 | 32.11 | 33.16 | 34.51 | 33.05 | 32.34 |
| McDowell | 34.66 | 34.04 | 38.92 | 40.06 | 42.11 | 44.07 | 44.25 | 39.73 |
| Mercer | 23.61 | 23.03 | 25.79 | 25.06 | 23.51 | 24.71 | 22.65 | 24.05 |
| Mineral | 15.78 | 14.96 | 15.60 | 21.91 | 19.33 | 22.43 | 22.61 | 18.94 |
| Mingo | 48.96 | 48.46 | 49.51 | 57.87 | 35.58 | 52.90 | 54.11 | 49.63 |
| Monongalia | 85.24 | 81.97 | 80.71 | 77.54 | 38.19 | 37.62 | 37.06 | 62.62 |
| Monroe | 20.06 | 19.71 | 21.43 | 21.36 | 22.15 | 22.02 | 22.20 | 21.27 |
| Morgan | 14.89 | 18.00 | 13.80 | 15.36 | 12.41 | 11.37 | 9.63 | 13.64 |
| Nicholas | 33.75 | 31.60 | 35.51 | 33.85 | 32.50 | 32.32 | 33.02 | 33.22 |
| Ohio | 53.58 | 53.00 | 53.97 | 54.93 | 55.30 | 55.67 | 56.05 | 54.64 |

**Table S-9, cont. Per capita Public Water Supply withdrawal by county. Results rounded to the hundredths of thousand gallons for display purposes.**

| County*, cont. | Per Capita Withdrawal Rate (kgal/yr) | | | | | | | Average Rate (kgal/yr) |
|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | |
| Pendleton | 16.80 | 19.92 | 16.62 | 18.24 | 16.75 | 15.36 | 15.02 | 16.96 |
| Pleasants | 32.26 | 39.94 | 38.04 | 35.73 | 34.94 | 35.41 | 34.86 | 35.88 |
| Pocahontas | 14.52 | 13.77 | 14.32 | 16.31 | 15.96 | 16.44 | 14.71 | 15.15 |
| Preston | 18.71 | 20.32 | 21.41 | 21.61 | 19.66 | 19.52 | 18.50 | 19.96 |
| Putnam | 16.16 | 14.41 | 15.04 | 17.04 | 15.05 | 14.95 | 14.84 | 15.36 |
| Raleigh | 42.18 | 42.87 | 44.24 | 43.05 | 43.11 | 43.21 | 43.06 | 43.10 |
| Randolph | 34.99 | 58.06 | 43.66 | 40.65 | 37.05 | 40.50 | 40.24 | 42.16 |
| Ritchie | 13.03 | 15.13 | 14.04 | 14.01 | 15.40 | 14.80 | 18.19 | 14.94 |
| Roane | 16.13 | 16.21 | 15.72 | 18.02 | 19.30 | 17.80 | 17.86 | 17.29 |
| Summers | 74.36 | 78.92 | 77.77 | 73.76 | 73.06 | 72.69 | 72.20 | 74.68 |
| Taylor | 43.77 | 43.67 | 42.75 | 42.56 | 42.35 | 40.79 | 41.45 | 42.48 |
| Tucker | 35.96 | 35.59 | 35.84 | 39.19 | 36.92 | 37.83 | 37.68 | 37.00 |
| Tyler | 16.45 | 17.22 | 22.86 | 21.05 | 20.49 | 16.47 | 15.52 | 18.58 |
| Upshur | 32.60 | 32.45 | 33.68 | 32.45 | 32.33 | 32.22 | 32.11 | 32.55 |
| Wayne | 26.21 | 27.89 | 29.42 | 28.34 | 24.96 | 27.93 | 28.16 | 27.56 |
| Webster | 16.76 | 16.40 | 16.80 | 18.38 | 18.36 | 18.12 | 18.23 | 17.58 |
| Wetzel | 37.27 | 35.68 | 36.69 | 36.98 | 37.17 | 37.46 | 37.71 | 37.00 |
| Wood | 35.96 | 36.06 | 34.43 | 32.47 | 32.00 | 32.55 | 87.80 | 41.61 |
| Wyoming | 26.70 | 26.01 | 28.49 | 20.96 | 20.76 | 24.93 | 25.33 | 24.74 |
| TOTALS† | 1,685 | 1,755 | 1,762 | 1,787 | 1,681 | 1,709 | 1,758 | 1,734 |

*Counties with no Public Water Supply withdrawals in the LQU database are not listed (Wirt). †Totals were rounded to whole numbers for display purposes.

**Table S-10 Projected withdrawals and high and low consumptive use estimates by county in 2020, 2030, and 2040 for the Public Water Supply water use sector. Results are shown in hundredths of billion gallons for display purposes.**

| County* | Withdrawal (Bgal/yr) | | | HIGH Consumptive Use (Bgal/yr) | | | LOW Consumptive Use (Bgal/yr) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Barbour | 0.49 | 0.51 | 0.53 | 0.10 | 0.10 | 0.11 | 0.07 | 0.08 | 0.08 |
| Berkeley | 4.98 | 6.03 | 7.00 | 1.00 | 1.21 | 1.40 | 0.75 | 0.90 | 1.05 |
| Boone | 0.06 | 0.05 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Braxton | 0.36 | 0.35 | 0.34 | 0.07 | 0.07 | 0.07 | 0.05 | 0.05 | 0.05 |
| Brooke | 1.81 | 1.66 | 1.55 | 0.36 | 0.33 | 0.31 | 0.27 | 0.25 | 0.23 |
| Cabell | 4.83 | 4.81 | 4.80 | 0.97 | 0.96 | 0.96 | 0.72 | 0.72 | 0.72 |
| Calhoun | 0.12 | 0.11 | 0.11 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Clay | 0.14 | 0.12 | 0.10 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Doddridge | 0.06 | 0.05 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Fayette | 1.90 | 1.81 | 1.75 | 0.38 | 0.36 | 0.35 | 0.28 | 0.27 | 0.26 |
| Gilmer | 0.21 | 0.21 | 0.20 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| Grant | 0.40 | 0.39 | 0.40 | 0.08 | 0.08 | 0.08 | 0.06 | 0.06 | 0.06 |
| Greenbrier | 1.08 | 1.08 | 1.11 | 0.22 | 0.22 | 0.22 | 0.16 | 0.16 | 0.17 |
| Hampshire | 0.25 | 0.26 | 0.28 | 0.05 | 0.05 | 0.06 | 0.04 | 0.04 | 0.04 |
| Hancock | 0.29 | 0.27 | 0.25 | 0.06 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 |
| Hardy | 1.53 | 1.62 | 1.75 | 0.31 | 0.32 | 0.35 | 0.23 | 0.24 | 0.26 |
| Harrison | 2.70 | 2.71 | 2.75 | 0.54 | 0.54 | 0.55 | 0.41 | 0.41 | 0.41 |
| Jackson | 0.68 | 0.70 | 0.73 | 0.14 | 0.14 | 0.15 | 0.10 | 0.10 | 0.11 |
| Jefferson | 1.28 | 1.46 | 1.65 | 0.26 | 0.29 | 0.33 | 0.19 | 0.22 | 0.25 |
| Kanawha | 12.04 | 11.71 | 11.52 | 2.41 | 2.34 | 2.30 | 1.81 | 1.76 | 1.73 |
| Lewis | 0.46 | 0.44 | 0.43 | 0.09 | 0.09 | 0.09 | 0.07 | 0.07 | 0.06 |
| Lincoln | 0.13 | 0.12 | 0.11 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Logan | 1.35 | 1.25 | 1.18 | 0.27 | 0.25 | 0.24 | 0.20 | 0.19 | 0.18 |
| Marion | 2.96 | 2.94 | 2.95 | 0.59 | 0.59 | 0.59 | 0.44 | 0.44 | 0.44 |
| Marshall | 0.99 | 0.90 | 0.83 | 0.20 | 0.18 | 0.17 | 0.15 | 0.14 | 0.12 |
| Mason | 0.90 | 0.88 | 0.88 | 0.18 | 0.18 | 0.18 | 0.13 | 0.13 | 0.13 |
| McDowell | 0.80 | 0.72 | 0.64 | 0.16 | 0.14 | 0.13 | 0.12 | 0.11 | 0.10 |
| Mercer | 1.49 | 1.45 | 1.43 | 0.30 | 0.29 | 0.29 | 0.22 | 0.22 | 0.21 |
| Mineral | 0.55 | 0.55 | 0.56 | 0.11 | 0.11 | 0.11 | 0.08 | 0.08 | 0.08 |
| Mingo | 1.26 | 1.16 | 1.08 | 0.25 | 0.23 | 0.22 | 0.19 | 0.17 | 0.16 |
| Monongalia | 6.75 | 7.63 | 8.39 | 1.35 | 1.53 | 1.68 | 1.01 | 1.14 | 1.26 |
| Monroe | 0.27 | 0.26 | 0.25 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 |
| Morgan | 0.27 | 0.29 | 0.31 | 0.05 | 0.06 | 0.06 | 0.04 | 0.04 | 0.05 |
| Nicholas | 0.87 | 0.85 | 0.84 | 0.17 | 0.17 | 0.17 | 0.13 | 0.13 | 0.13 |
| Ohio | 2.35 | 2.25 | 2.16 | 0.47 | 0.45 | 0.43 | 0.35 | 0.34 | 0.32 |

**Table S-10, cont. Projected withdrawals and high and low consumptive use estimates by county in 2020, 2030, and 2040 for the Public Water Supply water use sector. Results are shown in hundredths of billion gallons for display purposes.**

| County*, cont. | Withdrawal (Bgal/yr) | | | HIGH Consumptive Use (Bgal/yr) | | | LOW Consumptive Use (Bgal/yr) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Pendleton | 0.12 | 0.11 | 0.10 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Pleasants | 0.27 | 0.25 | 0.24 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 |
| Pocahontas | 0.13 | 0.12 | 0.11 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Preston | 0.68 | 0.67 | 0.68 | 0.14 | 0.13 | 0.14 | 0.10 | 0.10 | 0.10 |
| Putnam | 0.90 | 0.91 | 0.95 | 0.18 | 0.18 | 0.19 | 0.13 | 0.14 | 0.14 |
| Raleigh | 3.45 | 3.40 | 3.43 | 0.69 | 0.68 | 0.69 | 0.52 | 0.51 | 0.51 |
| Randolph | 1.24 | 1.20 | 1.19 | 0.25 | 0.24 | 0.24 | 0.19 | 0.18 | 0.18 |
| Ritchie | 0.16 | 0.16 | 0.16 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 |
| Roane | 0.25 | 0.23 | 0.22 | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 |
| Summers | 1.00 | 0.94 | 0.88 | 0.20 | 0.19 | 0.18 | 0.15 | 0.14 | 0.13 |
| Taylor | 0.78 | 0.80 | 0.86 | 0.16 | 0.16 | 0.17 | 0.12 | 0.12 | 0.13 |
| Tucker | 0.26 | 0.25 | 0.24 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 |
| Tyler | 0.16 | 0.14 | 0.13 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 |
| Upshur | 0.82 | 0.82 | 0.84 | 0.16 | 0.16 | 0.17 | 0.12 | 0.12 | 0.13 |
| Wayne | 1.14 | 1.08 | 1.05 | 0.23 | 0.22 | 0.21 | 0.17 | 0.16 | 0.16 |
| Webster | 0.16 | 0.15 | 0.15 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 |
| Wetzel | 0.57 | 0.52 | 0.48 | 0.11 | 0.10 | 0.10 | 0.09 | 0.08 | 0.07 |
| Wood | 3.63 | 3.56 | 3.55 | 0.73 | 0.71 | 0.71 | 0.54 | 0.53 | 0.53 |
| Wyoming | 0.55 | 0.50 | 0.45 | 0.11 | 0.10 | 0.09 | 0.08 | 0.07 | 0.07 |
| TOTALS | 72.88 | 73.41 | 74.67 | 14.58 | 14.65 | 14.98 | 10.89 | 11.01 | 11.21 |

*Counties with no Public Water Supply withdrawals in the LQU database are not listed (Wirt).

# Appendix T

## Development of the Thermoelectric withdrawal and consumptive use scenarios

Historic Thermoelectric withdrawals in the combined Thermoelectric sector (Thermoelectric SIC category from the LQU database) by watershed and by county can be found in **Table T-1** and **Table T-4**, respectively. Historic estimates of both High and Low Consumptive Use scenarios can be found by watershed and county in **Table T-2** and **Table T-5**, respectively. Results are shown in hundredths of billion gallons for display purposes.

## Thermoelectric Watershed Withdrawal and Consumptive Use Method

### Past withdrawal by HUC8

1. Sum Thermoelectric withdrawals by HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table T-1).

### Future growth rates by HUC8

2. Multiply the HUC8 Thermoelectric withdrawals in 2011 (step 1) by a predicted rate of change obtained from the literature.
    a. High Scenario – change in 2011 withdrawals by -2.3% annually through 2020 and -0.46% annually between 2030 and 2040 (WVU 2012).
    b. Low Scenario – use the same rates of change defined in the high scenario and remove six thermoelectric plants slated to close prior to 2020 (First Energy Corp. 2012, AEP 2013)

### Future withdrawal by HUC8

3. Multiply 2011 withdrawals (from step 1) by the rates of change defined in the high (step 2a) and low (step 2b) scenarios to obtain withdrawals by HUC8 for 2020, 2030, and 2040 (Table T-3).

### Future consumptive use estimates by HUC8

4. Multiply high 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. High scenario – 4% (Shaffer and Runkle 2007) (Table T-3)
5. Multiply low 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. Low scenario – 2% (Shaffer and Runkle 2007) (Table –E-3)

## Thermoelectric County Withdrawal and Consumptive Use Method

### Past withdrawal by county

1. Sum Thermoelectric withdrawals by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011 (Table T-4).

### Future growth rates by county

2. Multiply the county Thermoelectric withdrawals in 2011 (step 1) by a predicted rate of change obtained from the literature.
    a. High Scenario – change in 2011 withdrawals by -2.3% annually through 2020 and -0.46% annually between 2021 and 2040 (WVU 2012).
    b. Low Scenario – use the same rates of change defined in the high scenario and remove six thermoelectric plants slated to close prior to 2020 (First Energy Corp. 2012, AEP 2013)

### Future withdrawal by county

3. Multiply 2011 withdrawals (from step 1) by the rates of change defined in the high (step 2a) and low (step 2b) scenarios to obtain withdrawals by county for 2020, 2030, and 2040 (Table T-6).

### Future consumptive use estimates by county

4. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. High scenario – 4% (Shaffer and Runkle 2007) (Table T-6)
5. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. Low scenario – 2% (Shaffer and Runkle 2007) (Table T-6)

**The following tables provide results at the county and watershed (HUC8) levels. The results at the county scale are not comparable to the results at the watershed scale due to differences in the estimation methodologies described above.**

**Table T-1 Thermoelectric withdrawals by watershed, presented in billions of gallons per year.**

| HUC 8 | Historical Withdrawal | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Cheat | 53.97 | 38.39 | 50.76 | 29.81 | 0.70 | 1.13 | 0.70 |
| Lower Kanawha | 16.87 | 14.95 | 15.01 | 15.61 | 15.61 | 13.27 | 14.41 |
| Middle Ohio North | 59.04 | 30.19 | 39.50 | 35.52 | 10.70 | 19.02 | 22.87 |
| Middle Ohio South | 386.76 | 391.47 | 368.09 | 383.43 | 270.49 | 228.11 | 115.62 |
| Monongahela | 53.69 | 43.70 | 40.32 | 35.95 | 30.99 | 33.08 | 30.95 |
| North Branch Potomac | 383.18 | 421.41 | 405.03 | 403.22 | 403.21 | 403.20 | 403.20 |
| Upper Kanawha | 134.31 | 125.59 | 128.27 | 129.39 | 96.06 | 71.06 | 94.83 |
| Upper Ohio South | 206.63 | 204.09 | 199.56 | 182.30 | 129.00 | 115.13 | 141.15 |
| West Fork | 14.15 | 14.44 | 13.57 | 14.47 | 12.23 | 14.76 | 13.69 |
| TOTALS† | 1,309 | 1,284 | 1,260 | 1,230 | 969 | 899 | 837 |

† Totals were rounded to whole numbers for display purposes.

**Table T-2 Thermoelectric consumptive use scenario estimates by watershed, presented in billions of gallons per year.**

| HUC 8 | HIGH Consumptive Use (Bgal/yr) | | | | | | | LOW Consumptive Use (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Cheat | 2.16 | 1.54 | 2.03 | 1.19 | 0.03 | 0.05 | 0.03 | 1.08 | 0.77 | 1.02 | 0.60 | 0.01 | 0.02 | 0.01 |
| Lower Kanawha | 0.67 | 0.60 | 0.60 | 0.62 | 0.62 | 0.53 | 0.58 | 0.34 | 0.30 | 0.30 | 0.31 | 0.31 | 0.27 | 0.29 |
| Middle Ohio North | 2.36 | 1.21 | 1.58 | 1.42 | 0.43 | 0.76 | 0.91 | 1.18 | 0.60 | 0.79 | 0.71 | 0.21 | 0.38 | 0.46 |
| Middle Ohio South | 15.47 | 15.66 | 14.72 | 15.34 | 10.82 | 9.12 | 4.62 | 7.74 | 7.83 | 7.36 | 7.67 | 5.41 | 4.56 | 2.31 |
| Monongahela | 2.15 | 1.75 | 1.61 | 1.44 | 1.24 | 1.32 | 1.24 | 1.07 | 0.87 | 0.81 | 0.72 | 0.62 | 0.66 | 0.62 |
| North Branch Potomac | 15.33 | 16.86 | 16.20 | 16.13 | 16.13 | 16.13 | 16.13 | 7.66 | 8.43 | 8.10 | 8.06 | 8.06 | 8.06 | 8.06 |
| Upper Kanawha | 5.37 | 5.02 | 5.13 | 5.18 | 3.84 | 2.84 | 3.79 | 2.69 | 2.51 | 2.57 | 2.59 | 1.92 | 1.42 | 1.90 |
| Upper Ohio South | 8.27 | 8.16 | 7.98 | 7.29 | 5.16 | 4.61 | 5.65 | 4.13 | 4.08 | 3.99 | 3.65 | 2.58 | 2.30 | 2.82 |
| West Fork | 0.57 | 0.58 | 0.54 | 0.58 | 0.49 | 0.59 | 0.55 | 0.28 | 0.29 | 0.27 | 0.29 | 0.24 | 0.30 | 0.27 |
| TOTALS | 52.35 | 51.38 | 50.39 | 49.19 | 38.76 | 35.95 | 33.50 | 26.17 | 25.68 | 25.21 | 24.60 | 19.36 | 17.97 | 16.74 |

**Table T-3 Projected withdrawals and high and low consumptive use estimates by watershed in 2020, 2030, and 2040 for the Thermoelectric water use sector. Results are shown in hundredths of billion gallons for display purposes.**

| HUC 8 | Withdrawals (Bgal/yr) | | | | | | Consumptive Use (Bgal/yr) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HIGH | | | LOW | | | HIGH | | | LOW | | |
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Cheat* | 0.68 | 0.68 | 0.68 | 0.00 | 0.00 | 0.00 | 0.03 | 0.03 | 0.03 | 0.00 | 0.00 | 0.00 |
| Lower Kanawha | 14.08 | 14.01 | 13.95 | 14.08 | 14.01 | 13.95 | 0.56 | 0.56 | 0.56 | 0.28 | 0.28 | 0.28 |
| Middle Ohio North | 22.34 | 22.24 | 22.14 | 0.28 | 0.27 | 0.27 | 0.89 | 0.89 | 0.89 | 0.01 | 0.01 | 0.01 |
| Middle Ohio South | 112.96 | 112.44 | 111.92 | 5.86 | 5.84 | 5.81 | 4.52 | 4.50 | 4.48 | 0.12 | 0.12 | 0.12 |
| Monongahela | 30.24 | 30.10 | 29.97 | 29.66 | 29.52 | 29.39 | 1.21 | 1.20 | 1.20 | 0.59 | 0.59 | 0.59 |
| North Branch Potomac | 393.93 | 392.12 | 390.31 | 393.93 | 392.12 | 390.31 | 15.76 | 15.68 | 15.61 | 7.88 | 7.84 | 7.81 |
| Upper Kanawha* | 92.65 | 92.22 | 91.80 | 0.00 | 0.00 | 0.00 | 3.71 | 3.69 | 3.67 | 0.00 | 0.00 | 0.00 |
| Upper Ohio South | 137.90 | 137.27 | 136.64 | 8.55 | 8.51 | 8.48 | 5.52 | 5.49 | 5.47 | 0.17 | 0.17 | 0.17 |
| West Fork | 13.37 | 13.31 | 13.25 | 13.37 | 13.31 | 13.25 | 0.53 | 0.53 | 0.53 | 0.27 | 0.27 | 0.26 |
| TOTALS | 818.15 | 814.39 | 810.66 | 465.73 | 463.58 | 461.46 | 32.73 | 32.57 | 32.44 | 9.32 | 9.28 | 9.24 |

*The low scenario eliminated all Thermoelectric withdrawals in the Cheat and Upper Kanawha watersheds.

**Table T-4 Thermoelectric withdrawals by county, presented in billions of gallons per year.**

| County | Historical Withdrawal (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Grant | 383.18 | 421.41 | 405.03 | 403.22 | 403.21 | 403.20 | 403.20 |
| Harrison | 14.15 | 14.44 | 13.57 | 14.47 | 12.23 | 14.76 | 13.69 |
| Kanawha | 134.31 | 125.59 | 128.27 | 129.39 | 96.06 | 71.06 | 94.83 |
| Marion | 23.79 | 9.62 | 9.67 | 5.15 | 1.78 | 1.15 | 0.60 |
| Marshall | 206.63 | 204.09 | 199.56 | 182.30 | 129.00 | 115.13 | 141.15 |
| Mason | 386.76 | 391.47 | 368.09 | 383.43 | 270.49 | 228.11 | 115.62 |
| Monongalia | 29.90 | 34.08 | 30.66 | 30.80 | 29.21 | 31.93 | 30.36 |
| Pleasants | 59.04 | 30.19 | 39.50 | 35.52 | 10.70 | 19.02 | 22.87 |
| Preston | 53.97 | 38.39 | 50.76 | 29.81 | 0.70 | 1.13 | 0.70 |
| Putnam | 16.87 | 14.95 | 15.01 | 15.61 | 15.61 | 13.27 | 14.41 |
| TOTALS† | 1,309 | 1,284 | 1,260 | 1,230 | 969 | 899 | 837 |

† Totals were rounded to whole numbers for display purposes.

**Table T-5 Thermoelectric consumptive use scenario estimates by county, presented in billions of gallons per year.**

| County | HIGH Consumptive Use (Bgal/yr) | | | | | | | LOW Consumptive Use (Bgal/yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 |
| Grant | 15.33 | 16.86 | 16.20 | 16.13 | 16.13 | 16.13 | 16.13 | 7.66 | 8.43 | 8.10 | 8.06 | 8.06 | 8.06 | 8.06 |
| Harrison | 0.57 | 0.58 | 0.54 | 0.58 | 0.49 | 0.59 | 0.55 | 0.28 | 0.29 | 0.27 | 0.29 | 0.24 | 0.30 | 0.27 |
| Kanawha | 5.37 | 5.02 | 5.13 | 5.18 | 3.84 | 2.84 | 3.79 | 2.69 | 2.51 | 2.57 | 2.59 | 1.92 | 1.42 | 1.90 |
| Marion | 0.95 | 0.38 | 0.39 | 0.21 | 0.07 | 0.05 | 0.02 | 0.48 | 0.19 | 0.19 | 0.10 | 0.04 | 0.02 | 0.01 |
| Marshall | 8.27 | 8.16 | 7.98 | 7.29 | 5.16 | 4.61 | 5.65 | 4.13 | 4.08 | 3.99 | 3.65 | 2.58 | 2.30 | 2.82 |
| Mason | 15.47 | 15.66 | 14.72 | 15.34 | 10.82 | 9.12 | 4.62 | 7.74 | 7.83 | 7.36 | 7.67 | 5.41 | 4.56 | 2.31 |
| Monongalia | 1.20 | 1.36 | 1.23 | 1.23 | 1.17 | 1.28 | 1.21 | 0.60 | 0.68 | 0.61 | 0.62 | 0.58 | 0.64 | 0.61 |
| Pleasants | 2.36 | 1.21 | 1.58 | 1.42 | 0.43 | 0.76 | 0.91 | 1.18 | 0.60 | 0.79 | 0.71 | 0.21 | 0.38 | 0.46 |
| Preston | 2.16 | 1.54 | 2.03 | 1.19 | 0.03 | 0.05 | 0.03 | 1.08 | 0.77 | 1.02 | 0.60 | 0.01 | 0.02 | 0.01 |
| Putnam | 0.67 | 0.60 | 0.60 | 0.62 | 0.62 | 0.53 | 0.58 | 0.34 | 0.30 | 0.30 | 0.31 | 0.31 | 0.27 | 0.29 |
| TOTALS | 52.35 | 51.37 | 50.40 | 49.19 | 38.76 | 35.96 | 33.49 | 26.18 | 25.68 | 25.20 | 24.60 | 19.36 | 17.97 | 16.74 |

**Table T-6 Projected withdrawals and high and low consumptive use estimates by watershed in 2020, 2030, and 2040 for the Thermoelectric water use sector. Results are shown in hundredths of billion gallons for display purposes.**

| County | Withdrawals (Bgal/yr) | | | | | | Consumptive Use (Bgal/yr) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HIGH | | | LOW | | | HIGH | | | LOW | | |
| | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 | 2020 | 2030 | 2040 |
| Grant | 393.93 | 395.74 | 397.56 | 393.93 | 392.12 | 390.31 | 15.76 | 15.83 | 15.90 | 7.88 | 7.84 | 7.81 |
| Harrison | 13.37 | 13.43 | 13.49 | 13.37 | 13.31 | 13.25 | 0.53 | 0.54 | 0.54 | 0.27 | 0.27 | 0.26 |
| Kanawha* | 92.65 | 93.07 | 93.50 | 0.00 | 0.00 | 0.00 | 3.71 | 3.72 | 3.74 | 0.00 | 0.00 | 0.00 |
| Marion* | 0.58 | 0.58 | 0.59 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 |
| Marshall | 137.90 | 138.54 | 139.18 | 8.55 | 8.51 | 8.48 | 5.52 | 5.54 | 5.57 | 0.17 | 0.17 | 0.17 |
| Mason | 112.96 | 113.48 | 114.00 | 5.86 | 5.84 | 5.81 | 4.52 | 4.54 | 4.56 | 0.12 | 0.12 | 0.12 |
| Monongalia | 29.66 | 29.80 | 29.93 | 29.66 | 29.52 | 29.39 | 1.19 | 1.19 | 1.20 | 0.59 | 0.59 | 0.59 |
| Pleasants | 22.34 | 22.45 | 22.55 | 6.89 | 6.86 | 6.82 | 0.89 | 0.90 | 0.90 | 0.14 | 0.14 | 0.14 |
| Preston* | 0.68 | 0.69 | 0.69 | 0.00 | 0.00 | 0.00 | 0.03 | 0.03 | 0.03 | 0.00 | 0.00 | 0.00 |
| Putnam | 14.08 | 14.14 | 14.21 | 14.08 | 14.01 | 13.95 | 0.56 | 0.57 | 0.57 | 0.28 | 0.28 | 0.28 |
| TOTALS | 818.15 | 821.92 | 825.70 | 472.34 | 470.17 | 468.01 | 32.73 | 32.88 | 33.03 | 9.45 | 9.41 | 9.37 |

*The low scenario eliminated all Thermoelectric withdrawals in Kanawha, Marion, and Preston counties.

# Appendix U

Importance of water resources for federally threatened and endangered species in West Virginia

Importance of water resources for federally threatened and endangered species in West Virginia

| Common Name | Scientific Name | Type | Status | Importance of Water | Threats and Prospects | Source |
|---|---|---|---|---|---|---|
| Clubshell | Pleurobema clava | Mussel | Federally endangered | Aquatic species | Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels | DNR Wildlife Resources† |
| Fanshell | Cyprogenia stegaria | Mussel | Federally endangered | Aquatic species | Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels | DNR Wildlife Resources† |
| Harperella | Ptilimnium nodosum | Plant | Federally endangered | Habitat in WV consists of wet soils near clear, swiftly flowing streams | Grazing, habitat alteration (e.g. siltation) | DNR Wildlife Resources† |
| Indiana Myotis | Myotis sodalis | Bat | Federally endangered | Feeds in wooded areas along rivers and upland forests | Because these bats are concentrated into just a few caves during the winter, they are very vulnerable to disturbance. It is estimated that one cave in Pendleton County harbors over 90 percent of the Indiana myotis in West Virginia. Also contamination of food supplies. | DNR Wildlife Resources† |
| James Spiny Mussel | Pleurobema collina | Mussel | Federally endangered | Aquatic species | Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels | DNR Wildlife Resources† |
| Northeastern Bulrush | Scirpus ancistrochaetus | Plant | Federally endangered | Grows at the edge of ponds and other small expanses of standing water | Water quality deterioration, trampling by deer, off road vehicle damage, competition from other vegetation, permanent flooding (e.g. beaver dams) | DNR Wildlife Resources† |
| Northern Flying Squirrel | Glaucomys sabrinus fuscus | Squirrel | Federally endangered | General consumption and maintenance of foods | Habitat loss to timbering and development | DNR Wildlife Resources† |
| Northern Riffleshell | Epioblasma torulosa rangiana | Mussel | Federally endangered | Aquatic species | Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels | DNR Wildlife Resources† |
| Pink Mucket Pearly Mussel | Lampsilis abrupta | Mussel | Federally endangered | Aquatic species | Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels | DNR Wildlife Resources† |

| Common Name | Scientific Name | Type | Status | Importance of Water | Threats and Prospects | Source |
|---|---|---|---|---|---|---|
| Running Buffalo Clover | Trifolium stoloniferum | Plant | Federally endangered | General life cycle requirements | Loss of habitat, invasive non-native species | USFWS fact sheet** |
| Shale Barren Rockcress | Arabis serotina | Plant | Federally endangered | General life cycle requirements | Road construction, hiking, foraging | DNR Wildlife Resources† |
| Sheepnose* | Plethobasus cyphyus | Mussel | Federally endangered | Aquatic species | Primarily creation of dams, but also sedimentation/water quality deterioration, mining, channels, and dredging, oil and gas development | Federal register 3/13/2012 |
| Snuffbox | Epioblasma triquetra | Mussel | Federally endangered | Aquatic species | Water quality deterioration, creation of dams, levies, channels, and dredging, alteration affecting their larval host fish, zebra mussels | Federal register 2/14/2012 |
| Spectaclecase | Cumberlandia monodonta | Mussel | Federally endangered | Aquatic species | Primarily creation of dams, but also sedimentation/water quality deterioration, mining, channels, and dredging, oil and gas development | Federal register 3/13/2012 |
| Virginia Big-Eared Bat | Corynorhinus townsendii virginianus | Bat | Federally endangered | General life cycle requirements | Human disturbance in the cave roosts | DNR Wildlife Resources† |
| Cheat Mountain Salamander | Plethodon nettingi | Salamander | Federally threatened | Primary habitat requires moisture | Habitat alteration | DNR Wildlife Resources† |
| Flat-Spired Three-Toothed Land Snail | Triodopsis platysayoides | Snail | Federally threatened | Soil moisture content and humidity requirements, general life cycle requirements | Due to restricted range, local catastrophes could impact a large segment of the population, recreational activities, development, habitat alteration | DNR Wildlife Resources† |
| Madison Cave Isopod* | Antrolana lira | Isopod | Federally threatened | Aquatic species | Groundwater contamination. | DNR Wildlife Resources† |
| Small Whorled Pogonia | Isotria medeoloides | Plant | Federally threatened | General life cycle requirements | Cutting of forest habitats and conversion of the landscape to other land uses, digging of plants | DNR Wildlife Resources† |
| Virginia Spirea | Spiraea virginiana | Plant | Federally threatened | Habitat is usually rocky, flood scoured banks of high-energy streams or rivers | Reduction in required flood-scouring, riverside clearing, overuse by hikers, fishermen, and boaters, reservoir construction, | DNR Wildlife Resources† |

*Listed species occurring in this state that is not listed in this state according to USFWS listing and occurrences for West Virginia.

†Available online at http://www.wvdnr.gov/wildlife/endangered.shtm, accessed 1/10/13.

**Available online at http://www.fws.gov/midwest/endangered/plants/runningb.html, accessed 1/10/13.

# Appendix V

CEGAS Land Cover Change Comparison
(1992-2006)

# Land Cover Change Comparison

# Statewide

# 1992 to 2006

The charts below compare National Land Cover Database (NLCD) 1992 and 2006 Land Cover datasets.

| 1992 "from" class | 2006 "to" class Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Unchanged** | | | | | | | | | |
| | 0.71 | 1.18 | 0.14 | 76.05 | 0.00 | 0.00 | 6.97 | 0.05 | 85.09 |
| **Changed** | | | | | | | | | |
| Water | | 0.39 | 0.06 | 0.68 | 0.00 | 0.08 | 0.16 | 0.02 | 1.40 |
| Developed | 0.06 | | 0.06 | 0.74 | 0.00 | 0.06 | 0.22 | 0.00 | 1.14 |
| Barren | 0.07 | 0.89 | | 3.46 | 0.04 | 1.18 | 1.20 | 0.05 | 6.89 |
| Forest | 1.25 | 25.48 | 2.78 | | 0.48 | 7.73 | 11.26 | 0.31 | 49.29 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.17 | 12.27 | 0.66 | 25.10 | 0.10 | 1.38 | | 0.23 | 39.92 |
| Wetlands | 0.08 | 0.12 | 0.03 | 0.93 | 0.00 | 0.02 | 0.18 | | 1.36 |
| **Column totals** | **1.64** | **39.15** | **3.59** | **30.91** | **0.62** | **10.45** | **13.02** | **0.61** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 172,401 | 1.64 | Water | 146,633 | 1.40 | 25,768 | 9 |
| Developed | 4,109,091 | 39.15 | Developed | 120,062 | 1.14 | 3,989,029 | 1,386 |
| Barren | 376,735 | 3.59 | Barren | 722,923 | 6.89 | -346,188 | -120 |
| Forest | 3,244,596 | 30.91 | Forest | 5,173,357 | 49.29 | -1,928,761 | -670 |
| Shrubland | 64,724 | 0.62 | Shrubland | 0 | 0.00 | 64,724 | 22 |
| Herbaceous | 1,097,029 | 10.45 | Herbaceous | 0 | 0.00 | 1,097,029 | 381 |
| Planted/Cultivated | 1,366,492 | 13.02 | Planted/Cultivated | 4,189,714 | 39.92 | -2,823,222 | -981 |
| Wetlands | 64,257 | 0.61 | Wetlands | 142,636 | 1.36 | -78,379 | -27 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 2070001

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | | Unchanged | | | | | | | | |
| | | 0.38 | 0.20 | 0.04 | 77.04 | 0.00 | 0.00 | 11.25 | 0.00 | 88.90 |
| | | Changed | | | | | | | | |
| 1992 "from" class | Water | | 0.04 | 0.00 | 0.02 | 0.00 | 0.00 | 0.02 | 0.00 | 0.08 |
| | Developed | 0.00 | | 0.00 | 0.03 | 0.00 | 0.00 | 0.03 | 0.00 | 0.07 |
| | Barren | 0.00 | 0.03 | | 0.31 | 0.00 | 0.00 | 0.25 | 0.00 | 0.61 |
| | Forest | 0.13 | 2.14 | 0.06 | | 0.00 | 0.02 | 2.56 | 0.00 | 4.93 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.04 | 1.43 | 0.07 | 3.76 | 0.00 | 0.00 | | 0.00 | 5.31 |
| | Wetlands | 0.00 | 0.01 | 0.00 | 0.04 | 0.00 | 0.00 | 0.05 | | 0.10 |
| | **Column totals** | **0.19** | **3.66** | **0.13** | **4.17** | **0.00** | **0.03** | **2.92** | **0.01** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 7543 | 1.71 | Water | 3,319 | 0.75 | 4,224 | 1.5 |
| Developed | 145485 | 32.95 | Developed | 2,798 | 0.63 | 142,687 | 49.6 |
| Barren | 5037 | 1.14 | Barren | 24,078 | 5.45 | -19,041 | -6.6 |
| Forest | 165837 | 37.56 | Forest | 196,128 | 44.42 | -30,291 | -10.5 |
| Shrubland | 87 | 0.02 | Shrubland | 0 | 0.00 | 87 | 0.0 |
| Herbaceous | 1160 | 0.26 | Herbaceous | 0 | 0.00 | 1,160 | 0.4 |
| Planted/Cultivated | 116172 | 26.31 | Planted/Cultivated | 211,126 | 47.82 | -94,954 | -33.0 |
| Wetlands | 217 | 0.05 | Wetlands | 4,089 | 0.93 | -3,872 | -1.3 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 2070002

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| 1992 "from" class | Unchanged | | | | | | | | | |
| | | 1.13 | 0.77 | 0.67 | 73.08 | 0.00 | 0.00 | 9.01 | 0.04 | 84.70 |
| | Changed | | | | | | | | | |
| | Water | | 0.04 | 0.03 | 0.04 | 0.00 | 0.00 | 0.02 | 0.06 | 0.18 |
| | Developed | 0.01 | | 0.03 | 0.11 | 0.00 | 0.00 | 0.08 | 0.00 | 0.24 |
| | Barren | 0.04 | 0.20 | | 1.19 | 0.00 | 0.00 | 0.98 | 0.05 | 2.46 |
| | Forest | 0.23 | 3.27 | 0.80 | | 0.00 | 0.06 | 2.96 | 0.16 | 7.49 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.02 | 1.33 | 0.12 | 2.95 | 0.00 | 0.00 | | 0.03 | 4.46 |
| | Wetlands | 0.01 | 0.02 | 0.01 | 0.35 | 0.00 | 0.00 | 0.08 | | 0.46 |
| | **Column totals** | **0.32** | **4.86** | **0.99** | **4.63** | **0.00** | **0.06** | **4.13** | **0.31** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 5487 | 2.07 | Water | 3,185 | 1.20 | 2,302 | 0.8 |
| Developed | 84322 | 31.78 | Developed | 4,150 | 1.56 | 80,172 | 27.9 |
| Barren | 17229 | 6.49 | Barren | 42,746 | 16.11 | -25,517 | -8.9 |
| Forest | 80272 | 30.25 | Forest | 129,854 | 48.94 | -49,582 | -17.2 |
| Shrubland | 74 | 0.03 | Shrubland | 0 | 0.00 | 74 | 0.0 |
| Herbaceous | 1035 | 0.39 | Herbaceous | 0 | 0.00 | 1,035 | 0.4 |
| Planted/Cultivated | 71610 | 26.99 | Planted/Cultivated | 77,341 | 29.15 | -5,731 | -2.0 |
| Wetlands | 5295 | 2.00 | Wetlands | 8,048 | 3.03 | -2,753 | -1.0 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 2070003

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| 1992 "from" class | Unchanged | | | | | | | | | |
| | | 0.59 | 0.10 | 0.00 | 78.74 | 0.00 | 0.00 | 8.28 | 0.00 | 87.71 |
| | Changed | | | | | | | | | |
| | Water | | 0.03 | 0.00 | 0.04 | 0.00 | 0.00 | 0.02 | 0.00 | 0.09 |
| | Developed | 0.00 | | 0.00 | 0.04 | 0.00 | 0.00 | 0.03 | 0.00 | 0.07 |
| | Barren | 0.00 | 0.05 | | 0.36 | 0.00 | 0.00 | 0.21 | 0.00 | 0.62 |
| | Forest | 0.14 | 2.63 | 0.03 | | 0.00 | 0.15 | 3.25 | 0.01 | 6.21 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.01 | 1.02 | 0.01 | 4.17 | 0.00 | 0.01 | | 0.00 | 5.22 |
| | Wetlands | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.02 | | 0.09 |
| | **Column totals** | **0.16** | **3.73** | **0.04** | **4.67** | **0.00** | **0.16** | **3.53** | **0.01** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 3862 | 1.29 | Water | 2,156 | 0.72 | 1,706 | 0.6 |
| Developed | 90642 | 30.35 | Developed | 1,761 | 0.59 | 88,881 | 30.9 |
| Barren | 949 | 0.32 | Barren | 14,982 | 5.02 | -14,033 | -4.9 |
| Forest | 113480 | 37.99 | Forest | 150,810 | 50.49 | -37,330 | -13.0 |
| Shrubland | 0 | 0.00 | Shrubland | 0 | 0.00 | 0 | 0.0 |
| Herbaceous | 3774 | 1.26 | Herbaceous | 0 | 0.00 | 3,774 | 1.3 |
| Planted/Cultivated | 85757 | 28.71 | Planted/Cultivated | 126,808 | 42.46 | -41,051 | -14.3 |
| Wetlands | 212 | 0.07 | Wetlands | 2,159 | 0.72 | -1,947 | -0.7 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 2070004

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| 1992 "from" class | Unchanged | | | | | | | | | |
| | | 1.51 | 1.72 | 0.03 | 47.24 | 0.00 | 0.00 | 25.67 | 0.23 | 76.40 |
| | Changed | | | | | | | | | |
| | Water | | 0.05 | 0.00 | 0.05 | 0.00 | 0.00 | 0.04 | 0.01 | 0.14 |
| | Developed | 0.02 | | 0.00 | 0.12 | 0.00 | 0.00 | 0.26 | 0.00 | 0.39 |
| | Barren | 0.00 | 0.20 | | 0.12 | 0.00 | 0.00 | 0.15 | 0.00 | 0.48 |
| | Forest | 0.27 | 4.04 | 0.01 | | 0.00 | 0.23 | 7.17 | 0.14 | 11.86 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.04 | 4.86 | 0.02 | 5.53 | 0.00 | 0.03 | | 0.04 | 10.52 |
| | Wetlands | 0.05 | 0.02 | 0.00 | 0.10 | 0.00 | 0.00 | 0.03 | | 0.20 |
| | **Column totals** | **0.37** | **9.18** | **0.03** | **5.91** | **0.00** | **0.26** | **7.65** | **0.19** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 6561 | 1.58 | Water | 2,535 | 0.61 | 4,026 | 1.4 |
| Developed | 161416 | 38.91 | Developed | 6,942 | 1.67 | 154,474 | 53.7 |
| Barren | 549 | 0.13 | Barren | 8,387 | 2.02 | -7,838 | -2.7 |
| Forest | 103990 | 25.07 | Forest | 208,564 | 50.27 | -104,574 | -36.3 |
| Shrubland | 24 | 0.01 | Shrubland | 0 | 0.00 | 24 | 0.0 |
| Herbaceous | 4619 | 1.11 | Herbaceous | 0 | 0.00 | 4,619 | 1.6 |
| Planted/Cultivated | 134422 | 32.40 | Planted/Cultivated | 184,990 | 44.59 | -50,568 | -17.6 |
| Wetlands | 3285 | 0.79 | Wetlands | 3,448 | 0.83 | -163 | -0.1 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 2070005

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | **Unchanged** | | | | | | | | | |
| | | 0.03 | 0.00 | 0.00 | 94.60 | 0.00 | 0.00 | 0.00 | 0.00 | 94.63 |
| | **Changed** | | | | | | | | | |
| 1992 "from" class | Water | | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| | Developed | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Barren | 0.00 | 0.01 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| | Forest | 0.00 | 4.66 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 4.66 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.00 | 0.01 | 0.00 | 0.61 | 0.00 | 0.00 | | 0.00 | 0.63 |
| | Wetlands | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | | 0.05 |
| | **Column totals** | **0.00** | **4.69** | **0.00** | **0.68** | **0.00** | **0.00** | **0.00** | **0.00** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 0 | 0.00 | Water | 3 | 0.41 | -3 | 0.0 |
| Developed | 633 | 87.31 | Developed | 0 | 0.00 | 633 | 0.2 |
| Barren | 0 | 0.00 | Barren | 1 | 0.14 | -1 | 0.0 |
| Forest | 92 | 12.69 | Forest | 629 | 86.76 | -537 | -0.2 |
| Shrubland | 0 | 0.00 | Shrubland | 0 | 0.00 | 0 | 0.0 |
| Herbaceous | 0 | 0.00 | Herbaceous | 0 | 0.00 | 0 | 0.0 |
| Planted/Cultivated | 0 | 0.00 | Planted/Cultivated | 85 | 11.72 | -85 | 0.0 |
| Wetlands | 0 | 0.00 | Wetlands | 7 | 0.97 | -7 | 0.0 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 2070006

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| 1992 "from" class | **Unchanged** | | | | | | | | | |
| | | 0.01 | 0.02 | 0.02 | 85.21 | 0.00 | 0.00 | 3.01 | 0.00 | 88.26 |
| | **Changed** | | | | | | | | | |
| | Water | | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| | Developed | 0.00 | | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 | 0.00 | 0.02 |
| | Barren | 0.00 | 0.13 | | 1.18 | 0.00 | 0.00 | 1.18 | 0.00 | 2.49 |
| | Forest | 0.00 | 2.03 | 0.06 | | 0.00 | 0.02 | 1.81 | 0.00 | 3.92 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.00 | 1.17 | 0.01 | 4.10 | 0.00 | 0.00 | | 0.00 | 5.28 |
| | Wetlands | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | | 0.01 |
| | **Column totals** | **0.00** | **3.32** | **0.07** | **5.29** | **0.00** | **0.02** | **3.03** | **0.00** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 0 | 0.00 | Water | 12 | 0.11 | -12 | 0.0 |
| Developed | 3019 | 28.31 | Developed | 21 | 0.20 | 2,998 | 1.0 |
| Barren | 63 | 0.59 | Barren | 2,264 | 21.23 | -2,201 | -0.8 |
| Forest | 4805 | 45.06 | Forest | 3,558 | 33.36 | 1,247 | 0.4 |
| Shrubland | 0 | 0.00 | Shrubland | 0 | 0.00 | 0 | 0.0 |
| Herbaceous | 20 | 0.19 | Herbaceous | 0 | 0.00 | 20 | 0.0 |
| Planted/Cultivated | 2757 | 25.85 | Planted/Cultivated | 4,797 | 44.98 | -2,040 | -0.7 |
| Wetlands | 0 | 0.00 | Wetlands | 12 | 0.11 | -12 | 0.0 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 2070007

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| 1992 "from" class | Unchanged | | | | | | | | | |
| | | 2.04 | 3.10 | 0.19 | 24.59 | 0.00 | 0.00 | 43.51 | 0.84 | 74.27 |
| | Changed | | | | | | | | | |
| | Water | | 0.22 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.25 |
| | Developed | 0.01 | | 0.02 | 0.20 | 0.00 | 0.00 | 0.45 | 0.01 | 0.68 |
| | Barren | 0.15 | 0.17 | | 0.10 | 0.00 | 0.00 | 0.19 | 0.00 | 0.61 |
| | Forest | 0.52 | 6.50 | 0.05 | | 0.00 | 0.13 | 4.29 | 0.15 | 11.63 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.09 | 7.66 | 0.01 | 4.47 | 0.00 | 0.08 | | 0.07 | 12.38 |
| | Wetlands | 0.05 | 0.11 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | | 0.18 |
| | **Column totals** | **0.82** | **14.65** | **0.08** | **4.79** | **0.00** | **0.21** | **4.94** | **0.24** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 2485 | 3.19 | Water | 749 | 0.96 | 1,736 | 0.6 |
| Developed | 44333 | 56.95 | Developed | 2,058 | 2.64 | 42,275 | 14.7 |
| Barren | 234 | 0.30 | Barren | 1,847 | 2.37 | -1,613 | -0.6 |
| Forest | 14492 | 18.62 | Forest | 35,189 | 45.21 | -20,697 | -7.2 |
| Shrubland | 0 | 0.00 | Shrubland | 0 | 0.00 | 0 | 0.0 |
| Herbaceous | 627 | 0.81 | Herbaceous | 0 | 0.00 | 627 | 0.2 |
| Planted/Cultivated | 14960 | 19.22 | Planted/Cultivated | 37,447 | 48.11 | -22,487 | -7.8 |
| Wetlands | 712 | 0.91 | Wetlands | 553 | 0.71 | 159 | 0.1 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 2080201

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 0.01 | 0.03 | 0.03 | 84.19 | 0.00 | 0.00 | 5.23 | 0.00 | 89.50 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| | Developed | 0.00 | | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.02 |
| | Barren | 0.00 | 0.02 | | 0.32 | 0.00 | 0.00 | 0.03 | 0.00 | 0.36 |
| | Forest | 0.00 | 2.17 | 0.02 | | 0.77 | 2.56 | 0.66 | 0.01 | 6.19 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.00 | 1.18 | 0.03 | 2.54 | 0.00 | 0.04 | | 0.01 | 3.80 |
| | Wetlands | 0.00 | 0.01 | 0.00 | 0.06 | 0.00 | 0.00 | 0.03 | | 0.10 |
| | **Column totals** | **0.00** | **3.39** | **0.05** | **2.94** | **0.77** | **2.60** | **0.73** | **0.02** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 11 | 0.04 | Water | 80 | 0.26 | -69 | 0.0 |
| Developed | 9785 | 32.29 | Developed | 44 | 0.15 | 9,741 | 3.4 |
| Barren | 131 | 0.43 | Barren | 1,053 | 3.48 | -922 | -0.3 |
| Forest | 8483 | 27.99 | Forest | 17,858 | 58.93 | -9,375 | -3.3 |
| Shrubland | 2214 | 7.31 | Shrubland | 0 | 0.00 | 2,214 | 0.8 |
| Herbaceous | 7497 | 24.74 | Herbaceous | 0 | 0.00 | 7,497 | 2.6 |
| Planted/Cultivated | 2118 | 6.99 | Planted/Cultivated | 10,973 | 36.21 | -8,855 | -3.1 |
| Wetlands | 63 | 0.21 | Wetlands | 294 | 0.97 | -231 | -0.1 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5020001

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 0.58 | 0.71 | 0.22 | 75.38 | 0.00 | 0.00 | 8.46 | 0.00 | 85.37 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.06 | 0.00 | 0.04 | 0.00 | 0.00 | 0.02 | 0.00 | 0.12 |
| | Developed | 0.00 | | 0.02 | 0.08 | 0.00 | 0.00 | 0.03 | 0.00 | 0.13 |
| | Barren | 0.02 | 0.18 | | 0.51 | 0.03 | 0.00 | 0.26 | 0.01 | 1.01 |
| | Forest | 0.14 | 3.85 | 0.31 | | 0.04 | 0.04 | 1.67 | 0.03 | 6.09 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.02 | 2.03 | 0.23 | 4.61 | 0.06 | 0.01 | | 0.04 | 7.01 |
| | Wetlands | 0.02 | 0.02 | 0.00 | 0.16 | 0.00 | 0.00 | 0.06 | | 0.27 |
| | **Column totals** | **0.21** | **6.15** | **0.57** | **5.40** | **0.13** | **0.06** | **2.04** | **0.08** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 8157 | 1.41 | Water | 4,923 | 0.85 | 3,234 | 1.1 |
| Developed | 243416 | 41.99 | Developed | 5,077 | 0.88 | 238,339 | 82.8 |
| Barren | 22388 | 3.86 | Barren | 39,889 | 6.88 | -17,501 | -6.1 |
| Forest | 213950 | 36.91 | Forest | 241,398 | 41.64 | -27,448 | -9.5 |
| Shrubland | 5305 | 0.92 | Shrubland | 0 | 0.00 | 5,305 | 1.8 |
| Herbaceous | 2535 | 0.44 | Herbaceous | 0 | 0.00 | 2,535 | 0.9 |
| Planted/Cultivated | 80699 | 13.92 | Planted/Cultivated | 277,780 | 47.92 | -197,081 | -68.5 |
| Wetlands | 3217 | 0.55 | Wetlands | 10,600 | 1.83 | -7,383 | -2.6 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5020002

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| 1992 "from" class | Unchanged | | | | | | | | | |
| | | 0.59 | 1.73 | 0.20 | 65.21 | 0.00 | 0.00 | 11.52 | 0.00 | 79.25 |
| | Changed | | | | | | | | | |
| | Water | | 0.10 | 0.00 | 0.07 | 0.00 | 0.00 | 0.03 | 0.00 | 0.20 |
| | Developed | 0.01 | | 0.04 | 0.22 | 0.00 | 0.00 | 0.08 | 0.00 | 0.35 |
| | Barren | 0.02 | 0.29 | | 0.57 | 0.00 | 0.06 | 0.55 | 0.00 | 1.48 |
| | Forest | 0.24 | 4.36 | 0.24 | | 0.00 | 0.14 | 2.96 | 0.00 | 7.94 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.07 | 3.18 | 0.24 | 7.08 | 0.00 | 0.12 | | 0.00 | 10.70 |
| | Wetlands | 0.00 | 0.01 | 0.00 | 0.05 | 0.00 | 0.00 | 0.02 | | 0.09 |
| | **Column totals** | **0.33** | **7.94** | **0.52** | **8.00** | **0.00** | **0.32** | **3.64** | **0.01** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 8420 | 1.59 | Water | 5,054 | 0.95 | 3,366 | 1.2 |
| Developed | 202978 | 38.24 | Developed | 9,060 | 1.71 | 193,918 | 67.4 |
| Barren | 13209 | 2.49 | Barren | 37,806 | 7.12 | -24,597 | -8.5 |
| Forest | 204531 | 38.53 | Forest | 202,992 | 38.24 | 1,539 | 0.5 |
| Shrubland | 15 | 0.00 | Shrubland | 0 | 0.00 | 15 | 0.0 |
| Herbaceous | 8267 | 1.56 | Herbaceous | 0 | 0.00 | 8,267 | 2.9 |
| Planted/Cultivated | 93194 | 17.56 | Planted/Cultivated | 273,615 | 51.55 | -180,421 | -62.7 |
| Wetlands | 210 | 0.04 | Wetlands | 2,297 | 0.43 | -2,087 | -0.7 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5020003

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 0.76 | 2.71 | 0.05 | 67.24 | 0.00 | 0.00 | 9.41 | 0.00 | 80.17 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.14 | 0.01 | 0.15 | 0.00 | 0.01 | 0.02 | 0.00 | 0.32 |
| | Developed | 0.01 | | 0.04 | 0.30 | 0.00 | 0.01 | 0.09 | 0.00 | 0.45 |
| | Barren | 0.03 | 0.22 | | 0.31 | 0.00 | 0.11 | 0.14 | 0.00 | 0.82 |
| | Forest | 0.25 | 6.49 | 0.16 | | 0.01 | 0.58 | 1.91 | 0.00 | 9.40 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.02 | 2.91 | 0.07 | 5.58 | 0.00 | 0.12 | | 0.00 | 8.69 |
| | Wetlands | 0.02 | 0.02 | 0.01 | 0.08 | 0.00 | 0.00 | 0.02 | | 0.15 |
| | **Column totals** | **0.33** | **9.77** | **0.27** | **6.41** | **0.02** | **0.83** | **2.19** | **0.01** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 4334 | 1.67 | Water | 4,223 | 1.63 | 111 | 0.0 |
| Developed | 127975 | 49.28 | Developed | 5,854 | 2.25 | 122,121 | 42.4 |
| Barren | 3589 | 1.38 | Barren | 10,724 | 4.13 | -7,135 | -2.5 |
| Forest | 83997 | 32.34 | Forest | 123,136 | 47.41 | -39,139 | -13.6 |
| Shrubland | 198 | 0.08 | Shrubland | 0 | 0.00 | 198 | 0.1 |
| Herbaceous | 10896 | 4.20 | Herbaceous | 0 | 0.00 | 10,896 | 3.8 |
| Planted/Cultivated | 28648 | 11.03 | Planted/Cultivated | 113,796 | 43.82 | -85,148 | -29.6 |
| Wetlands | 67 | 0.03 | Wetlands | 1,971 | 0.76 | -1,904 | -0.7 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5020004

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| 1992 "from" class | Unchanged | | | | | | | | | |
| | | 0.72 | 0.27 | 0.44 | 81.18 | 0.00 | 0.00 | 4.61 | 0.48 | 87.69 |
| | Changed | | | | | | | | | |
| | Water | | 0.05 | 0.01 | 0.03 | 0.00 | 0.00 | 0.01 | 0.00 | 0.10 |
| | Developed | 0.00 | | 0.01 | 0.04 | 0.00 | 0.00 | 0.01 | 0.00 | 0.07 |
| | Barren | 0.02 | 0.15 | | 0.87 | 0.00 | 0.01 | 0.30 | 0.07 | 1.42 |
| | Forest | 0.13 | 3.44 | 0.31 | | 0.02 | 0.04 | 1.29 | 0.25 | 5.48 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.02 | 0.97 | 0.37 | 2.85 | 0.02 | 0.01 | | 0.14 | 4.37 |
| | Wetlands | 0.02 | 0.03 | 0.02 | 0.76 | 0.00 | 0.00 | 0.03 | | 0.87 |
| | **Column totals** | **0.19** | **4.64** | **0.72** | **4.55** | **0.04** | **0.06** | **1.65** | **0.47** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 7127 | 1.52 | Water | 3,792 | 0.81 | 3,335 | 1.2 |
| Developed | 177061 | 37.70 | Developed | 2,610 | 0.56 | 174,451 | 60.6 |
| Barren | 27344 | 5.82 | Barren | 54,219 | 11.54 | -26,875 | -9.3 |
| Forest | 173468 | 36.94 | Forest | 209,038 | 44.51 | -35,570 | -12.4 |
| Shrubland | 1685 | 0.36 | Shrubland | 0 | 0.00 | 1,685 | 0.6 |
| Herbaceous | 2161 | 0.46 | Herbaceous | 0 | 0.00 | 2,161 | 0.8 |
| Planted/Cultivated | 62867 | 13.39 | Planted/Cultivated | 166,926 | 35.54 | -104,059 | -36.2 |
| Wetlands | 17921 | 3.82 | Wetlands | 33,049 | 7.04 | -15,128 | -5.3 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5020005

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 0.08 | 0.23 | 0.11 | 74.75 | 0.00 | 0.00 | 8.24 | 0.00 | 83.41 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.07 | 0.01 | 0.23 | 0.00 | 0.02 | 0.03 | 0.01 | 0.36 |
| | Developed | 0.00 | | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 |
| | Barren | 0.08 | 0.10 | | 0.27 | 0.00 | 0.05 | 0.01 | 0.00 | 0.51 |
| | Forest | 0.22 | 3.14 | 0.22 | | 0.00 | 0.40 | 0.63 | 0.06 | 4.68 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.02 | 2.44 | 0.01 | 8.24 | 0.00 | 0.15 | | 0.02 | 10.88 |
| | Wetlands | 0.00 | 0.01 | 0.00 | 0.06 | 0.00 | 0.01 | 0.01 | | 0.09 |
| | **Column totals** | **0.33** | **5.76** | **0.24** | **8.85** | **0.00** | **0.62** | **0.68** | **0.09** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 1055 | 1.96 | Water | 1,183 | 2.20 | -128 | 0.0 |
| Developed | 18676 | 34.74 | Developed | 207 | 0.39 | 18,469 | 6.4 |
| Barren | 793 | 1.47 | Barren | 1,644 | 3.06 | -851 | -0.3 |
| Forest | 28702 | 53.39 | Forest | 15,159 | 28.20 | 13,543 | 4.7 |
| Shrubland | 15 | 0.03 | Shrubland | 0 | 0.00 | 15 | 0.0 |
| Herbaceous | 2022 | 3.76 | Herbaceous | 0 | 0.00 | 2,022 | 0.7 |
| Planted/Cultivated | 2198 | 4.09 | Planted/Cultivated | 35,275 | 65.61 | -33,077 | -11.5 |
| Wetlands | 303 | 0.56 | Wetlands | 296 | 0.55 | 7 | 0.0 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5020006

# 1992 to 2006

| | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| **Unchanged** | | | | | | | | | |
| | 0.39 | 0.21 | 0.09 | 60.62 | 0.00 | 0.00 | 15.34 | 0.38 | 77.03 |
| **Changed** (1992 "from" class) | | | | | | | | | |
| Water | | 0.08 | 0.00 | 0.03 | 0.00 | 0.00 | 0.01 | 0.01 | 0.13 |
| Developed | 0.00 | | 0.01 | 0.05 | 0.00 | 0.00 | 0.02 | 0.00 | 0.08 |
| Barren | 0.00 | 0.05 | | 0.26 | 0.00 | 0.00 | 0.48 | 0.00 | 0.79 |
| Forest | 0.07 | 5.18 | 0.20 | | 0.04 | 0.00 | 1.93 | 0.25 | 7.66 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.01 | 2.93 | 0.73 | 6.76 | 0.07 | 0.02 | | 0.62 | 11.14 |
| Wetlands | 0.01 | 0.19 | 0.01 | 2.68 | 0.00 | 0.01 | 0.26 | | 3.16 |
| **Column totals** | **0.09** | **8.43** | **0.94** | **9.79** | **0.11** | **0.04** | **2.70** | **0.88** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 193 | 0.38 | Water | 290 | 0.58 | -97 | 0.0 |
| Developed | 18413 | 36.71 | Developed | 171 | 0.34 | 18,242 | 6.3 |
| Barren | 2055 | 4.10 | Barren | 1,730 | 3.45 | 325 | 0.1 |
| Forest | 21381 | 42.62 | Forest | 16,738 | 33.37 | 4,643 | 1.6 |
| Shrubland | 231 | 0.46 | Shrubland | 0 | 0.00 | 231 | 0.1 |
| Herbaceous | 79 | 0.16 | Herbaceous | 0 | 0.00 | 79 | 0.0 |
| Planted/Cultivated | 5889 | 11.74 | Planted/Cultivated | 24,343 | 48.53 | -18,454 | -6.4 |
| Wetlands | 1923 | 3.83 | Wetlands | 6,892 | 13.74 | -4,969 | -1.7 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5030101

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 5.37 | 7.48 | 0.07 | 53.61 | 0.00 | 0.00 | 7.81 | 0.00 | 74.35 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.52 | 0.07 | 0.30 | 0.00 | 0.03 | 0.02 | 0.00 | 0.93 |
| | Developed | 0.24 | | 0.03 | 1.02 | 0.00 | 0.14 | 0.07 | 0.00 | 1.50 |
| | Barren | 0.05 | 0.74 | | 0.32 | 0.00 | 0.35 | 0.12 | 0.00 | 1.59 |
| | Forest | 0.75 | 8.86 | 0.29 | | 0.01 | 1.66 | 1.05 | 0.01 | 12.64 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.04 | 3.59 | 0.05 | 4.64 | 0.04 | 0.36 | | 0.00 | 8.72 |
| | Wetlands | 0.08 | 0.09 | 0.01 | 0.07 | 0.00 | 0.00 | 0.01 | | 0.27 |
| | **Column totals** | **1.17** | **13.81** | **0.45** | **6.35** | **0.05** | **2.54** | **1.27** | **0.02** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 4592 | 4.54 | Water | 3,669 | 3.63 | 923 | 0.3 |
| Developed | 54405 | 53.84 | Developed | 5,897 | 5.84 | 48,508 | 16.9 |
| Barren | 1754 | 1.74 | Barren | 6,268 | 6.20 | -4,514 | -1.6 |
| Forest | 25010 | 24.75 | Forest | 49,799 | 49.28 | -24,789 | -8.6 |
| Shrubland | 204 | 0.20 | Shrubland | 0 | 0.00 | 204 | 0.1 |
| Herbaceous | 9997 | 9.89 | Herbaceous | 0 | 0.00 | 9,997 | 3.5 |
| Planted/Cultivated | 5016 | 4.96 | Planted/Cultivated | 34,375 | 34.02 | -29,359 | -10.2 |
| Wetlands | 79 | 0.08 | Wetlands | 1,049 | 1.04 | -970 | -0.3 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5030106

# 1992 to 2006

| | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| **Unchanged** | | | | | | | | | |
| | 1.62 | 2.75 | 0.04 | 64.19 | 0.00 | 0.00 | 10.66 | 0.00 | 79.27 |
| **Changed** (1992 "from" class) | | | | | | | | | |
| Water | | 0.22 | 0.03 | 0.27 | 0.00 | 0.02 | 0.02 | 0.01 | 0.56 |
| Developed | 0.07 | | 0.04 | 0.34 | 0.00 | 0.02 | 0.02 | 0.00 | 0.49 |
| Barren | 0.01 | 0.15 | | 0.10 | 0.00 | 0.06 | 0.05 | 0.00 | 0.38 |
| Forest | 0.36 | 4.93 | 0.12 | | 0.00 | 1.15 | 1.40 | 0.04 | 8.00 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.04 | 3.22 | 0.08 | 7.61 | 0.00 | 0.26 | | 0.01 | 11.23 |
| Wetlands | 0.02 | 0.02 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | | 0.07 |
| **Column totals** | **0.50** | **8.55** | **0.27** | **8.34** | **0.01** | **1.51** | **1.50** | **0.06** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 8297 | 2.40 | Water | 9,387 | 2.72 | -1,090 | -0.4 |
| Developed | 142259 | 41.22 | Developed | 8,146 | 2.36 | 134,113 | 46.6 |
| Barren | 4457 | 1.29 | Barren | 6,310 | 1.83 | -1,853 | -0.6 |
| Forest | 138835 | 40.23 | Forest | 133,190 | 38.59 | 5,645 | 2.0 |
| Shrubland | 85 | 0.02 | Shrubland | 0 | 0.00 | 85 | 0.0 |
| Herbaceous | 25212 | 7.31 | Herbaceous | 0 | 0.00 | 25,212 | 8.8 |
| Planted/Cultivated | 24970 | 7.24 | Planted/Cultivated | 186,869 | 54.15 | -161,899 | -56.3 |
| Wetlands | 982 | 0.28 | Wetlands | 1,195 | 0.35 | -213 | -0.1 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5030201

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | | **Unchanged** | | | | | | | | |
| | | 1.45 | 0.73 | 0.01 | 80.68 | 0.00 | 0.00 | 5.19 | 0.00 | 88.05 |
| | | **Changed** | | | | | | | | |
| 1992 "from" class | Water | | 0.09 | 0.01 | 0.20 | 0.00 | 0.02 | 0.03 | 0.00 | 0.35 |
| | Developed | 0.01 | | 0.00 | 0.07 | 0.00 | 0.01 | 0.01 | 0.00 | 0.10 |
| | Barren | 0.01 | 0.10 | | 0.13 | 0.00 | 0.02 | 0.02 | 0.00 | 0.28 |
| | Forest | 0.26 | 3.11 | 0.01 | | 0.01 | 0.36 | 0.64 | 0.00 | 4.40 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.06 | 2.19 | 0.00 | 4.37 | 0.01 | 0.12 | | 0.00 | 6.75 |
| | Wetlands | 0.01 | 0.02 | 0.00 | 0.03 | 0.00 | 0.00 | 0.01 | | 0.07 |
| | **Column totals** | **0.35** | **5.52** | **0.02** | **4.80** | **0.01** | **0.53** | **0.70** | **0.01** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 9857 | 2.96 | Water | 9,750 | 2.93 | 107 | 0.0 |
| Developed | 153802 | 46.21 | Developed | 2,743 | 0.82 | 151,059 | 52.5 |
| Barren | 451 | 0.14 | Barren | 7,787 | 2.34 | -7,336 | -2.5 |
| Forest | 133741 | 40.18 | Forest | 122,506 | 36.81 | 11,235 | 3.9 |
| Shrubland | 397 | 0.12 | Shrubland | 0 | 0.00 | 397 | 0.1 |
| Herbaceous | 14864 | 4.47 | Herbaceous | 0 | 0.00 | 14,864 | 5.2 |
| Planted/Cultivated | 19521 | 5.87 | Planted/Cultivated | 188,068 | 56.51 | -168,547 | -58.6 |
| Wetlands | 201 | 0.06 | Wetlands | 1,980 | 0.59 | -1,779 | -0.6 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5030202

## 1992 to 2006

| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2006 "to" class | | | | | | | | |
| | Unchanged | | | | | | | | | |
| | | 3.07 | 2.37 | 0.01 | 61.05 | 0.00 | 0.00 | 17.00 | 0.00 | 83.49 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.08 | 0.01 | 0.16 | 0.00 | 0.03 | 0.07 | 0.01 | 0.35 |
| | Developed | 0.03 | | 0.00 | 0.18 | 0.00 | 0.03 | 0.06 | 0.00 | 0.31 |
| | Barren | 0.01 | 0.17 | | 0.09 | 0.00 | 0.06 | 0.06 | 0.00 | 0.38 |
| | Forest | 0.37 | 3.16 | 0.05 | | 0.01 | 0.46 | 1.49 | 0.03 | 5.58 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.10 | 4.74 | 0.01 | 4.71 | 0.02 | 0.13 | | 0.00 | 9.70 |
| | Wetlands | 0.05 | 0.03 | 0.00 | 0.07 | 0.00 | 0.01 | 0.03 | | 0.18 |
| | **Column totals** | **0.56** | **8.17** | **0.07** | **5.21** | **0.03** | **0.72** | **1.71** | **0.04** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 11524 | 3.38 | Water | 7,255 | 2.13 | 4,269 | 1.5 |
| Developed | 168865 | 49.51 | Developed | 6,490 | 1.90 | 162,375 | 56.4 |
| Barren | 1457 | 0.43 | Barren | 7,863 | 2.31 | -6,406 | -2.2 |
| Forest | 107609 | 31.55 | Forest | 115,315 | 33.81 | -7,706 | -2.7 |
| Shrubland | 633 | 0.19 | Shrubland | 0 | 0.00 | 633 | 0.2 |
| Herbaceous | 14951 | 4.38 | Herbaceous | 0 | 0.00 | 14,951 | 5.2 |
| Planted/Cultivated | 35254 | 10.34 | Planted/Cultivated | 200,509 | 58.78 | -165,255 | -57.4 |
| Wetlands | 811 | 0.24 | Wetlands | 3,672 | 1.08 | -2,861 | -1.0 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5030203

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 0.14 | 0.65 | 0.00 | 81.68 | 0.00 | 0.00 | 6.36 | 0.00 | 88.84 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.02 | 0.00 | 0.12 | 0.00 | 0.01 | 0.02 | 0.00 | 0.17 |
| | Developed | 0.00 | | 0.00 | 0.09 | 0.00 | 0.00 | 0.01 | 0.00 | 0.11 |
| | Barren | 0.00 | 0.05 | | 0.28 | 0.00 | 0.02 | 0.04 | 0.00 | 0.40 |
| | Forest | 0.12 | 3.19 | 0.03 | | 0.02 | 0.34 | 0.81 | 0.00 | 4.51 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.02 | 1.96 | 0.02 | 3.82 | 0.01 | 0.11 | | 0.00 | 5.94 |
| | Wetlands | 0.01 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | | 0.04 |
| | **Column totals** | **0.15** | **5.24** | **0.04** | **4.33** | **0.03** | **0.48** | **0.88** | **0.00** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 10049 | 1.36 | Water | 11,043 | 1.49 | -994 | -0.3 |
| Developed | 347162 | 46.93 | Developed | 7,057 | 0.95 | 340,105 | 118.2 |
| Barren | 2971 | 0.40 | Barren | 26,232 | 3.55 | -23,261 | -8.1 |
| Forest | 286763 | 38.76 | Forest | 299,018 | 40.42 | -12,255 | -4.3 |
| Shrubland | 2105 | 0.28 | Shrubland | 0 | 0.00 | 2,105 | 0.7 |
| Herbaceous | 31861 | 4.31 | Herbaceous | 0 | 0.00 | 31,861 | 11.1 |
| Planted/Cultivated | 58616 | 7.92 | Planted/Cultivated | 393,725 | 53.22 | -335,109 | -116.4 |
| Wetlands | 247 | 0.03 | Wetlands | 2,699 | 0.36 | -2,452 | -0.9 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5050002

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | **Unchanged** | | | | | | | | | |
| | | 0.58 | 1.52 | 0.01 | 65.93 | 0.00 | 0.00 | 10.71 | 0.00 | 78.75 |
| | **Changed** | | | | | | | | | |
| 1992 "from" class | Water | | 0.02 | 0.00 | 0.12 | 0.00 | 0.02 | 0.04 | 0.00 | 0.20 |
| | Developed | 0.00 | | 0.00 | 0.05 | 0.00 | 0.01 | 0.02 | 0.00 | 0.08 |
| | Barren | 0.00 | 0.16 | | 0.24 | 0.00 | 0.08 | 0.18 | 0.00 | 0.65 |
| | Forest | 0.12 | 4.92 | 0.07 | | 0.02 | 1.94 | 3.30 | 0.00 | 10.38 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.01 | 2.94 | 0.07 | 5.46 | 0.00 | 1.35 | | 0.01 | 9.84 |
| | Wetlands | 0.01 | 0.01 | 0.00 | 0.05 | 0.00 | 0.01 | 0.02 | | 0.10 |
| | **Column totals** | **0.14** | **8.05** | **0.14** | **5.91** | **0.02** | **3.41** | **3.56** | **0.02** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 3263 | 0.66 | Water | 4,722 | 0.95 | -1,459 | -0.5 |
| Developed | 188252 | 37.89 | Developed | 1,957 | 0.39 | 186,295 | 64.7 |
| Barren | 3369 | 0.68 | Barren | 15,084 | 3.04 | -11,715 | -4.1 |
| Forest | 138197 | 27.82 | Forest | 242,680 | 48.85 | -104,483 | -36.3 |
| Shrubland | 517 | 0.10 | Shrubland | 0 | 0.00 | 517 | 0.2 |
| Herbaceous | 79648 | 16.03 | Herbaceous | 0 | 0.00 | 79,648 | 27.7 |
| Planted/Cultivated | 83185 | 16.74 | Planted/Cultivated | 229,965 | 46.29 | -146,780 | -51.0 |
| Wetlands | 373 | 0.08 | Wetlands | 2,396 | 0.48 | -2,023 | -0.7 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5050003

# 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 0.41 | 0.34 | 0.08 | 76.13 | 0.00 | 0.00 | 10.41 | 0.01 | 87.37 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.06 | 0.00 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 0.09 |
| | Developed | 0.00 | | 0.00 | 0.05 | 0.00 | 0.00 | 0.03 | 0.00 | 0.09 |
| | Barren | 0.00 | 0.08 | | 0.52 | 0.01 | 0.01 | 0.29 | 0.00 | 0.91 |
| | Forest | 0.13 | 2.44 | 0.06 | | 0.07 | 0.16 | 0.92 | 0.04 | 3.82 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.01 | 1.86 | 0.16 | 5.30 | 0.04 | 0.03 | | 0.11 | 7.51 |
| | Wetlands | 0.00 | 0.02 | 0.00 | 0.14 | 0.00 | 0.00 | 0.04 | | 0.21 |
| | **Column totals** | **0.16** | **4.45** | **0.22** | **6.03** | **0.12** | **0.20** | **1.30** | **0.16** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 7406 | 1.24 | Water | 4,475 | 0.75 | 2,931 | 1.0 |
| Developed | 211391 | 35.27 | Developed | 4,042 | 0.67 | 207,349 | 72.1 |
| Barren | 10397 | 1.73 | Barren | 43,269 | 7.22 | -32,872 | -11.4 |
| Forest | 286353 | 47.77 | Forest | 181,309 | 30.25 | 105,044 | 36.5 |
| Shrubland | 5531 | 0.92 | Shrubland | 0 | 0.00 | 5,531 | 1.9 |
| Herbaceous | 9408 | 1.57 | Herbaceous | 0 | 0.00 | 9,408 | 3.3 |
| Planted/Cultivated | 61528 | 10.27 | Planted/Cultivated | 356,445 | 59.47 | -294,917 | -102.5 |
| Wetlands | 7376 | 1.23 | Wetlands | 9,850 | 1.64 | -2,474 | -0.9 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5050004

# 1992 to 2006

| 1992 "from" class | 2006 "to" class: Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Unchanged** | | | | | | | | | |
| | 0.95 | 2.73 | 0.10 | 73.89 | 0.00 | 0.00 | 3.60 | 0.00 | 81.26 |
| **Changed** | | | | | | | | | |
| Water | | 0.04 | 0.00 | 0.09 | 0.00 | 0.01 | 0.04 | 0.00 | 0.19 |
| Developed | 0.01 | | 0.01 | 0.09 | 0.00 | 0.01 | 0.03 | 0.00 | 0.15 |
| Barren | 0.01 | 0.24 | | 0.98 | 0.00 | 0.12 | 0.35 | 0.01 | 1.71 |
| Forest | 0.28 | 5.76 | 0.16 | | 0.02 | 1.24 | 4.10 | 0.03 | 11.60 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.01 | 1.87 | 0.22 | 2.52 | 0.01 | 0.23 | | 0.07 | 4.93 |
| Wetlands | 0.02 | 0.02 | 0.00 | 0.10 | 0.00 | 0.01 | 0.02 | | 0.16 |
| **Column totals** | **0.32** | **7.93** | **0.40** | **3.77** | **0.03** | **1.62** | **4.55** | **0.11** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 6412 | 1.72 | Water | 3,707 | 0.99 | 2,705 | 0.9 |
| Developed | 157732 | 42.30 | Developed | 3,080 | 0.83 | 154,652 | 53.7 |
| Barren | 7999 | 2.15 | Barren | 34,004 | 9.12 | -26,005 | -9.0 |
| Forest | 75067 | 20.13 | Forest | 230,816 | 61.91 | -155,749 | -54.1 |
| Shrubland | 612 | 0.16 | Shrubland | 0 | 0.00 | 612 | 0.2 |
| Herbaceous | 32286 | 8.66 | Herbaceous | 0 | 0.00 | 32,286 | 11.2 |
| Planted/Cultivated | 90470 | 24.26 | Planted/Cultivated | 97,988 | 26.28 | -7,518 | -2.6 |
| Wetlands | 2272 | 0.61 | Wetlands | 3,255 | 0.87 | -983 | -0.3 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5050005

## 1992 to 2006

| | | Water | Developed | Barren | Forest | Shrubland | Herbaceous | Planted/Cultivated | Wetlands | Row Totals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2006 "to" class | | | | | | | | |
| | | (%) | (%) | (%) | (%) | (%) | (%) | (%) | (%) | (%) |
| | Unchanged | | | | | | | | | |
| | | 0.46 | 0.37 | 0.41 | 83.48 | 0.00 | 0.00 | 2.54 | 0.17 | 87.43 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.04 | 0.04 | 0.12 | 0.00 | 0.01 | 0.01 | 0.00 | 0.22 |
| | Developed | 0.00 | | 0.01 | 0.10 | 0.00 | 0.01 | 0.01 | 0.00 | 0.13 |
| | Barren | 0.01 | 0.16 | | 1.30 | 0.02 | 0.18 | 0.21 | 0.01 | 1.90 |
| | Forest | 0.12 | 2.90 | 0.77 | | 0.57 | 0.79 | 0.69 | 0.11 | 5.95 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.00 | 0.93 | 0.22 | 2.22 | 0.03 | 0.03 | | 0.14 | 3.57 |
| | Wetlands | 0.01 | 0.06 | 0.04 | 0.59 | 0.00 | 0.01 | 0.08 | | 0.80 |
| | **Column totals** | **0.16** | **4.08** | **1.09** | **4.33** | **0.61** | **1.02** | **1.01** | **0.27** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 6373 | 1.24 | Water | 8,842 | 1.72 | -2,469 | -0.9 |
| Developed | 166541 | 32.48 | Developed | 5,503 | 1.07 | 161,038 | 56.0 |
| Barren | 44390 | 8.66 | Barren | 77,481 | 15.11 | -33,091 | -11.5 |
| Forest | 176561 | 34.44 | Forest | 242,568 | 47.31 | -66,007 | -22.9 |
| Shrubland | 24995 | 4.88 | Shrubland | 0 | 0.00 | 24,995 | 8.7 |
| Herbaceous | 41511 | 8.10 | Herbaceous | 0 | 0.00 | 41,511 | 14.4 |
| Planted/Cultivated | 41176 | 8.03 | Planted/Cultivated | 145,750 | 28.43 | -104,574 | -36.3 |
| Wetlands | 11157 | 2.18 | Wetlands | 32,560 | 6.35 | -21,403 | -7.4 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5050006

## 1992 to 2006

| | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| **Unchanged** | | | | | | | | | |
| | 0.86 | 3.01 | 0.29 | 81.85 | 0.00 | 0.00 | 0.42 | 0.00 | 86.44 |
| **Changed** (1992 "from" class) | | | | | | | | | |
| Water | | 0.08 | 0.02 | 0.13 | 0.00 | 0.02 | 0.01 | 0.00 | 0.26 |
| Developed | 0.02 | | 0.00 | 0.28 | 0.00 | 0.02 | 0.00 | 0.00 | 0.34 |
| Barren | 0.02 | 0.19 | | 1.73 | 0.02 | 0.74 | 0.07 | 0.00 | 2.77 |
| Forest | 0.10 | 3.79 | 1.21 | | 0.10 | 2.77 | 0.54 | 0.00 | 8.50 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.01 | 0.45 | 0.01 | 0.93 | 0.00 | 0.26 | | 0.00 | 1.67 |
| Wetlands | 0.00 | 0.01 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | | 0.04 |
| **Column totals** | **0.16** | **4.52** | **1.25** | **3.09** | **0.13** | **3.81** | **0.62** | **0.00** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 2329 | 1.14 | Water | 3,832 | 1.88 | -1,503 | -0.5 |
| Developed | 67835 | 33.31 | Developed | 5,062 | 2.49 | 62,773 | 21.8 |
| Barren | 18694 | 9.18 | Barren | 41,558 | 20.41 | -22,864 | -7.9 |
| Forest | 46335 | 22.75 | Forest | 127,592 | 62.66 | -81,257 | -28.2 |
| Shrubland | 1884 | 0.93 | Shrubland | 0 | 0.00 | 1,884 | 0.7 |
| Herbaceous | 57262 | 28.12 | Herbaceous | 0 | 0.00 | 57,262 | 19.9 |
| Planted/Cultivated | 9234 | 4.53 | Planted/Cultivated | 25,051 | 12.30 | -15,817 | -5.5 |
| Wetlands | 54 | 0.03 | Wetlands | 532 | 0.26 | -478 | -0.2 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5050007

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Water** (%) | **Developed** (%) | **Barren** (%) | **Forest** (%) | **Shrubland** (%) | **Herbaceous** (%) | **Planted/Cultivated** (%) | **Wetlands** (%) | **Row Totals** (%) |
| | **Unchanged** | | | | | | | | | |
| | | 0.32 | 0.66 | 0.08 | 88.59 | 0.00 | 0.00 | 1.62 | 0.00 | 91.27 |
| | **Changed** | | | | | | | | | |
| 1992 "from" class | Water | | 0.05 | 0.00 | 0.12 | 0.00 | 0.01 | 0.00 | 0.00 | 0.19 |
| | Developed | 0.01 | | 0.00 | 0.17 | 0.00 | 0.01 | 0.01 | 0.00 | 0.20 |
| | Barren | 0.00 | 0.08 | | 0.49 | 0.01 | 0.05 | 0.03 | 0.00 | 0.67 |
| | Forest | 0.20 | 3.64 | 0.44 | | 0.04 | 0.36 | 0.47 | 0.06 | 5.21 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.01 | 0.76 | 0.05 | 1.53 | 0.02 | 0.05 | | 0.01 | 2.43 |
| | Wetlands | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | | 0.02 |
| | **Column totals** | **0.21** | **4.53** | **0.50** | **2.34** | **0.08** | **0.48** | **0.52** | **0.07** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 9466 | 2.46 | Water | 8,263 | 2.15 | 1,203 | 0.4 |
| Developed | 199513 | 51.89 | Developed | 8,872 | 2.31 | 190,641 | 66.2 |
| Barren | 21862 | 5.69 | Barren | 29,684 | 7.72 | -7,822 | -2.7 |
| Forest | 103046 | 26.80 | Forest | 229,634 | 59.73 | -126,588 | -44.0 |
| Shrubland | 3483 | 0.91 | Shrubland | 0 | 0.00 | 3,483 | 1.2 |
| Herbaceous | 21119 | 5.49 | Herbaceous | 0 | 0.00 | 21,119 | 7.3 |
| Planted/Cultivated | 22880 | 5.95 | Planted/Cultivated | 106,993 | 27.83 | -84,113 | -29.2 |
| Wetlands | 3116 | 0.81 | Wetlands | 1,039 | 0.27 | 2,077 | 0.7 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5050008

## 1992 to 2006

| | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| **Unchanged** | | | | | | | | | |
| | 0.86 | 3.65 | 0.02 | 71.83 | 0.00 | 0.00 | 7.95 | 0.00 | 84.32 |
| **Changed** (1992 "from" class) | | | | | | | | | |
| Water | | 0.07 | 0.02 | 0.12 | 0.00 | 0.02 | 0.04 | 0.00 | 0.27 |
| Developed | 0.01 | | 0.01 | 0.32 | 0.00 | 0.02 | 0.03 | 0.00 | 0.40 |
| Barren | 0.00 | 0.06 | | 0.07 | 0.00 | 0.02 | 0.01 | 0.00 | 0.16 |
| Forest | 0.18 | 4.59 | 0.07 | | 0.02 | 0.59 | 1.24 | 0.02 | 6.72 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.03 | 3.02 | 0.02 | 4.76 | 0.00 | 0.20 | | 0.00 | 8.04 |
| Wetlands | 0.01 | 0.03 | 0.01 | 0.05 | 0.00 | 0.00 | 0.01 | | 0.10 |
| **Column totals** | **0.23** | **7.77** | **0.13** | **5.32** | **0.03** | **0.85** | **1.32** | **0.03** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 6225 | 1.49 | Water | 7,134 | 1.71 | -909 | -0.3 |
| Developed | 206568 | 49.55 | Developed | 10,573 | 2.54 | 195,995 | 68.1 |
| Barren | 3436 | 0.82 | Barren | 4,257 | 1.02 | -821 | -0.3 |
| Forest | 141365 | 33.91 | Forest | 178,558 | 42.83 | -37,193 | -12.9 |
| Shrubland | 761 | 0.18 | Shrubland | 0 | 0.00 | 761 | 0.3 |
| Herbaceous | 22470 | 5.39 | Herbaceous | 0 | 0.00 | 22,470 | 7.8 |
| Planted/Cultivated | 35182 | 8.44 | Planted/Cultivated | 213,594 | 51.24 | -178,412 | -62.0 |
| Wetlands | 847 | 0.20 | Wetlands | 2,738 | 0.66 | -1,891 | -0.7 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5050009

## 1992 to 2006

| | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| **Unchanged** | | | | | | | | | |
| | 0.11 | 1.03 | 0.32 | 80.57 | 0.00 | 0.00 | 0.86 | 0.00 | 82.88 |
| **Changed** (1992 "from" class) | | | | | | | | | |
| Water | | 0.01 | 0.01 | 0.18 | 0.00 | 0.03 | 0.04 | 0.00 | 0.28 |
| Developed | 0.00 | | 0.00 | 0.05 | 0.00 | 0.02 | 0.01 | 0.00 | 0.08 |
| Barren | 0.02 | 0.12 | | 0.82 | 0.00 | 1.19 | 0.07 | 0.00 | 2.22 |
| Forest | 0.21 | 3.06 | 2.37 | | 0.12 | 5.19 | 1.44 | 0.01 | 12.40 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.01 | 0.41 | 0.03 | 1.27 | 0.00 | 0.37 | | 0.00 | 2.10 |
| Wetlands | 0.00 | 0.01 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | | 0.04 |
| **Column totals** | **0.25** | **3.61** | **2.41** | **2.33** | **0.13** | **6.81** | **1.56** | **0.02** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 6283 | 1.43 | Water | 7,085 | 1.61 | -802 | -0.3 |
| Developed | 92484 | 21.08 | Developed | 2,056 | 0.47 | 90,428 | 31.4 |
| Barren | 61807 | 14.09 | Barren | 56,954 | 12.98 | 4,853 | 1.7 |
| Forest | 59806 | 13.63 | Forest | 317,861 | 72.44 | -258,055 | -89.7 |
| Shrubland | 3250 | 0.74 | Shrubland | 0 | 0.00 | 3,250 | 1.1 |
| Herbaceous | 174593 | 39.79 | Herbaceous | 0 | 0.00 | 174,593 | 60.7 |
| Planted/Cultivated | 39969 | 9.11 | Planted/Cultivated | 53,846 | 12.27 | -13,877 | -4.8 |
| Wetlands | 571 | 0.13 | Wetlands | 961 | 0.22 | -390 | -0.1 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5070101

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 0.17 | 0.79 | 0.17 | 82.60 | 0.00 | 0.00 | 0.28 | 0.00 | 84.01 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.02 | 0.01 | 0.10 | 0.00 | 0.05 | 0.02 | 0.00 | 0.19 |
| | Developed | 0.00 | | 0.00 | 0.03 | 0.00 | 0.01 | 0.00 | 0.00 | 0.05 |
| | Barren | 0.01 | 0.23 | | 0.75 | 0.01 | 0.88 | 0.13 | 0.00 | 2.01 |
| | Forest | 0.13 | 4.73 | 1.48 | | 0.08 | 4.85 | 0.87 | 0.00 | 12.12 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.00 | 0.26 | 0.02 | 0.98 | 0.00 | 0.35 | | 0.00 | 1.61 |
| | Wetlands | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | | 0.02 |
| | **Column totals** | **0.14** | **5.23** | **1.50** | **1.87** | **0.09** | **6.14** | **1.01** | **0.00** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 3792 | 0.88 | Water | 5,059 | 1.17 | -1,267 | -0.4 |
| Developed | 141612 | 32.70 | Developed | 1,387 | 0.32 | 140,225 | 48.7 |
| Barren | 40737 | 9.41 | Barren | 54,293 | 12.54 | -13,556 | -4.7 |
| Forest | 50719 | 11.71 | Forest | 328,217 | 75.80 | -277,498 | -96.4 |
| Shrubland | 2322 | 0.54 | Shrubland | 0 | 0.00 | 2,322 | 0.8 |
| Herbaceous | 166315 | 38.41 | Herbaceous | 0 | 0.00 | 166,315 | 57.8 |
| Planted/Cultivated | 27450 | 6.34 | Planted/Cultivated | 43,466 | 10.04 | -16,016 | -5.6 |
| Wetlands | 63 | 0.01 | Wetlands | 588 | 0.14 | -525 | -0.2 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5070102

## 1992 to 2006

| | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| **Unchanged** | | | | | | | | | |
| | 0.10 | 1.72 | 0.03 | 77.40 | 0.00 | 0.00 | 2.26 | 0.00 | 81.51 |
| **Changed** (1992 "from" class) | | | | | | | | | |
| Water | | 0.04 | 0.00 | 0.16 | 0.00 | 0.02 | 0.09 | 0.00 | 0.32 |
| Developed | 0.00 | | 0.00 | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.04 |
| Barren | 0.00 | 0.13 | | 0.07 | 0.00 | 0.30 | 0.01 | 0.00 | 0.52 |
| Forest | 0.20 | 5.20 | 0.70 | | 0.02 | 3.27 | 1.63 | 0.02 | 11.05 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.03 | 1.61 | 0.05 | 4.04 | 0.00 | 0.81 | | 0.01 | 6.54 |
| Wetlands | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | | 0.02 |
| **Column totals** | **0.23** | **6.98** | **0.75** | **4.31** | **0.02** | **4.41** | **1.74** | **0.04** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 4972 | 1.26 | Water | 6,738 | 1.71 | -1,766 | -0.6 |
| Developed | 149115 | 37.78 | Developed | 879 | 0.22 | 148,236 | 51.5 |
| Barren | 16055 | 4.07 | Barren | 11,077 | 2.81 | 4,978 | 1.7 |
| Forest | 92046 | 23.32 | Forest | 235,881 | 59.76 | -143,835 | -50.0 |
| Shrubland | 484 | 0.12 | Shrubland | 0 | 0.00 | 484 | 0.2 |
| Herbaceous | 94099 | 23.84 | Herbaceous | 0 | 0.00 | 94,099 | 32.7 |
| Planted/Cultivated | 37174 | 9.42 | Planted/Cultivated | 139,701 | 35.39 | -102,527 | -35.6 |
| Wetlands | 756 | 0.19 | Wetlands | 425 | 0.11 | 331 | 0.1 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5070201

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 0.15 | 0.95 | 0.18 | 82.66 | 0.00 | 0.00 | 0.26 | 0.00 | 84.19 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.05 | 0.01 | 0.13 | 0.00 | 0.05 | 0.02 | 0.00 | 0.26 |
| | Developed | 0.01 | | 0.01 | 0.07 | 0.00 | 0.03 | 0.02 | 0.00 | 0.14 |
| | Barren | 0.01 | 0.17 | | 0.68 | 0.02 | 0.81 | 0.11 | 0.00 | 1.81 |
| | Forest | 0.17 | 5.45 | 1.27 | | 0.08 | 4.04 | 0.87 | 0.00 | 11.88 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.00 | 0.36 | 0.02 | 1.02 | 0.00 | 0.30 | | 0.00 | 1.70 |
| | Wetlands | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | | 0.02 |
| | **Column totals** | **0.20** | **6.02** | **1.30** | **1.91** | **0.11** | **5.24** | **1.03** | **0.00** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 5425 | 1.25 | Water | 7,091 | 1.63 | -1,666 | -0.6 |
| Developed | 165978 | 38.11 | Developed | 3,752 | 0.86 | 162,226 | 56.4 |
| Barren | 35943 | 8.25 | Barren | 49,807 | 11.43 | -13,864 | -4.8 |
| Forest | 52511 | 12.06 | Forest | 327,452 | 75.18 | -274,941 | -95.5 |
| Shrubland | 3038 | 0.70 | Shrubland | 0 | 0.00 | 3,038 | 1.1 |
| Herbaceous | 144259 | 33.12 | Herbaceous | 0 | 0.00 | 144,259 | 50.1 |
| Planted/Cultivated | 28301 | 6.50 | Planted/Cultivated | 46,893 | 10.77 | -18,592 | -6.5 |
| Wetlands | 121 | 0.03 | Wetlands | 581 | 0.13 | -460 | -0.2 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

# Watershed: 5070204

# 1992 to 2006

| | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Water** (%) | **Developed** (%) | **Barren** (%) | **Forest** (%) | **Shrubland** (%) | **Herbaceous** (%) | **Planted/Cultivated** (%) | **Wetlands** (%) | **Row Totals** (%) |
| **Unchanged** | | | | | | | | | |
| | 1.32 | 2.93 | 0.04 | 61.44 | 0.00 | 0.00 | 5.40 | 0.00 | 71.14 |
| **Changed** (1992 "from" class) | | | | | | | | | |
| Water | | 0.15 | 0.01 | 0.22 | 0.01 | 0.03 | 0.03 | 0.00 | 0.44 |
| Developed | 0.11 | | 0.02 | 0.18 | 0.01 | 0.04 | 0.08 | 0.00 | 0.43 |
| Barren | 0.05 | 0.25 | | 0.03 | 0.00 | 0.01 | 0.01 | 0.00 | 0.34 |
| Forest | 0.64 | 7.10 | 0.11 | | 0.24 | 3.56 | 2.66 | 0.01 | 14.33 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.12 | 4.03 | 0.02 | 6.94 | 0.13 | 1.54 | | 0.01 | 12.78 |
| Wetlands | 0.00 | 0.18 | 0.00 | 0.14 | 0.00 | 0.00 | 0.20 | | 0.53 |
| **Column totals** | **0.92** | **11.71** | **0.17** | **7.51** | **0.39** | **5.17** | **2.98** | **0.02** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 2039 | 3.17 | Water | 976 | 1.52 | 1,063 | 0.4 |
| Developed | 26057 | 40.57 | Developed | 961 | 1.50 | 25,096 | 8.7 |
| Barren | 372 | 0.58 | Barren | 761 | 1.18 | -389 | -0.1 |
| Forest | 16705 | 26.01 | Forest | 31,896 | 49.67 | -15,191 | -5.3 |
| Shrubland | 863 | 1.34 | Shrubland | 0 | 0.00 | 863 | 0.3 |
| Herbaceous | 11509 | 17.92 | Herbaceous | 0 | 0.00 | 11,509 | 4.0 |
| Planted/Cultivated | 6632 | 10.33 | Planted/Cultivated | 28,440 | 44.28 | -21,808 | -7.6 |
| Wetlands | 45 | 0.07 | Wetlands | 1,188 | 1.85 | -1,143 | -0.4 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5090101

## 1992 to 2006

| | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| **Unchanged** | | | | | | | | | |
| | 5.36 | 5.97 | 0.00 | 56.55 | 0.00 | 0.00 | 9.22 | 0.02 | 77.13 |
| **Changed** (1992 "from" class) | | | | | | | | | |
| Water | | 0.07 | 0.00 | 0.06 | 0.00 | 0.01 | 0.07 | 0.00 | 0.21 |
| Developed | 0.02 | | 0.00 | 0.03 | 0.00 | 0.00 | 0.01 | 0.00 | 0.06 |
| Barren | 0.01 | 0.06 | | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.09 |
| Forest | 0.55 | 5.28 | 0.01 | | 0.01 | 0.95 | 3.52 | 0.13 | 10.45 |
| Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| Planted/Cultivated | 0.17 | 3.45 | 0.01 | 6.92 | 0.05 | 1.10 | | 0.06 | 11.77 |
| Wetlands | 0.06 | 0.07 | 0.00 | 0.08 | 0.00 | 0.01 | 0.07 | | 0.29 |
| **Column totals** | **0.81** | **8.94** | **0.02** | **7.09** | **0.07** | **2.07** | **3.68** | **0.19** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 5467 | 3.53 | Water | 1,421 | 0.92 | 4,046 | 1.4 |
| Developed | 60516 | 39.09 | Developed | 429 | 0.28 | 60,087 | 20.9 |
| Barren | 145 | 0.09 | Barren | 597 | 0.39 | -452 | -0.2 |
| Forest | 47999 | 31.00 | Forest | 70,760 | 45.71 | -22,761 | -7.9 |
| Shrubland | 451 | 0.29 | Shrubland | 0 | 0.00 | 451 | 0.2 |
| Herbaceous | 14013 | 9.05 | Herbaceous | 0 | 0.00 | 14,013 | 4.9 |
| Planted/Cultivated | 24926 | 16.10 | Planted/Cultivated | 79,663 | 51.46 | -54,737 | -19.0 |
| Wetlands | 1301 | 0.84 | Wetlands | 1,948 | 1.26 | -647 | -0.2 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Land Cover Change Comparison

## Watershed: 5090102

## 1992 to 2006

| | | 2006 "to" class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water (%) | Developed (%) | Barren (%) | Forest (%) | Shrubland (%) | Herbaceous (%) | Planted/Cultivated (%) | Wetlands (%) | Row Totals (%) |
| | Unchanged | | | | | | | | | |
| | | 0.48 | 0.51 | 0.12 | 78.63 | 0.00 | 0.00 | 1.24 | 0.00 | 80.98 |
| | Changed | | | | | | | | | |
| 1992 "from" class | Water | | 0.02 | 0.04 | 0.21 | 0.00 | 0.01 | 0.07 | 0.00 | 0.36 |
| | Developed | 0.00 | | 0.00 | 0.02 | 0.00 | 0.01 | 0.00 | 0.00 | 0.03 |
| | Barren | 0.01 | 0.03 | | 0.15 | 0.00 | 0.43 | 0.01 | 0.00 | 0.63 |
| | Forest | 0.21 | 5.00 | 0.45 | | 0.23 | 5.38 | 0.95 | 0.03 | 12.25 |
| | Shrubland | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| | Herbaceous | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 |
| | Planted/Cultivated | 0.05 | 1.20 | 0.04 | 3.40 | 0.02 | 1.01 | | 0.01 | 5.73 |
| | Wetlands | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | | 0.02 |
| | **Column totals** | **0.26** | **6.26** | **0.54** | **3.79** | **0.26** | **6.84** | **1.04** | **0.04** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 1992 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Water | 3366 | 1.39 | Water | 4,606 | 1.90 | -1,240 | -0.4 |
| Developed | 79548 | 32.90 | Developed | 393 | 0.16 | 79,155 | 27.5 |
| Barren | 6869 | 2.84 | Barren | 8,059 | 3.33 | -1,190 | -0.4 |
| Forest | 48168 | 19.92 | Forest | 155,703 | 64.39 | -107,535 | -37.4 |
| Shrubland | 3261 | 1.35 | Shrubland | 0 | 0.00 | 3,261 | 1.1 |
| Herbaceous | 86955 | 35.96 | Herbaceous | 0 | 0.00 | 86,955 | 30.2 |
| Planted/Cultivated | 13201 | 5.46 | Planted/Cultivated | 72,799 | 30.10 | -59,598 | -20.7 |
| Wetlands | 455 | 0.19 | Wetlands | 263 | 0.11 | 192 | 0.1 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Appendix W

CEGAS Imperviousness Change Comparison
(2001-2006)

## Imperviousness Change Comparison

## 2001 to 2006

The charts below compare National Land Cover Database (NLCD) 2001 and 2006 Percent Developed Imperviousness datasets.

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | Pervious (%) | Impervious (%) | Row Totals (%) |
| 2001 "from" class | Unchanged | | | |
| | | 97.19 | 2.22 | 99.41 |
| | Changed | | | |
| | Pervious | | 61.88 | 61.88 |
| | Impervious | 38.12 | | 38.12 |
| | **Column totals** | **38.12** | **61.88** | **100.00** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 158,979 | 38.12 | Pervious | 258,035 | 61.88 | -99,056 | -34 |
| Impervious | 258,035 | 61.88 | Impervious | 158,979 | 38.12 | 99,056 | 34 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 2070001

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 99.16 | 0.63 | 99.79 |
| | **Changed** | | | |
| | Pervious | | 60.64 | 60.64 |
| | Impervious | 39.36 | | 39.36 |
| | **Column totals** | **39.36** | **60.64** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 3,279 | 39.36 | Pervious | 5,052 | 60.64 | -1,773 | -0.62 |
| Impervious | 5,052 | 60.64 | Impervious | 3,279 | 39.36 | 1,773 | 0.62 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 2070002

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 98.28 | 1.42 | 99.70 |
| | **Changed** | | | |
| | Pervious | | 57.44 | 57.44 |
| | Impervious | 42.56 | | 42.56 |
| | **Column totals** | **42.56** | **57.44** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 2,204 | 42.56 | Pervious | 2,975 | 57.44 | -771 | -0.27 |
| Impervious | 2,975 | 57.44 | Impervious | 2,204 | 42.56 | 771 | 0.27 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 2070003

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 99.23 | 0.53 | 99.76 |
| | **Changed** | | | |
| | Pervious | | 60.07 | 60.07 |
| | Impervious | 39.93 | | 39.93 |
| | **Column totals** | **39.93** | **60.07** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 2,294 | 39.93 | Pervious | 3,451 | 60.07 | -1,157 | -0.40 |
| Impervious | 3,451 | 60.07 | Impervious | 2,294 | 39.93 | 1,157 | 0.40 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Imperviousness Change Comparison

## Watershed: 2070004

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | Pervious (%) | Impervious (%) | Row Totals (%) |
| 2001 "from" class | Unchanged | | | |
| | | 94.33 | 4.12 | 98.46 |
| | Changed | | | |
| | Pervious | | 73.12 | 73.12 |
| | Impervious | 26.88 | | 26.88 |
| | **Column totals** | **26.88** | **73.12** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 7,432 | 26.88 | Pervious | 20,221 | 73.12 | -12,789 | -4.44 |
| Impervious | 20,221 | 73.12 | Impervious | 7,432 | 26.88 | 12,789 | 4.44 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 2070005

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 99.93 | 0.03 | 99.97 |
| | **Changed** | | | |
| | Pervious | | 66.67 | 66.67 |
| | Impervious | 33.33 | | 33.33 |
| | **Column totals** | **33.33** | **66.67** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 1 | 33.33 | Pervious | 2 | 66.67 | -1 | 0.00 |
| Impervious | 2 | 66.67 | Impervious | 1 | 33.33 | 1 | 0.00 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 2070006

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 99.62 | 0.27 | 99.88 |
| | **Changed** | | | |
| | Pervious | | 50.68 | 50.68 |
| | Impervious | 49.32 | | 49.32 |
| | **Column totals** | **49.32** | **50.68** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 72 | 49.32 | Pervious | 74 | 50.68 | -2 | 0.00 |
| Impervious | 74 | 50.68 | Impervious | 72 | 49.32 | 2 | 0.00 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 2070007

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | | **Unchanged** | | |
| | | 92.42 | 5.55 | 97.97 |
| | | **Changed** | | |
| | Pervious | | 73.58 | 73.58 |
| | Impervious | 26.42 | | 26.42 |
| | **Column totals** | **26.42** | **73.58** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 1,646 | 26.42 | Pervious | 4,584 | 73.58 | -2,938 | -1.02 |
| Impervious | 4,584 | 73.58 | Impervious | 1,646 | 26.42 | 2,938 | 1.02 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 2080201

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | | **Unchanged** | | |
| | | 99.60 | 0.29 | 99.89 |
| | | **Changed** | | |
| | Pervious | | 50.78 | 50.78 |
| | Impervious | 49.22 | | 49.22 |
| | **Column totals** | **49.22** | **50.78** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 190 | 49.22 | Pervious | 196 | 50.78 | -6 | 0.00 |
| Impervious | 196 | 50.78 | Impervious | 190 | 49.22 | 6 | 0.00 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5020001

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 97.99 | 1.60 | 99.60 |
| | **Changed** | | | |
| | Pervious | | 61.37 | 61.37 |
| | Impervious | 38.63 | | 38.63 |
| | **Column totals** | **38.63** | **61.37** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 6,177 | 38.63 | Pervious | 9,814 | 61.37 | -3,637 | -1.26 |
| Impervious | 9,814 | 61.37 | Impervious | 6,177 | 38.63 | 3,637 | 1.26 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5020002

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 96.01 | 3.25 | 99.26 |
| | **Changed** | | | |
| | Pervious | | 59.61 | 59.61 |
| | Impervious | 40.39 | | 40.39 |
| | **Column totals** | **40.39** | **59.61** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 7,662 | 40.39 | Pervious | 11,306 | 59.61 | -3,644 | -1.27 |
| Impervious | 11,306 | 59.61 | Impervious | 7,662 | 40.39 | 3,644 | 1.27 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5020003

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 94.61 | 4.25 | 98.87 |
| | **Changed** | | | |
| | Pervious | | 69.20 | 69.20 |
| | Impervious | 30.80 | | 30.80 |
| | **Column totals** | **30.80** | **69.20** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 4,582 | 30.80 | Pervious | 10,297 | 69.20 | -5,715 | -1.99 |
| Impervious | 10,297 | 69.20 | Impervious | 4,582 | 30.80 | 5,715 | 1.99 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5020004

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 99.13 | 0.65 | 99.78 |
| | **Changed** | | | |
| | Pervious | | 61.76 | 61.76 |
| | Impervious | 38.24 | | 38.24 |
| | **Column totals** | **38.24** | **61.76** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 3,186 | 38.24 | Pervious | 5,146 | 61.76 | -1,960 | -0.68 |
| Impervious | 5,146 | 61.76 | Impervious | 3,186 | 38.24 | 1,960 | 0.68 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5020005

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 99.07 | 0.61 | 99.68 |
| | **Changed** | | | |
| | Pervious | | 65.25 | 65.25 |
| | Impervious | 34.75 | | 34.75 |
| | **Column totals** | **34.75** | **65.25** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 369 | 34.75 | Pervious | 693 | 65.25 | -324 | -0.11 |
| Impervious | 693 | 65.25 | Impervious | 369 | 34.75 | 324 | 0.11 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5020006

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 99.02 | 0.63 | 99.66 |
| | **Changed** | | | |
| | Pervious | | 61.72 | 61.72 |
| | Impervious | 38.28 | | 38.28 |
| | **Column totals** | **38.28** | **61.72** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 281 | 38.28 | Pervious | 453 | 61.72 | -172 | -0.06 |
| Impervious | 453 | 61.72 | Impervious | 281 | 38.28 | 172 | 0.06 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5030101

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 87.31 | 10.19 | 97.51 |
| | **Changed** | | | |
| | Pervious | | 75.30 | 75.30 |
| | Impervious | 24.70 | | 24.70 |
| | **Column totals** | **24.70** | **75.30** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 2,474 | 24.70 | Pervious | 7,544 | 75.30 | -5,070 | -1.76 |
| Impervious | 7,544 | 75.30 | Impervious | 2,474 | 24.70 | 5,070 | 1.76 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5030106

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | Pervious (%) | Impervious (%) | Row Totals (%) |
| 2001 "from" class | Unchanged | | | |
| | | 95.36 | 3.70 | 99.06 |
| | Changed | | | |
| | Pervious | | 70.68 | 70.68 |
| | Impervious | 29.32 | | 29.32 |
| | **Column totals** | **29.32** | **70.68** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 4,566 | 29.32 | Pervious | 11,005 | 70.68 | -6,439 | -2.24 |
| Impervious | 11,005 | 70.68 | Impervious | 4,566 | 29.32 | 6,439 | 2.24 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5030201

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 98.42 | 1.26 | 99.68 |
| | **Changed** | | | |
| | Pervious | | 58.70 | 58.70 |
| | Impervious | 41.30 | | 41.30 |
| | **Column totals** | **41.30** | **58.70** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 3,695 | 41.30 | Pervious | 5,251 | 58.70 | -1,556 | -0.54 |
| Impervious | 5,251 | 58.70 | Impervious | 3,695 | 41.30 | 1,556 | 0.54 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5030202

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 95.29 | 3.83 | 99.12 |
| | **Changed** | | | |
| | Pervious | | 60.72 | 60.72 |
| | Impervious | 39.28 | | 39.28 |
| | **Column totals** | **39.28** | **60.72** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 7,239 | 39.28 | Pervious | 11,192 | 60.72 | -3,953 | -1.37 |
| Impervious | 11,192 | 60.72 | Impervious | 7,239 | 39.28 | 3,953 | 1.37 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5030203

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 98.67 | 1.03 | 99.70 |
| | **Changed** | | | |
| | Pervious | | 60.53 | 60.53 |
| | Impervious | 39.47 | | 39.47 |
| | **Column totals** | **39.47** | **60.53** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 7,761 | 39.47 | Pervious | 11,902 | 60.53 | -4,141 | -1.44 |
| Impervious | 11,902 | 60.53 | Impervious | 7,761 | 39.47 | 4,141 | 1.44 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5050002

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 95.03 | 3.99 | 99.02 |
| | **Changed** | | | |
| | Pervious | | 59.79 | 59.79 |
| | Impervious | 40.21 | | 40.21 |
| | **Column totals** | **40.21** | **59.79** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 9,351 | 40.21 | Pervious | 13,903 | 59.79 | -4,552 | -1.58 |
| Impervious | 13,903 | 59.79 | Impervious | 9,351 | 40.21 | 4,552 | 1.58 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5050003

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| 2001 "from" class | **Unchanged** | | | |
| | | 98.38 | 1.28 | 99.65 |
| | **Changed** | | | |
| | Pervious | | 53.62 | 53.62 |
| | Impervious | 46.38 | | 46.38 |
| | **Column totals** | **46.38** | **53.62** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 7,666 | 46.38 | Pervious | 8,861 | 53.62 | -1,195 | -0.42 |
| Impervious | 8,861 | 53.62 | Impervious | 7,666 | 46.38 | 1,195 | 0.42 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5050004

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 93.14 | 5.74 | 98.88 |
| | **Changed** | | | |
| | Pervious | | 59.90 | 59.90 |
| | Impervious | 40.10 | | 40.10 |
| | **Column totals** | **40.10** | **59.90** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 8,964 | 40.10 | Pervious | 13,392 | 59.90 | -4,428 | -1.54 |
| Impervious | 13,392 | 59.90 | Impervious | 8,964 | 40.10 | 4,428 | 1.54 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5050005

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 98.54 | 1.15 | 99.69 |
| | **Changed** | | | |
| | Pervious | | 56.80 | 56.80 |
| | Impervious | 43.20 | | 43.20 |
| | **Column totals** | **43.20** | **56.80** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 5,414 | 43.20 | Pervious | 7,118 | 56.80 | -1,704 | -0.59 |
| Impervious | 7,118 | 56.80 | Impervious | 5,414 | 43.20 | 1,704 | 0.59 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5050006

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 95.73 | 3.58 | 99.31 |
| | **Changed** | | | |
| | Pervious | | 62.55 | 62.55 |
| | Impervious | 37.45 | | 37.45 |
| | **Column totals** | **37.45** | **62.55** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 3,872 | 37.45 | Pervious | 6,467 | 62.55 | -2,595 | -0.90 |
| Impervious | 6,467 | 62.55 | Impervious | 3,872 | 37.45 | 2,595 | 0.90 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5050007

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 98.90 | 0.84 | 99.74 |
| | **Changed** | | | |
| | Pervious | | 61.53 | 61.53 |
| | Impervious | 38.47 | | 38.47 |
| | **Column totals** | **38.47** | **61.53** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 4,409 | 38.47 | Pervious | 7,052 | 61.53 | -2,643 | -0.92 |
| Impervious | 7,052 | 61.53 | Impervious | 4,409 | 38.47 | 2,643 | 0.92 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5050008

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 94.65 | 4.37 | 99.02 |
| | **Changed** | | | |
| | Pervious | | 64.01 | 64.01 |
| | Impervious | 35.99 | | 35.99 |
| | **Column totals** | **35.99** | **64.01** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 9,395 | 35.99 | Pervious | 16,709 | 64.01 | -7,314 | -2.54 |
| Impervious | 16,709 | 64.01 | Impervious | 9,395 | 35.99 | 7,314 | 2.54 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5050009

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 97.36 | 1.99 | 99.35 |
| | **Changed** | | | |
| | Pervious | | 59.01 | 59.01 |
| | Impervious | 40.99 | | 40.99 |
| | **Column totals** | **40.99** | **59.01** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 6,876 | 40.99 | Pervious | 9,899 | 59.01 | -3,023 | -1.05 |
| Impervious | 9,899 | 59.01 | Impervious | 6,876 | 40.99 | 3,023 | 1.05 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5070101

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 97.10 | 2.22 | 99.31 |
| | **Changed** | | | |
| | Pervious | | 57.97 | 57.97 |
| | Impervious | 42.03 | | 42.03 |
| | **Column totals** | **42.03** | **57.97** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 7,810 | 42.03 | Pervious | 10,772 | 57.97 | -2,962 | -1.03 |
| Impervious | 10,772 | 57.97 | Impervious | 7,810 | 42.03 | 2,962 | 1.03 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5070102

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 95.16 | 3.73 | 98.89 |
| | **Changed** | | | |
| | Pervious | | 59.13 | 59.13 |
| | Impervious | 40.87 | | 40.87 |
| | **Column totals** | **40.87** | **59.13** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 9,708 | 40.87 | Pervious | 14,045 | 59.13 | -4,337 | -1.51 |
| Impervious | 14,045 | 59.13 | Impervious | 9,708 | 40.87 | 4,337 | 1.51 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5070201

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 96.22 | 2.89 | 99.10 |
| | **Changed** | | | |
| | Pervious | | 58.08 | 58.08 |
| | Impervious | 41.92 | | 41.92 |
| | **Column totals** | **41.92** | **58.08** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 10,469 | 41.92 | Pervious | 14,503 | 58.08 | -4,034 | -1.40 |
| Impervious | 14,503 | 58.08 | Impervious | 10,469 | 41.92 | 4,034 | 1.40 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5070204

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 90.20 | 8.01 | 98.21 |
| | **Changed** | | | |
| | Pervious | | 63.47 | 63.47 |
| | Impervious | 36.53 | | 36.53 |
| | **Column totals** | **36.53** | **63.47** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 1,531 | 36.53 | Pervious | 2,660 | 63.47 | -1,129 | -0.39 |
| Impervious | 2,660 | 63.47 | Impervious | 1,531 | 36.53 | 1,129 | 0.39 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Imperviousness Change Comparison

## Watershed: 5090101

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | Pervious (%) | Impervious (%) | Row Totals (%) |
| 2001 "from" class | **Unchanged** | | | |
| | | 89.90 | 8.72 | 98.62 |
| | **Changed** | | | |
| | Pervious | | 55.81 | 55.81 |
| | Impervious | 44.19 | | 44.19 |
| | **Column totals** | **44.19** | **55.81** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 4,125 | 44.19 | Pervious | 5,210 | 55.81 | -1,085 | -0.38 |
| Impervious | 5,210 | 55.81 | Impervious | 4,125 | 44.19 | 1,085 | 0.38 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

## Imperviousness Change Comparison

## Watershed: 5090102

## 2001 to 2006

| | | 2006 "to" class | | |
|---|---|---|---|---|
| | | **Pervious (%)** | **Impervious (%)** | **Row Totals (%)** |
| **2001 "from" class** | **Unchanged** | | | |
| | | 97.10 | 2.08 | 99.18 |
| | **Changed** | | | |
| | Pervious | | 59.47 | 59.47 |
| | Impervious | 40.53 | | 40.53 |
| | **Column totals** | **40.53** | **59.47** | **100** |

Change results matrix for West Virginia. Unchanged pixels are a percentage of all pixels, while changed pixels are a percentage of all changed pixels.

| 2006 "to" class | Number of pixels | Percent of total changed pixels | 2001 "from" class | Number of pixels | Percent of total changed pixels | Net gain/loss pixels | Net gain/loss square miles |
|---|---|---|---|---|---|---|---|
| Pervious | 4,225 | 40.53 | Pervious | 6,200 | 59.47 | -1,975 | -0.69 |
| Impervious | 6,200 | 59.47 | Impervious | 4,225 | 40.53 | 1,975 | 0.69 |

To and from class change statistics with net gain/loss expressed in pixels and square miles. Changed pixel percentages are expressed as the percent of total changed pixels. The conversion factor used in calculating the land area was square miles = number of pixels x .0009 x .386102.

# Appendix X

## Source Water Quantity Not Adequate for the Next Five Years (self-reported)

This report was generated by the DEP based on several relevant reports and data including a Department of Health and Human Services survey, Public Service Commission Reports (PSC), West Virginia Infrastructure and Job Development Council project data, and Sanitary Surveys. For this appendix pages labeled INSERT were omitted, however, that data is available to the public, via online interface, in the corresponding PSC report.

# Table of Contents

*PSD NAME* | *PWSID#* | *CONTACT*

## Buffalo Creek PSD (B) (1720) 3302347 David Crawford

35 Cartwright Branch Road Crites, WV
PO Box 209 Amherstdale, WV

304-583-6586
dvallet@suddenlinkmail.com

## Supply Sources

### Surface Water

- Main Buffalo Creek - Gravity
- Davy Branch – Gravity

### Groundwater

- Mine 1
- Mine 2
- Mine 3

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 8,730 |
| Fire department use | 625 |
| Backwashing | 13,882 |
| Unaccounted loss | 14,484 |
| Gallons sold | 60,551 |
| Percent unaccounted for | 14.74% |

| 2011-2012 Electric Pumping Statistics (Gallons station pumping into distribution mains) | |
|---|---|
| July | 1,020 |
| August | 9,814 |
| September | 9,558 |
| October | 9,558 |
| November | 9,000 |
| December | 8,725 |
| January | 8,900 |
| February | 8,500 |
| March | 7,777 |
| April | 8,200 |
| May | 8,900 |
| June | 8,320 |
| Total for Year | 98,272 |

## Storage Reservoir

- 1,650,000 storage capacity
- Steel tank

## Counties Served

- Logan

## District Office

- St. Albans

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 55,079 | 58,703 | 1,180 | 1,177 |
| Commercial | 5,472 | 5,379 | 3 | 3 |
| TOTAL Sales | 60,551 | 64,082 | 1,183 | 1,180 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Annual total number of leaks | 17.0 |
| Annual total number of breaks | 0.0 |
| Planned maintenance hours | 300.0 |
| Corrective maintenance hours | 40.0 |
| Planned budgeted maintenance cost | 14,000.0 |
| Corrective (experienced) maintenance cost | 2,000.0 |

## Pumping Station Equipment (Buffalo Creek PSD, pg. 703A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Buffalo Creek PSD, pg. 704A-704B INSERT)

*No new feet of water Mains, water services, or new hydrants were added to the system (2012)

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | In Stock | TOTAL |
|---|---|---|---|---|
| 5/8" | 1,210 | | 17 | 1,227 |
| 2" | 7 | 3 | | 10 |
| TOTAL | 1,217 | 3 | 17 | 1,237 |

**115 Old Meters were tested during the period. All were 1% to 2%, inclusive, slow.

## WVIJDC

Shows water served area but no water plant or lines near center of served area.

Shows nearest wastewater plant in Man on connected served area.

| PSD NAME | PWSID# | CONTACT |
|---|---|---|
| **Century Volga PSD (B)** | **3300107** | **Linda Rice** |

946 Buckhannon Road Philippi, WV

304-457-5735
centuryvolgapsd@aol.com

## Supply Sources

### Surface/Purchase Water

- The City of Philippi – Gravity
- Gallons supplied: 52,862,200

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 500 |
| Backwashing | 1,660 |
| Unaccounted loss | 8,921 |
| Gallons sold | 36,756 |
| Percent unaccounted for | 18.65% |
| Cost of Gallons unaccounted for | $51,831 |

## Storage

### Reservoir

- 445,000 storage capacity
- Steel tanks

## Counties Served

- Barbour

## District Office

- Philippi

| 2011 - 2012 Purchased Water Statistics (Gallons station pumping into distribution mains) | |
|---|---|
| July | 4,433 |
| August | 3,957 |
| September | 5,545 |
| October | 4,515 |
| November | 2,795 |
| December | 3,506 |
| January | 4,114 |
| February | 3,532 |
| March | 3,196 |
| April | 4,195 |
| May | 3,477 |
| June | 4,572 |
| Total for year | 47,837 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 35,041 | 35,027 | 994 | 968 |
| Commercial | 1,715 | 1,796 | 36 | 32 |
| TOTAL Sales | 36,756 | 36,823 | 1,030 | 1,000 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 6.0 |
| Water Main Breaks Repaired | 4.0 |
| Annual total number of leaks | 4.0 |
| Annual total number of breaks | 6.0 |
| Planned maintenance hours | 4,160.0 |
| Corrective maintenance hours | 160.0 |
| Planned budgeted maintenance cost | 44,805.0 |
| Corrective (experienced) maintenance cost | 2,585.0 |

## Pumping Station Equipment (Century Volga PSD, pg. 703A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Century Volga PSD, pg. 704A-704B INSERT)

*No new feet of water Mains, water services, or new hydrants were added to the system (2011-2012)

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | In Stock | TOTAL |
|---|---|---|---|---|
| 3/4' | 1,086 | 38 | 10 | 1,134 |
| 1" | | 3 | 1 | 4 |
| 1 ½" | | | | |
| 2" | | 2 | 3 | 5 |
| TOTAL | 1,086 | 43 | 14 | 1,143 |

**33 Old Meters were tested during the period. 20 were < 1% slow and 2 were 1% to 2%, inclusive, slow. One meter was <1% fast. **380 meters are past due for testing**.

## WVIJDC

Shows water served area but no water plant near center of served area.

Shows nearest wastewater plant in Philippi on connected served area.

### Project: Century Volga

- ➔ Water Line Extension – 2002W-664
  - o 88 residential customers in Brushy Fork, Spawlick, and Scales Roads
  - o One water storage tank and booster station
- ➔ Project Cost - $1, 816,153.49

- Under construction

### Project: City of Philippi

- New water plant – 2008W-1070
  - New 2,100gpm water treatment to replace 1,500gpm plant
- Project Cost - $14,664,000.00
  - Under construction

| *PSD NAME* | *PWSID#* | *CONTACT* |
|---|---|---|
| **Chestnut Ridge PSDs (B)** | **3300109 AND 102** | **Sharon Miller** |

209 South Main Street Philippi, WV

304-457-4935
crpsd@frontier.com

## Supply Sources

### Surface/Purchase Water

- The City of Philippi

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 447 |
| Fire department use | 30 |
| Main Leaks | 2,235 |
| Unaccounted loss | 27,645 |
| Gallons sold | 39,993 |
| Percent unaccounted for | 39.30% |
| Cost of Gallons unaccounted for | $103,392 |

## Storage Reservoir

- 350,000 storage capacity
- Steel tanks

## Counties Served

- Barbour

## District Office

- Philippi

| 2011 - 2012 Purchased Water Statistics (Gallons station pumping into distribution mains) | |
|---|---|
| July | 6,548 |
| August | 5,707 |
| September | 6,162 |
| October | 6,338 |
| November | 4,685 |
| December | 5,145 |
| January | 6,618 |
| February | 7,254 |
| March | 3,758 |
| April | 6,219 |
| May | 5,277 |
| June | 6,639 |
| Total for year | 70,350 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 38,385 | 38,938 | 1,170 | 1,046 |
| Commercial | 1,608 | 1,790 | 36 | 37 |
| TOTAL Sales | 39,993 | 40,728 | 1,206 | 1,083 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 23.0 |
| Water Main Breaks Repaired | 23.0 |
| Annual total number of leaks | 30.0 |
| Planned maintenance hours | 200.0 |
| Corrective maintenance hours | 125.0 |

## Pumping Station Equipment (Century Volga PSD, pg. 703A – 703B INSERT)

*980 new feet of 2" HDPE pipes were added to the water mains. No new water services or new hydrants were added to the system (2011-2012)

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | TOTAL |
|---|---|---|---|
| 5/8" | 1,170 | 36 | 1,206 |
| TOTAL | 1,170 | 36 | 1,206 |

**20 Old Meters were tested during the period. None were slow or fast. **280 meters are past due for testing**.

## WVIJDC

Shows water served area but no water plant near center of served area.

Shows nearest wastewater plant in Philippi on connected served area.

### Project: City of Philippi

- ➔ New water plant – 2008W-1070
  - o New 2,100gpm water treatment to replace 1,500gpm plant
- ➔ Project Cost - $14,664,000.00
  - o Under construction

| *PSD NAME* | *PWSID#* | *CONTACT* |
|---|---|---|
| **City of Cameron (C) (10020)** | **3302603** | **Mark Frazier** |

44 Main Street Cameron, WV

304-686-2366
cityofcameron@swave.net

## Supply Sources

### Surface Water

- ➔ Earthen Dam City of Cameron – pump
- ➔ 2 intakes
- ➔ Gallons supplied: 1.8M/month

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 500 |
| Fire Department Use | 50 |
| Main Leaks | 50 |
| Backwashing | 1,001 |
| Gallons sold | 19,854 |
| Unaccounted for water lost | 20,165 |
| Percent unaccounted for | 48.45% |
| Cost of Gallons unaccounted for | $20,971.60 |

## Storage Reservoir

- ➔ 500,000 storage capacity
- ➔ Steel tanks

## Counties Served

- ➔ Marshall

## District Office

- ➔ Wheeling

| 2011 - 2012 Electric Pumping Statistics (Gallons station pumping into distribution mains) | |
|---|---|
| July | 3,590 |
| August | 3,876 |
| September | 3,861 |
| October | 4,195 |
| November | 3,562 |
| December | 2,959 |
| January | 3,279 |
| February | 2,875 |
| March | 3,396 |
| April | 4,011 |
| May | 3,097 |
| June | 2,919 |
| Total for year | 41,620 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 14,823 | 14,702 | 385 | 413 |
| Commercial | 3,615 | 3,692 | 42 | 16 |
| Public Authorities | 1,416 | 1,393 | 6 | 9 |
| TOTAL Sales | 19,854 | 19,787 | 433 | 438 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 10.0 |
| Water Main Breaks Repaired | 10.0 |
| Annual total number of leaks | 22.0 |
| Annual total number of breaks | 4.0 |
| Planned maintenance hours | 20,000.0 |
| Corrective maintenance hours | 12,000.0 |

## Pumping Station Equipment (City of Cameron, pg. 702A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (City of Cameron, pg. 703A INSERT)

*No new feet of water Mains, water services, or new hydrants were added to the system (2011-2012)

## Water Meters

- ➔ No meter testing program maintained

| Size | Residential | Commercial | TOTAL |
|---|---|---|---|
| 5/8" x ¾" | 388 | 39 | 427 |
| 1" | | 2 | 2 |
| 1 ½" | | 1 | 1 |
| 2" | | 3 | 3 |
| 3" | | 1 | 1 |
| TOTAL | 388 | 46 | 434 |

## WVIJDC

Shows water served area but no water plant near center of served area.

Two nearby wastewater plants are shown in Cameron on connected served area.

There are no local projects indicated.

| PSD NAME | PWSID# | CONTACT |
|---|---|---|
| **Hurricane Municipal (A&B)** | **(1871) 3304005** | **Charles McCallister** |

City of Hurricane
3255 Teays Valley Road Hurricane, WV

304-562-5896

## Supply Sources

### Surface Water

- Mill Creek
  - One intake
- Rooper Hollow
  - Three intakes

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 500 |
| Backwashing | 1,660 |
| Unaccounted loss | 8,921 |
| Gallons sold | 36,756 |
| Percent unaccounted for | 18.65% |
| Cost of Gallons unaccounted for | $51,831 |

## Storage Reservoir

- 28,000,000 storage capacity

## Counties Served

- Putnam

## District Office

- St. Albans

| 2011 - 2012 Electric Pumping Statistics (Gallons station pumping into distribution mains) | |
|---|---|
| July | 21,650 |
| August | 21,820 |
| September | 20,345 |
| October | 21,325 |
| November | 19,830 |
| December | 21,870 |
| January | 20,410 |
| February | 17,930 |
| March | 18,763 |
| April | 19,560 |
| May | 21,190 |
| June | 20,040 |
| Total for year | 244,733 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 142,973 | 163,667 | 3,272 | 3,318 |
| Commercial | 40,074 | 17,700 | 208 | 183 |
| Public Fire Protection | 9,351 | 9,213 | 18 | 18 |
| Sales for Resale | - | - | - | - |
| TOTAL Sales | 192,398 | 190,580 | 3,498 | 3,519 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 55.0 |
| Water Main Breaks Repaired | 55.0 |

## Pumping Station Equipment (Hurricane Municipal WW, pg. 703A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Hurricane Municipal WW, pg. 704A INSERT)

*1,048 feet of new 2"AC, 381 feet of new 6"AC, 1,891 feet of new 4"C-900, 341 feet of new ½"PVC, 380 feet of new ¾: PVC, 25 feet of new 1"PVC, 8,361feet of new 2"PVC, 261 feet of new 4"PVC, 11,209 feet of new 6"PVC, 170 feet of new 2"Steel, and 237 feet of new 1"UNKNOWN Water Mains were in operation by the end of the fiscal year. 3,034 feet of 2'CI was removed from service. (2011-2012)

**No change was made to the water services.

*** Five new M&H Unknown, 3 new M&H 5.25, 1 new Mueller 2.25 hydrants were added to the system. One Kennedy 4.50, 5 M&H 4.25, 3 Muller 4.25 hydrants were removed from service. (2011-2012)

## Water Meters

- ➔ No meter testing program maintained

| Size | Residential | Commercial | Industrial | In public use | TOTAL |
|---|---|---|---|---|---|
| 5/8" x ¾" | 3,354 | 164 | 6 | 5 | 3,529 |
| 1" | | 11 | | 4 | 15 |
| 1 ½" | | 2 | | 2 | 5 |
| 2" | | 29 | | 8 | 537 |
| 4" | | | | 1 | 1 |
| TOTAL | 3,354 | 206 | 6 | 21 | 1,143 |

## WVIJDC

Shows no water served area or pipes in center of Hurricane with closest water plant in Teays Valley.

The two nearby wastewater plants are in Hurricane and Culloden.

The nearest water works project is in The Town of Milton.

*PSD NAME* *PWSID#* *CONTACT*

## City of Saint Marys (A&B) (10063) 3303704 Linda Wilson

418 Second Street Saint Marys, WV

304-684-2401
cityrecorder@frontiernet.net

## Supply Sources

### Groundwater

- Well No. 5, 96'deep, 600gpm
- Well No. 6, 93'deep, 600gpm

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 1,500 |
| Backwashing | 1,500 |
| Main leaks | 1,500 |
| Unaccounted loss | 41,018 |
| Gallons sold | 112,880 |
| Percent unaccounted for | 25.90% |
| Cost of Gallons unaccounted for | $30,764 |

## Storage Reservoir

- 846,000 M.Gals. storage capacity
- Steel tanks

## Counties Served

- Pleasant

## District Office

- Wheeling

| 2011 - 2012 Electric Pumping Statistics (Gallons – omit 000's - station pumping into distribution mains) | |
|---|---|
| July | 14,497 |
| August | 12,772 |
| September | 11,976 |
| October | 12,346 |
| November | 11,927 |
| December | 13,294 |
| January | 13,404 |
| February | 13,172 |
| March | 13,481 |
| April | 12,761 |
| May | 14,787 |
| June | 13,981 |
| Total for year | 158,398 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 49,712 | 53,010 | 985 | 978 |
| Commercial | 10,160 | 10,199 | 108 | 108 |
| Industrial | 348 | 419 | 2 | 2 |
| Public Authorities | 11,722 | 18,123 | 24 | 24 |
| Sales for Resale | 40,938 | 31,248 | 1 | 1 |
| TOTAL Sales | 112,880 | 112,999 | 1,120 | 1,113 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 8.0 |
| Water Main Breaks Repaired | 8.0 |
| Annual total number of leaks | 8.0 |
| Annual total number of breaks | 8.0 |
| Planned maintenance hours | 250.0 |
| Corrective maintenance hours | 225.0 |
| Planned budgeted maintenance cost | 60,000.0 |
| Corrective (experienced) maintenance cost | 58,544.0 |

## Pumping Station Equipment (City of St. Marys, pg. 703A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (City of St. Marys, pg. 704A INSERT)

*No new feet of water Mains, water services, or new hydrants were added to the system (2011-2012)

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | Industrial | In Public Use | TOTAL |
|---|---|---|---|---|---|
| 5/8" and ¾" | 966 | 104 | 2 | 18 | 1,090 |
| 1" | 1 | 4 | 1 | 1 | 6 |
| 2" | 1 | 5 | 1 | 5 | 12 |
| 4" | | 1 | 3 | 1 | 2 |
| 6" | | | 1 | | 1 |
| Rt 16 Resale 4" | | 1 | | | 1 |
| Plt Co PSD 4" | | 2 | | | 2 |
| Plt Co PSD 1" | | 1 | | | 1 |
| TOTAL | 1,086 | 43 | 14 | | 1,143 |

**7 Old Meters were tested during the period.  7 were > 2% slow.

## WVIJDC

Shows water served area but no water plant or lines in served area of the city.

Shows nearby wastewater plant on the Ohio, connected to served area.

### Project: Pleasants County Development Authority

- ➔ Water Line Extension – 2008W-1062

- 225 new customers in Pleasants Ridge, Federal Ridge, Calcutta and Horseneck
- Water lines and storage tanks

➔ Project Cost - $7,652,500.00
  - Under construction

| PSD NAME | PWSID# | CONTACT |
|---|---|---|
| **Cool Ridge-FlatTop PSD (B)** | **3304139** | **Jerry Farley** |

P.O. Box 550 Coolridge, WV

304-763-4151
Coolridgepsd1@yahoo.com

## Supply Sources

### Surface/Purchase Water

- Beckley Water Company

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 5,703 |
| Main leaks | 5,675 |
| Unaccounted loss | 40,223 |
| Gallons sold | 91,164 |
| Percent unaccounted for | 28.17% |

## Storage Reservoir

- 5 M.Gals. storage capacity
- Steel tanks

## Counties Served

- Raleigh
- Summers
- Mercer

## District Office

- Beckley

| 2010 - 2011 Purchased Water Stats (Gallons – omit 000's - station pumping into distribution mains) | |
|---|---|
| July | 13,439 |
| August | 12,990 |
| September | 11,829 |
| October | 10,315 |
| November | 11,719 |
| December | 10,997 |
| January | 13,741 |
| February | 12,670 |
| March | 11,144 |
| April | 11,669 |
| May | 11,411 |
| June | 10,841 |
| Total for year | 142,765 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 66,918 | 65,354 | 1,744 | 1,752 |
| Commercial | 8,768 | 7,730 | 50 | 48 |
| Public Authorities | 25 | 25 | 4 | 4 |
| Sales for Resale | 15,452 | 20,203 | 1 | 1 |
| TOTAL Sales | 91,164 | 93,312 | 1,799 | 1,805 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 11.0 |
| Water Main Breaks Repaired | 11.0 |
| Annual total number of leaks | 42.0 |
| Annual total number of breaks | 6.0 |
| Planned maintenance hours | 720.0 |
| Corrective maintenance hours | 720.0 |

## Pumping Station Equipment (Cool Ridge-Flat Top PSD, pg. 702A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Cool Ridge-Flat Top PSD, pg. 703A INSERT)

*No new feet of water Mains, water services, or new hydrants were added to the system (2011-2012)

## Water Meters

➔ Meter testing program maintained**

| Size | Residential | Commercial | TOTAL |
|---|---|---|---|
| 5/8" | 1,780 | - | 1,780 |
| 1" | - | 3 | 3 |
| 2" | - | 6 | 6 |
| 6" | - | 2 | 2 |
| TOTAL | 1,780 | 11 | 1,791 |

**0 meters were tested.

## WVIJDC

Shows no water served in area, no water plant near center of served area.

Central wastewater plant and service lines shown.

There are no nearby projects.

*PSD NAME* *PWSID#* *CONTACT*

## City of Point Pleasant (B) (1945) 3302710 Amber Tatterson

400 Viand Street Point Pleasant, WV

304-675-2366
cityclerk@ptpleasantwv.org

## Supply Sources

### Groundwater

- ➔ Well#1-#10 R. 62 North
- ➔ Well #1-#4 80'deep
- ➔ Well #5&#6 out of service
- ➔ Well #7-#10 are 79-203'deep
- ➔ Yield/day 240,000-403,000/well

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | - |
| Main leaks | 1,000 |
| Fire department use | 4,000 |
| Blowing setting basins | 4,258 |
| Gallons sold | 230,334 |
| Unaccounted for lost water | 239,592 |

## Storage Reservoir

- ➔ 3500 M. Gals.
- ➔ 4 Steel tanks and 1 concrete tank

## Counties Served

- ➔ Mason

## District Office

- ➔ St. Albans

| 2010 - 2011 Gallons Sold to General Customers (Gallons – omit 000's -) | |
|---|---|
| July | 14,488 |
| August | 16,459 |
| September | 13,723 |
| October | 13,479 |
| November | 13,645 |
| December | 12,851 |
| January | 13,196 |
| February | 13,544 |
| March | 11,435 |
| April | 11,657 |
| May | 13,661 |
| June | 14,593 |
| Total for year | 162,731 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 94,815 | 99,324 | 2,205 | 2,205 |
| Commercial | 67,688 | 69,356 | 329 | 339 |
| Industrial | 228 | 303 | 4 | 4 |
| Sales for Resale | 67,603 | 59,652 | - | - |

| | | | | |
|---|---|---|---|---|
| TOTAL Sales | 230,334 | 228,635 | 2,541 | 2,551 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 65.0 |
| Water Main Breaks Repaired | 65.0 |
| Annual total number of leaks | 65.0 |
| Annual total number of breaks | 65.0 |

## Pumping Station Equipment (Point Pleasant Water Works, pg. 702A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Point Pleasant Water Works, pg. 703A INSERT)

*No new feet of water Mains, water services, or new hydrants were added to the system (2011-2012)

## Water Meters

- ➔ No water meters were indicated in the report.

## WVIJDC

Shows water served area but no water lines.

Nearby water plant is north of town near the Mason Co. Airport.

Wastewater plants are to the north and south of center of served area with only a few mapped lines.

There are no nearby or related projects.

| *PSD NAME* | *PWSID#* | *CONTACT* |
|---|---|---|

## Preston Co. PSD No. 4 (B) (1815) 3303923 — Robert Bailey

225 Glade Meadow Avenue Albright, WV

304-379-3130
Psd4@frontiernet.net

## Supply Sources

### Groundwater

- Plant, 200'deep, 100,000gal/day yield
- Southern #1, 200'deep, 100,000gal/d
- Southern #2, 200'deep, 100,000gal/d
- Northern, 200'deep, 100,000gal/day

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 4,143 |
| Fire department use | 51 |
| Gallons sold | 167,869 |
| Unaccounted loss | 18,671 |
| Percent unaccounted for | 9.79% |
| Cost of Gallons unaccounted for | $15,497 |

## Storage Reservoir

- No cumulative reservoir capacity reported.

## Counties Served

- Preston
    - Brandonville, Valley Point, Glade Farms, Laurel Run, Shady Grove, Pisgah

## District office

- Philippi

| 2011 - 2012 Electric Pumping Statistics (Gallons – omit 000's - station pumping into distribution mains) | |
|---|---|
| July | 16,213 |
| August | 16,265 |
| September | 15,017 |
| October | 15,432 |
| November | 14,218 |
| December | 15,394 |
| January | 15,358 |
| February | 13,930 |
| March | 15,992 |
| April | 16,394 |
| May | 18,618 |
| June | 17,873 |
| Total for year | 190,734 |

## Customer Sales

| Unmetered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 38,724 | 40,156 | 930 | 918 |

| | | | | |
|---|---|---|---|---|
| Commercial | 7,630 | 6,809 | 37 | 38 |
| Industrial | 4,726 | 4,117 | 5 | 6 |
| Public Authorities | 110,628 | 78,348 | 6 | 6 |
| Sales for Resale* | 6,161 | 6,423 | 1 | 1 |
| TOTAL Sales | 167,869 | 135,853 | 979 | 969 |

*Metered sales.

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 10.0 |
| Water Main Breaks Repaired | 10.0 |
| Annual total number of leaks | 10.0 |
| Annual total number of breaks | 10.0 |
| Planned maintenance hours | 1,358.25 |
| Corrective maintenance hours | 528.75 |

## Pumping Station Equipment (Preston Co. PSD #4, pg. 703A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Preston Co. PSD #4, pg. 704A – 704B INSERT)

*No new feet of water Mains, or new hydrants were added to the system (2011-2012)

**109' of ¾" PVC, 87'of 1"PVC, and 243' of 2" PVC were added to the water services system.

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | Industrial | In Public Use | In Stock | TOTAL |
|---|---|---|---|---|---|---|
| ¾" | 933 | 33 | - | 3 | - | 969 |
| 1" | - | 1 | - | - | 1 | 2 |
| 1 ½" | - | 1 | - | - | - | 1 |
| 2" | | 2 | 4 | 1 | 3 | 10 |
| 3" | - | - | 1 | 1 | - | 2 |
| 10" | - | - | - | 2 | - | 2 |
| TOTAL | 933 | 37 | 5 | 7 | 4 | 986 |

**51 Old Meters were tested during the period. 29 were > 1% slow, 1 was 1% to 2%, inclusive, slow. 21 were <1% fast

## WVIJDC

Shows water served area and lines but no water plant in served around the physical address.

Nearby wastewater plant being installed for Valley point area only.

### Project: Preston Co. Sewer PSD (Valley Point)

- ➔ Install sanitary sewer – 2011S-1272
  - o Collection system and wastewater treatment plant for Valley Point area.
- ➔ Project Cost - $1,821,000.00
  - o Under construction

| PSD NAME | PWSID# | CONTACT |
|---|---|---|
| **Valley Water and Sewer Services (D)** | **3303314** | **Jeff Pippel** |

270 Industrial Blvd. Kearneysville, WV

Lee Snyder: 304-725-9140

## Supply Sources

### Groundwater

- ➔ Well #1 Upper, 700' deep, 46,080g/d
- ➔ Well #1 Lower, 360' deep, 161,280g/d
- ➔ Well #1, 220' deep, 43,200g/d yield
- ➔ Well #4, 500' deep, 1,400g/d yield
- ➔ Well #5, 600' deep, 24,480g/d yield

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | - |
| Fire department use | - |
| Gallons sold | 5,461 |
| Unaccounted loss | 5,001 |

## Storage Reservoir

- ➔ 0.064 M. Gals
- ➔ Steel tank

## Counties Served

- ➔ Jefferson
  - o 80 customers in DW and 46 customers in AOA

## District Office

- ➔ Kearneysville

| 2010 - 2011 Electric Pumping Statistics (Gallons – omit 000's - station pumping into distribution mains) | |
|---|---|
| July | 770 |
| August | 674 |
| September | 735 |
| October | 766 |
| November | 644 |
| December | 1,012 |
| January | 1,139 |
| February | 888 |
| March | 1,036 |
| April | 1,026 |
| May | 1,036 |
| June | 736 |
| Total for year | 10,462 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 4,006 | 3,858 | 92 | 82 |
| TOTAL Sales | 5,461* | 3,858 | 131* | 82 |

*Difference is from unmetered sales.

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 1.0 |
| Water Main Breaks Repaired | 1.0 |
| Annual total number of leaks | 1.0 |
| Annual total number of breaks | 1.0 |

## Pumping Station Equipment (Valley Water and Sewer Services, Inc., pg. 702A – 702B INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Valley Water and Sewer Services, Inc., pg. 703A INSERT)

*No new feet of water mains, water services, or new hydrants were added to the system (2011-2012)

## Water Meters

- ➔ Meter testing program not maintained**

| Size | Residential | TOTAL |
|---|---|---|
| 5/8" x ¾" | 126 | 969 |
| TOTAL | 126 | 126 |

**0 Old Meters were tested during the period.

## WVIJDC

Shows water served area and lines but no water plant in served around the physical address.

Sewer lines and service area around physical address by no wastewater plant

No projects in area.

# NO PSC REPORT ONLINE:

## Coal River Energy

### District Office

- St. Albans

## Cavaland

### District Office

- Kearneysville

## Glen Haven

### District Office

- Kearneysville

## Zela Elem School

### District Office

- Beckley

# Appendix Y

## The Finished Water Does Not Meet SDWA Standards without Extensive Treatment (self-reported)

This report was generated by the DEP based on several relevant reports and data including a Department of Health and Human Services survey, Public Service Commission Reports (PSC), West Virginia Infrastructure and Job Development Council project data, and Sanitary Surveys. For this appendix pages labeled INSERT were omitted, however, that data is available to the public, via online interface, in the corresponding PSC report.

# Table of Contents

| *PSD NAME* | *PWSID#* | *CONTACT* |
|---|---|---|
| **Berkeley Co. PSWDs(A) (7133 and 10002)** | **3300202 and 218** | **Paul Fisher** |

83 Monroe Street Martinsburg, WV

304-267-3855
pfisher@berkeleywater.org

## Supply Sources

### Surface Water

- Bunker Hill
  - Lefever Springs – 2 intakes, pump
    - 694,152,000 gallons
- Potomac River
  - Falling waters – 1 intake, pump
    - 805,087,439 gallons

### Purchased Water

- City of Martinsburg

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 53,117 |
| Fire department use | 1,860 |
| Main leaks | 262 |
| Backwashing | 10,168 |
| Gallons sold | 1,362,899 |
| Unaccounted for lost water | 207,829 |
| Percent unaccounted for | 12.70% |

2011 Power, Pumping, and Purchased Water Statistics (Gallons – 000's omitted)

| | Purchased | Electric pumped |
|---|---|---|
| July | 7,991 | 150,531 |
| August | 7,540 | 151,012 |
| September | 8,240 | 132,584 |
| October | 4,505 | 137,299 |
| November | 9,480 | 130,660 |
| December | 9,012 | 126,133 |
| January | 7,964 | 127,757 |
| February | 6,976 | 114,647 |
| March | 8,018 | 111,370 |
| April | 6,949 | 113,442 |
| May | 8,112 | 122,691 |
| June | 8,776 | 124,451 |
| Total for Year | 93,563 | 1,542,577 |

## Counties Served

- Berkeley
- Western Jefferson

## District Office

- Kearneysville

## Operational Programs

| #DEP Violations Cited (pretreatment permit) | Compliance Achieved | If no, expected date of compliance achievement |
|---|---|---|
| 3 | 2 YES | 1 NO 12/31/12 |
| **Capacity Development Report prepared?** | **Compliance achieved with recommendations?** | **If no, expected date of compliance achievement** |
| NO | N/A | N/A |
| **Last Sanitary Survey Performed – Year** | **Items to be completed to be in full compliance** | **Total # Customers Added** |
| 2011 | NONE | 243 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 888,919 | 906,580 | 19,066 | 18,809 |
| Commercial | 291,817 | 286,708 | 920 | 917 |
| Industrial | 145,703 | 151,093 | 23 | 23 |
| Public Authorities | 22,818 | 25,651 | 44 | 42 |
| Private Fire Protection | | | 159 | 142 |
| TOTAL Sales | 1,362,899 | 1,375,412 | 20,225 | 19,946 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 24.0 |
| Water main breaks repaired | 24.0 |
| Annual total number of leaks | 0.48 |
| Annual total number of breaks | 0.06 |
| Planned maintenance hours | 32,495.0 |
| Corrective maintenance hours | 5,401.0 |

## Pumping Station Equipment (Berkeley Co PSWD – Bunker Hill and Potomac River, pg. 703D, 703E, 703N, & 703O INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Berkeley Co PSWD – Bunker Hill and Potomac River, pg. 704A-704D INSERT)

*770' of 16" DI, 1375' of 12" DI, 140' of 8" DI, 1485' of 8"PVC, and 295' of 6" PVC were added to the water mains. 254 new services were added to the system. New nozzles were added but no new hydrants.

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | Industrial | In Public Use | In Stock | TOTAL |
|---|---|---|---|---|---|---|
| 5/8" | 19,133 | 541 | 1 | 9 | 5 | 19,689 |
| ¾" | 1 | 2 | | | 1 | 4 |
| 1" | 8 | 190 | 5 | 6 | 1 | 210 |
| 1 ½" | 3 | 59 | 5 | 7 | | 74 |
| 2" | 3 | 114 | 3 | 19 | 2 | 139 |
| 3" | | 13 | 2 | 5 | | 20 |
| 4" | | 3 | 2 | | | 5 |
| 6" | 1 | 3 | 3 | | | 7 |
| 8" | 1 | 2 | | | | 3 |
| 10" | | 1 | | | | 1 |
| TOTAL | 19,149 | 927 | 23 | 44 | 9 | 20,152 |

**1868 Old Meters were tested during the period. 4 were >2% slow, 272 were <1% slow, 22 were 1% to 2%, inclusive, slow. 1,280 were <1% fast, 290 were 1%-2%, inclusive, fast.

## WVIJDC

Shows 4 water plants in the county with the largest water served area centralized around the physical address with dense concentration of lines near center of served area.

Shows 7 wastewater plants in the county with the largest water served area centralized around the physical address with dense concentration of lines only around the provided physical address.

There are no projects in the county.

| *PSD NAME* | *PWSID#* | *CONTACT* |
|---|---|---|
| **Cheat Mountain Water Co. (B) (5082)** | **3303808** | **Michael Ritter** |

10 Snowshoe Drive Snowshoe, WV

304-572-5626
tritter@snowshoemountain.com

## Supply Sources

### Surface Water

- Lake (manmade) – 1 Intake, pump

### Groundwater

- Arbuckles-140'deep – 99gal/day yield
- Sugar Shack-136'deep – 295gal/day yield
- Shavers-325'deep – 87gal/day yield
- Inn-280'deep – 7,334gal/day yield
- Silver Creek-142'deep - 38gal/day yield
- Boathouse-180'deep – 246gal/day yield

### Purchased Water

- Snowshoe Mountain, Inc.

| **Gallons Lost and Sold** | |
|---|---|
| Mains, plants, filters, flushing | - |
| Main leaks | - |
| Backwashing | 4,307 |
| Gallons sold | 12,722 |
| Unaccounted for lost water | 73,092 |
| Percent unaccounted for | 81.10% |

## Storage Reservoir

- 1840 M. Gal Capacity

## Counties Served

- Pocahontas

## District Office

- Philippi

| 2011-2012 Power, Pumping, and Purchased Water Statistics (Gallons – 000's omitted) | |
|---|---|
| | Total from Purchased Water* |
| July | 6,517 |
| August | 6,457 |
| September | 6,129 |
| October | 5,627 |
| November | 6,969 |
| December | 9,939 |
| January | 13,114 |
| February | 11,387 |
| March | 7,590 |
| April | 5,291 |
| May | 5,334 |
| June | 5,767 |
| Total for Year | 90,121 |

*Amount pumped monthly not reported.

## Operational Programs

| #DEP Violations Cited (pretreatment permit) | Compliance Achieved | If no, expected date of compliance achievement |
|---|---|---|
| 0 | | |
| **Capacity Development Report prepared?** | **Compliance achieved with recommendations?** | **If no, expected date of compliance achievement** |
| NO | | |
| **Last Sanitary Survey Performed – Year** | **Items to be completed to be in full compliance** | **Total # Customers Added** |
| 2012 | No Deficiencies | 10 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Commercial | 12,722 | 12,107 | 86 | 83 |
| TOTAL Sales | 12,722 | 12,107 | 607* | 602* |

*Difference resulting from unmetered water customers.

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 2.0 |
| Water main breaks repaired | 2.0 |
| Annual total number of leaks | 3.0 |
| Annual total number of breaks | 0 |
| Planned maintenance hours | 700.0 |
| Corrective maintenance hours | 572.0 |

## Pumping Station Equipment (Cheat Mountain Water Company, Inc., pg. 703A and 703B INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Cheat Mountain Water Company, Inc., pg. 704A INSERT)

*No new water mains, hydrants, or water services were added.

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | TOTAL |
|---|---|---|---|
| ¾" | 519 | 54 | 573 |
| 1" | - | 13 | 13 |
| 1 ½" | - | 11 | 11 |
| 2" | - | 15 | 15 |
| 3" | - | 5 | 5 |
| 4" | - | 1 | 1 |
| 6" | - | 1 | 1 |
| TOTAL | 519 | 100 | 619 |

**0 water meters were tested during this period.

## WVIJDC

A water plant is shown to be located central to the physical address with served area and water lines visible.

No wastewater plant is shown but a served are and lines are visible.

### Project: Pocahontas County Public Service District (Sewer)

- ➔ Collection system 2009S-1090
  - o 126 new customers to serve Linwood, Slaty Fork, Snowshoe and Hawthorne Valley.
  - o Regional facility will replace several smaller separate facilities in Snowshoe resort.
- ➔ Project Cost - $25,483,000.00
  - o Binding Commitment Approved

### Project: Pocahontas County Public Service District (Sewer)

- ➔ Phase I – 2003S-762a
  - o 1810 New customers
  - o Pocahontas County PSD has come to an agreement to take control of Snowshoe Resort's current customer base.
- ➔ Project Cost - $4,505,000.00
  - o Under Construction

*PSD NAME* | *PWSID#* | *CONTACT*

## City of Ravenswood (B) (2102)

## 3301810


## Kimberly D. Benson

304-273-2621

kdbenson@cityofravenswood.com


212 Walnut Street Ravenswood, WV

# Supply Sources

## Groundwater

- ➔ Well 1-7; 90' each – 120-335GPM

## Storage Reservoir

- ➔ Non reported

## Monthly Water*

- ➔ *Amount pumped monthly, unaccounted for water, and gallons lost and sold not reported.

## Counties Served

- ➔ City of Ravenswood and Silverton PSD

## District Office

- ➔ St. Albans

## Operational Programs

| #DEP Violations Cited (pretreatment permit) | Compliance Achieved | If no, expected date of compliance achievement |
|---|---|---|
| Non Reported | Non Reported | Non Reported |
| **Capacity Development Report prepared?** | **Compliance achieved with recommendations?** | **If no, expected date of compliance achievement** |
| Non Reported | Non Reported | Non Reported |
| **Last Sanitary Survey Performed – Year** | **Items to be completed to be in full compliance** | **Total # Customers Added** |
| Non Reported | Non Reported | Non Reported |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | - | 100,892 | 1,949 | - |
| Sales for Resale | - | 52,008 | 1 | 1 |
| TOTAL Sales | - | 152,900 | - | - |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | - |
| Water main breaks repaired | - |
| Annual total number of leaks | - |

## Pumping Station Equipment (City of Ravenswood, pg. 702A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (City of Ravenswood, pg. 703A INSERT)

*No new water mains, hydrants, or water services were added.

## Water Meters

Meter testing program not maintained, No answer was provided.

| Size | Residential | Commercial | TOTAL |
|---|---|---|---|
| ¾” | - | - | - |
| 5/8” | - | - | - |
| 1 ½” | - | - | - |
| 1” | - | - | - |
| 2” | - | - | - |
| 3” | - | - | - |
| 4” | - | - | - |
| TOTAL | - | - | - |

## WVIJDC

No water plant is shown to be located central to the physical address, however there is a served area and water lines are visible around the physical address.

A wastewater plant is shown as well as a served area and lines are visible.

There are no nearby projects.

| *PSD NAME* | *PWSID#* | *CONTACT* |
|---|---|---|
| **City of Romney (B) (1794)** | **3301405** | **Betty Colebank** |
| 340 East Main Street Romney, WV | | 304-822-5118<br>bettyc@atlanticbb.net |

## Supply Sources

### Surface Water

- ➔ South Branch Potomac – 1 Intake
  - Gravity supplied 163,348 gallons
  - Below ground intake system ½ mile North of Rt 50 Bridge

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 375 |
| Main leaks | 2,937 |
| Backwashing | - |
| Gallons sold | 131,293 |
| Unaccounted for lost water | 28,743 |
| Percent unaccounted for | 17.60% |

## Storage Reservoir

- ➔ 900 M. Gal Capacity

## Counties Served

- ➔ City of Romney, WV

## District Office

- ➔ Kearneysville

| 2011-2012 Power, Pumping, and Purchased Water Statistics (Gallons – 000's omitted) | |
|---|---|
| | Gallons of water electrically pumped |
| July | 16,871 |
| August | 15,677 |
| September | 13,639 |
| October | 12,681 |
| November | 13,016 |
| December | 13,322 |
| January | 13,903 |
| February | 12,159 |
| March | 12,809 |
| April | 12,750 |
| May | 14,051 |
| June | 12,470 |
| Total for Year | 163,348 |

## Operational Programs

| #DEP Violations Cited (pretreatment permit) | Compliance Achieved | If no, expected date of compliance achievement |
|---|---|---|
| 0 | | |
| **Capacity Development Report prepared?** | **Compliance achieved with recommendations?** | **If no, expected date of compliance achievement** |
| NO | No | |
| **Last Sanitary Survey Performed – Year** | **Items to be completed to be in full compliance** | **Total # Customers Added** |
| 2010 | 1 | N/A |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential* | | | | |
| Commercial* | | | | |
| Industrial* | | | | |
| Sales for Resale | 89,973 | 100,200 | 1 | 1 |
| TOTAL Sales | 41,320 | 47,944 | 870 | 880 |

*Only operating revenues, not gallons sold/customers were reported for the category.

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 25.0 |
| Water main breaks repaired | 25.0 |
| Annual total number of leaks | 25.0 |
| Annual total number of breaks | 25.0 |
| Planned maintenance hours | 2,000.0 |
| Corrective maintenance hours | 210.0 |

## Pumping Station Equipment (City of Romney, pg. 703A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (City of Romney, pg. 704A INSERT)

*No new water mains, hydrants, or water services were added.

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | Industrial | In Stock | TOTAL |
|---|---|---|---|---|---|
| 5/8” | 755 | 84 | 3 | 72 | 914 |
| ¾” | 8 | 6 | | 4 | 18 |
| 1” | 12 | 19 | | 15 | 46 |
| 1.5” | | 3 | | | 3 |
| 2” | 5 | 11 | 3 | 2 | 21 |
| 3” | 1 | | | 1 | 2 |
| 6” | | 2 | | | 2 |
| TOTAL | 781 | 125 | 6 | 94 | 1,006 |

**11 water meters were tested during this period, 2 were slow. **342 meters are past due for testing.**

## WVIJDC

No water plant is shown to be located central to the physical address; however there is a served area with visible water lines.

There are two wastewater plants shown around the central location with a served area and lines visible.

There is no project associated with the city of Romney.

*PSD NAME* | *PWSID#* | *CONTACT*

## Ravencliff McGraws Salusville PSD (B) (2601) 3305518 Kathy Winfrey

PO Box 17 McGraws, WV
304-294-4511
RMSPSD@JETBROADBAND.COM

## Supply Sources

### Groundwater

- Well #1-3 McGraws
  - 220'-230' deep
  - 432,000 -880,000 gal/day yield
- Well #1-2 Matheny
  - 200' deep each
  - 86,400 gal/day yield each

### Purchased Water

- Glen Rogers PSD

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 1,410 |
| Main leaks | - |
| Backwashing | 11,331 |
| Gallons sold | 77,486 |
| Unaccounted for lost water | 44,901 |
| Percent unaccounted for | 33.23% |

2010-2011 Power, Pumping, and Purchased Water Statistics (Gallons – 000's omitted)

| | Total from electric pumping | Total from purchased water |
|---|---|---|
| July | 10,034 | - |
| August | 10,233 | 41 |
| September | 9,241 | 62 |
| October | 9,822 | 46 |
| November | 9,686 | 37 |
| December | 13,044 | 32 |
| January | 12,145 | 51 |
| February | 11,234 | 50 |
| March | 11,945 | 51 |
| April | 11,414 | 41 |
| May | 12,575 | 49 |
| June | 13,755 | 36 |
| Total for Year | 135,128 | 496 |

## Counties Served

- Kanawha
  - Cabin Creek
- Wyoming
  - Ravencliff
  - McGraws
  - New Richmond
  - Saulsville
  - Sabine
  - Glen Fork
  - Twin Falls
  - Matheny

## District Office

- Beckley

## Operational Programs

| #DEP Violations Cited (pretreatment permit) | Compliance Achieved | If no, expected date of compliance achievement |
|---|---|---|
| NO | | |
| **Capacity Development Report prepared?** | **Compliance achieved with recommendations?** | **If no, expected date of compliance achievement** |
| Yes | Yes | |
| **Last Sanitary Survey Performed – Year** | **Items to be completed to be in full compliance** | **Total # Customers Added** |
| 2009-2010 | Fences Around | 0 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 52,419 | 48,663 | 1,200 | 1,118 |
| Commercial | 16,820 | 14,470 | 46 | 46 |
| Interdepartmental Sales | 8,247 | 7,187 | 1 | 1 |
| TOTAL Sales | 77,486 | 70,320 | 1,247 | 1,165 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 3.0 |
| Water main breaks repaired | 3.0 |
| Annual total number of leaks | 15.0 |
| Annual total number of breaks | 3.0 |
| Planned maintenance hours | 17,333.0 |
| Corrective maintenance hours | 4,000.0 |

## Pumping Station Equipment (Ravencliff-McGraws-Saulsville PSD, pg. 702A 702B 702C and 702D INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Ravencliff-McGraws-Saulsville PSD, pg. 703A 703B and 703C INSERT)

*No new water mains, hydrants, or water services were added.

## Water Meters

- ➔ No answer provided for meter testing program status**

| Size | Residential | Commercial | TOTAL |
|---|---|---|---|
| 5/8" x ¾" | 1,286 | 33 | 1,319 |
| 1" | - | 2 | 2 |
| 1 ½" | - | 1 | 1 |
| 2" | - | 8 | 8 |
| 4" | - | 3 | 3 |
| 6" | - | 1 | 1 |
| TOTAL | 1,286 | 48 | 1,334 |

**0 water meters were tested during this period.

## WVIJDC

A water plant is shown to be located central to the physical address with served area and water lines visible.

A wastewater plant is shown but the served area and lines are visible but significantly less than water service area.

### Project: Ravencliff-McGraws-Saulsville PSD

- ➔ Distribution upgrades 95W-163b
  - o 83 new customers to serve Matheny area/Phase II.
- ➔ Project Cost - $1,527,000.00
  - o Under Construction

*PSD NAME* *PWSID#* *CONTACT*

## Summersville Municipal Water (WTP) (A) (10029) 3303404 James Corbitt


507 Gauley River Road Summersville, WV

304-619-0642
jamescorbitt@summersvillewv.org


## Supply Sources

### Surface Water

- ➔ Screen – Gauley River
  - o 1 Intake with pump
- ➔ Screen – S'ville Reservior
  - o 1 Intake with pump

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 10,742 |
| Fire department use | 155 |
| Main leaks | 52,744 |
| Gallons sold | 161,759 |
| Unaccounted for lost water | 37,396 |
| Percent unaccounted for | 14.23% |

## Storage Reservoir

- ➔ 1.72 M. Gallon capacity

## Counties Served

- ➔ Nicholas
  - o Summersville
  - o Glade Creek

## District Office

- ➔ Beckley

| 2011-2012 Power, Pumping, and Purchased Water Statistics (Gallons – 000's omitted) | |
|---|---|
| | Total from electric pumping |
| July | 24,363 |
| August | 23,400 |
| September | 21,487 |
| October | 21,749 |
| November | 21,528 |
| December | 21,931 |
| January | 19,948 |
| February | 19,500 |
| March | 23,256 |
| April | 20,232 |
| May | 22,116 |
| June | 23,286 |
| Total for Year | 262,796 |

## Operational Programs

| #DEP Violations Cited (pretreatment permit) | Compliance Achieved | If no, expected date of compliance achievement |
|---|---|---|
| 0 | | |
| **Capacity Development Report prepared?** | **Compliance achieved with recommendations?** | **If no, expected date of compliance achievement** |
| No | | |
| **Last Sanitary Survey Performed – Year** | **Items to be completed to be in full compliance** | **Total # Customers Added** |
| 2012 | None | - |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 91,368 | 87,842 | 2,208 | 2,066 |
| Commercial | 57,122 | 58,095 | 324 | 309 |
| Industrial | 66 | 142 | 1 | 1 |
| Public Authorities | 11,292 | 11,731 | 57 | 59 |
| Sales for Resale | 1,911 | - | | |
| Total Sales of Water | 161,759 | 157,810 | 2,590 | 2,435 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 52.0 |
| Water main breaks repaired | 52.0 |
| Annual total number of leaks | - |
| Annual total number of breaks | 52.0 |

## Pumping Station Equipment (Summersville Municipal Water, pg. 703A and 703B INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Summersville Municipal Water, pg. 704A and 704B INSERT)

*127,232 new water mains and 63 new hydrants were added, but no new water services were added.

## Water Meters

- ➔ A meter testing program is maintained**

| Size | Residential | Commercial | Industrial | In Public Use | In Stock | TOTAL |
|---|---|---|---|---|---|---|
| 5/8" | 2,244 | 272 | | 43 | 48 | 2,607 |
| 1" | 5 | 19 | 1 | 9 | 2 | 36 |
| 1 ½" | | 6 | | 1 | 1 | 8 |
| 2" | 1 | 10 | | 5 | 3 | 19 |
| 4" | | 1 | | | | 1 |
| TOTAL | 2,250 | 309 | 1 | 59 | 54 | 2,673 |

**38 water meters were tested during this period. 6 were slow and 12 were fast. **755 meters are past due for testing.**

## WVIJDC

A water plant is shown to be located central to the physical address with served area and water lines visible.

A wastewater plant is shown to be located central to the physical address with served area and water lines visible.

### Project: City of Summersville

- ➔ Extension of water service – 2003W-735
    - o 353 new customers to serve Glade Creek area; Lower Glade Creek Road, Armstrong Road, Maria Estates, Phillips run, Muddletty, McMillion Creek and Tanglewood Road.
- ➔ Project Cost - $7,071,386.83
    - o Under Construction

*PSD NAME* | *PWSID#* | *CONTACT*

## Town of Alderson (B) (3569)

P.O. Box 179 Alderson, WV

## 3301315

## Crystal Byer

304-445-2916
clerk@aldersonwv.com

# Supply Sources

## Surface Water

- Greenbrier River – 2 Intakes, pump

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | - |
| Fire Department Use | 13,550 |
| Main Leaks | 3,450 |
| Backwashing | 11,680 |
| Gallons sold | 77,059 |
| Unaccounted for lost water | 64,492 |
| Percent unaccounted for | 37.89% |

# Storage Reservoir

- 600,000 M. Gal Capacity

# Counties Served

- Greenbrier
- Monroe

# District Office

- Beckley

2011-2012 Power, Pumping, and Purchased Water Statistics (Gallons – 000's omitted)

| | Total from Electric power pump |
|---|---|
| July | 13,885 |
| August | 14,133 |
| September | 13,475 |
| October | 14,606 |
| November | 18,815 |
| December | 14,628 |
| January | 15,116 |
| February | 14,086 |
| March | 14,649 |
| April | 14,096 |
| May | 10,766 |
| June | 11,976 |
| Total for Year | 170,231 |

# Operational Programs

| #DEP Violations Cited (pretreatment permit) | Compliance Achieved | If no, expected date of compliance achievement |
|---|---|---|
| 0 | | |
| **Capacity Development Report prepared?** | **Compliance achieved with recommendations?** | **If no, expected date of compliance achievement** |
| N/A | | |
| **Last Sanitary Survey Performed – Year** | **Items to be completed to be in full compliance** | **Total # Customers Added** |
| 2010 | | 0 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 26,485 | 26,737 | 645 | 650 |
| Commercial | 5,159 | 3,817 | 41 | 50 |
| Public Authorities | 45,416 | 33,778 | 11 | 10 |
| TOTAL Sales | 77,059 | 64,332 | 697 | 710 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 5.0 |
| Water main breaks repaired | 5.0 |
| Annual total number of leaks | 0 |
| Annual total number of breaks | 0 |
| Planned maintenance hours | 0 |
| Corrective maintenance hours | 0 |

## Pumping Station Equipment (Town of Alderson, pg. 703A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Town of Alderson, pg. 704A INSERT)

*No new water mains, hydrants, or water services were added.

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | TOTAL |
|---|---|---|---|
| 5/8” | 789 | 38 | 827 |
| 1” | 2 | 12 | 14 |
| 1 ½” | - | 2 | 2 |
| 2” | - | 8 | 8 |
| 4” | - | 3 | 3 |
| 6” | - | 2 | 2 |
| TOTAL | 791 | 65 | 856 |

**4 water meters were tested during this period.  All were fast.

## WVIJDC

A water plant is shown to be located central to the physical address but without served area or water lines visible.

A wastewater plant is shown but a served are and lines are not visible.

There is no planned project in the area.

*PSD NAME* | *PWSID#* | *CONTACT*

## Town of Tunnelton (B) (4268)

75 Bank Street Tunnelton, WV

## 3303918

**Rita Nicholson**

304-568-2992
therock31_us@yahoo.com

## Supply Sources

### Purchase Water

- ➔ Town of Rowlesburg

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | - |
| Fire department use | - |
| Main leaks | - |
| Gallons sold | 18,071 |
| Unaccounted for lost water | 3,820 |
| Percent unaccounted for | 17.45% |

## Counties Served

- ➔ Preston
  - o Tunnelton
  - o Denver (Resale Customer)

## District Office

- ➔ Philippi

| 2011-2012 Power, Pumping, and Purchased Water Statistics (Gallons – 000's omitted) | |
|---|---|
| | Total from purchased water |
| July | 1,626 |
| August | 1,752 |
| September | 2,247 |
| October | 1,871 |
| November | 2,069 |
| December | 1,789 |
| January | 2,233 |
| February | 1,535 |
| March | 1,564 |
| April | 1,582 |
| May | 1,683 |
| June | 1,940 |
| Total for Year | 21,891 |

## Operational Programs

| #DEP Violations Cited (pretreatment permit) | Compliance Achieved | If no, expected date of compliance achievement |
|---|---|---|
| 0 | 0 | 0 |
| **Capacity Development Report prepared?** | **Compliance achieved with recommendations?** | **If no, expected date of compliance achievement** |
| 0 | 0 | 0 |
| **Last Sanitary Survey Performed – Year** | **Items to be completed to be in full compliance** | **Total # Customers Added** |
| 2010 | Yes | 0 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 11,528 | 13,432 | 347 | 352 |
| Commercial | 178 | 156 | 7 | 8 |
| Public Authorities | 148 | 89 | 6 | 5 |
| Sales for Resale | 6,217 | 6,430 | 1 | 1 |
| Total Sales of Water | 18,071 | 20,107 | 361 | 366 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 2.0 |
| Water main breaks repaired | 2.0 |
| Annual total number of leaks | 3.0 |
| Annual total number of breaks | 2.0 |

## Pumping Station Equipment (Tunnelton Municipal Water Works, pg. 703A INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Tunnelton Municipal Water Works, pg. 704A INSERT)

*No new water mains, hydrants, or water services were added.

## Water Meters

- ➔ A meter testing program is maintained**

**0 water meters were tested during this period. **100 meters are past due for testing.**

## WVIJDC

No water plant is shown to be located central to the physical address but a served area and water lines are visible.

A wastewater plant is shown to be located near the physical address with served area and water lines visible.

There are no local projects.

| *PSD NAME* | *PWSID#* | *CONTACT* |
|---|---|---|
| **Wayne Water Services (B) (1561)** | **3305007** | **Karen R. Clay** |

10328 Route 152 Road Wayne, WV

304-272-3221
townofwaynekaren@frontier.net

## Supply Sources

### Surface Water

- ➔ Twelve Pole Creek – 2 Intakes

| Gallons Lost and Sold | |
|---|---|
| Mains, plants, filters, flushing | 1,500 |
| Fire Department Use | 1,000 |
| Main Leaks | 49,675 |
| Backwashing | 8,016 |
| Blowing setting basins | 1,182 |
| Gallons Sold | 105,869 |
| Unaccounted for lost water | 35,545 |
| Percent unaccounted for | 17.53% |

## Storage Reservoir

- ➔ 252,000 M. Gal Capacity

## Counties Served

- ➔ Wayne
  - o Town of Wayne and surrounding

## District Office

- ➔ St. Albans

| 2011-2012 Power, Pumping, and Purchased Water Statistics (Gallons – 000's omitted) | |
|---|---|
| | Total from Electric power pump |
| July | 17,088 |
| August | 17,042 |
| September | 16,269 |
| October | 16,250 |
| November | 16,228 |
| December | 17,021 |
| January | 17,260 |
| February | 16,003 |
| March | 16,560 |
| April | 15,462 |
| May | 19,523 |
| June | 18,081 |
| Total for Year | 202,787 |

## Operational Programs

| **#DEP Violations Cited (pretreatment permit)** | **Compliance Achieved** | **If no, expected date of compliance achievement** |
|---|---|---|
| 0 | | |
| **Capacity Development Report prepared?** | **Compliance achieved with recommendations?** | **If no, expected date of compliance achievement** |
| No | | |
| **Last Sanitary Survey Performed – Year** | **Items to be completed to be in full compliance** | **Total # Customers Added** |
| 2011 | None | 0 |

## Customer Sales

| Metered Water Revenue | Gallons Sold (000 omitted) | | Average Number of Customers | |
|---|---|---|---|---|
| | For this year | From last year | Number for year | Number from Last Year |
| Residential | 91,065 | 92,952 | 2,196 | 2,183 |
| Commercial | 11,262 | 10,539 | 101 | 110 |
| Industrial | 627 | 625 | 25 | 25 |
| Public Authorities | 2,915 | 3,148 | 22 | 22 |
| TOTAL Sales | 105,869 | 107,264 | 2,344 | 2,340 |

## Distribution Integrity and Planned Maintenance Ratio: Water (hours)

| | |
|---|---|
| Water Main Breaks | 28.0 |
| Water main breaks repaired | 28.0 |
| Annual total number of leaks | 195.0 |
| Annual total number of breaks | 50.0 |

## Pumping Station Equipment (Wayne Water Service, pg. 703A - 703E INSERT)

## Reservoirs, Standpipes, and Water Treatment Plant (Wayne Water Service, pg. 704A and 704B INSERT)

*8,800 new water mains were added but no new hydrants or water services were added.

## Water Meters

- ➔ Meter testing program maintained**

| Size | Residential | Commercial | Industrial | In Public Use | Total |
|---|---|---|---|---|---|
| 5/8” | 2,195 | 83 | 17 | 20 | 2,315 |
| 1” | 1 | 8 | | 2 | 11 |
| 1 1/4” | | 3 | | | 3 |
| 1 ½” | | 5 | 7 | | 12 |
| 2” | | 2 | 1 | | 3 |
| TOTAL | 2,196 | 101 | 25 | 22 | 2,344 |

**0 meters were reported as being tested.

## WVIJDC

A water plant is shown to be located central to the physical address and has a served area and water lines visible.

A wastewater plant is shown and has a served area and water lines visible.

There is no planned project in the area.

## NO PSC REPORT ONLINE:

### Coal River Energy

#### District Office

- St. Albans

### Aurora School

#### District Office

- Philippi

### Carter Roag Coal Co. – Pleasant Hill Mine

#### District Office

- Philippi

### Jefferson Utilities Inc. – Burr Industrial Park

#### District Office

- Kearneysville

### Slab Fork

#### District Office

- Beckley

### Zela Elem School

#### District Office

- Beckley

# Appendix Z

## Evaluation of the Washington D.C. Metropolitan Area Water Supply System

# Washington, D.C., Metropolitan Area Water Supply System

The Potomac River is the primary water supply source for the Washington, D.C., metropolitan area (WMA) – defined as the District of Columbia and the city's Maryland and Virginia suburbs. Most WMA residents receive water from one of three water suppliers:

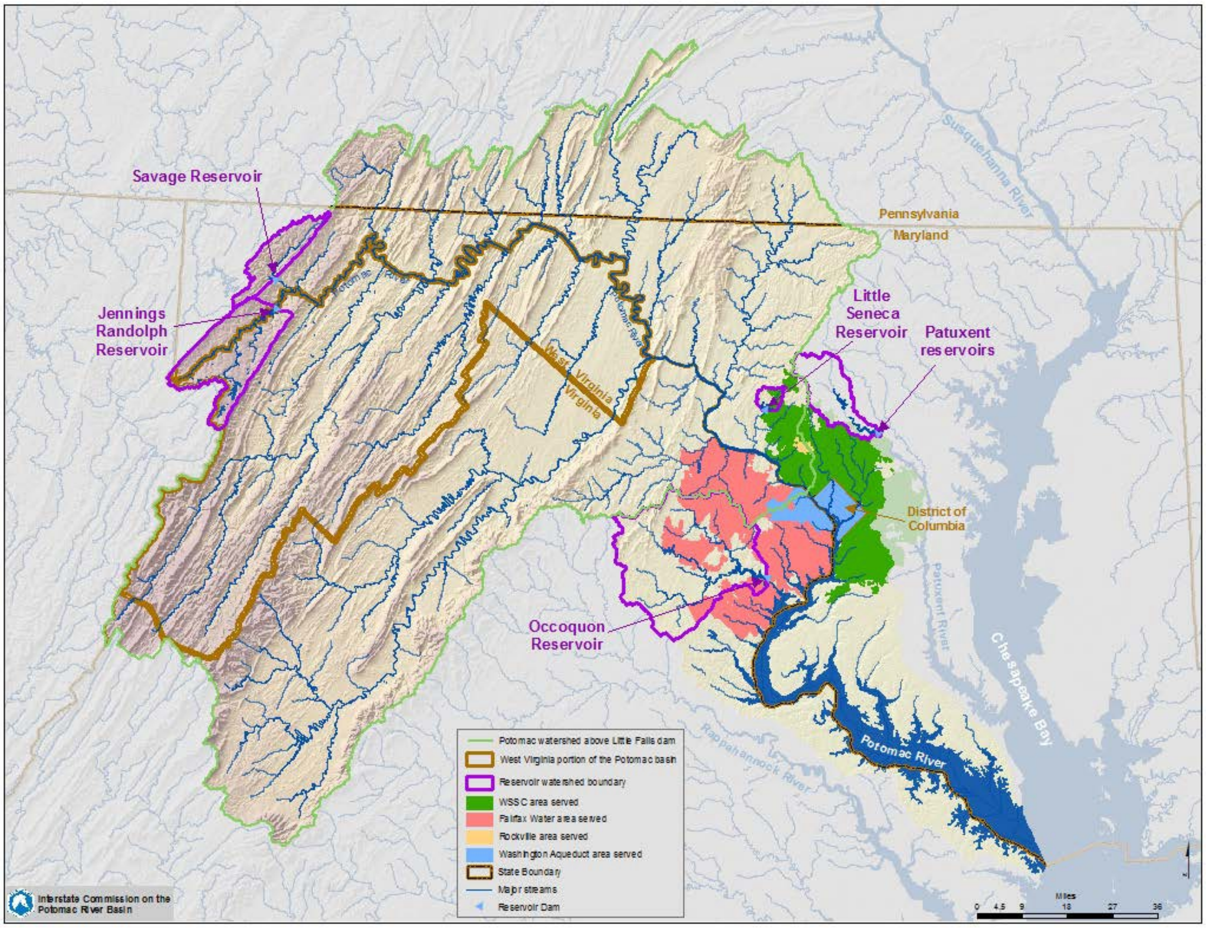
- Washington Aqueduct Division of the U.S. Army Corps of Engineers (Aqueduct), serving the District of Columbia via the D.C. Water and Sewer Authority (DC Water), and parts of northern Virginia;
- Washington Suburban Sanitary Commission (WSSC), serving parts of Maryland; and
- Fairfax Water, serving Fairfax County, Virginia, and providing wholesale water to other suppliers in northern Virginia.

These three suppliers obtain approximately 78 percent of their water from the Potomac River (Ahmed et al. 2010). The WMA suppliers jointly own storage capacity (not the water itself) in two upstream reservoirs, Jennings Randolph and Little Seneca. The water in Jennings Randolph available to the WMA is referred to as being in the reservoir's water supply account. Storage in the reservoir is also allocated for flood control and water quality uses.

Releases from these reservoirs can be used to augment natural river flows during times of drought. The suppliers provide funding for operations and maintenance for a third reservoir, Savage Reservoir, which is used to match a portion of water supply releases from Jennings Randolph. In addition, Fairfax Water and WSSC rely on water stored in reservoirs that are outside of the Potomac River drainage area on the Occoquan and Patuxent rivers, respectively (Figure 1). The WMA suppliers provide treated water either directly to customers or to independent wholesale suppliers.

The Section for Cooperative Water Supply Operations on the Potomac (CO-OP) of the Interstate Commission on the Potomac River Basin (ICRPB) assists the WMA suppliers in 1) cooperatively managing the water supply system during droughts and 2) forecasting future demands and assessing the system's ability to meet these demands. CO-OP also provides a variety of technical and logistical support to the utilities. This includes special studies on water supply issues; tool and model development; drought response exercises; hazardous spill travel-time estimates; participation in third-party research projects; assessments of water withdrawal permit applications; and outreach to local, national, and international audiences.

**Figure 1.** CO-OP water supply system, including reservoirs and areas served by the WMA water suppliers.




## 1.1 History of Cooperative Water Supply Operations

After experiencing the lowest Potomac River flow on record in 1966 and a severe drought in the Occoquan sub-watershed in 1977, basin stakeholders were looking for ways to improve the reliability of water supply to Washington, D.C. Subsequently in 1978, the Low Flow Allocation Agreement (LFAA) was signed by the Secretary of the Army of the United States, Maryland, Virginia, District of Columbia, Fairfax Water, and WSSC. This agreement equitably divides the available water between the WMA suppliers in the event of an emergency shortage. The LFAA also calls for an environmental flow-by of 100 million gallons per day (Mgal/d) at the Little Falls dam.

With the LFAA newly in place, CO-OP was created in 1979 at the request of WMA suppliers and the Potomac basin states. The goal in creating CO-OP was to cooperatively manage water supply resources as a means of meeting demands during dry periods without having to enact the required LFAA allocations.

While the LFAA guaranteed that available water would be equitably allocated, there was still a need to meet growing demands. In the decades leading up to the establishment of CO-OP, the region had experienced rapid population growth and a severe drought. This led many to dire predictions of serious water supply shortages. After considering structural solutions, including a series of 16 reservoirs, many in the region, including ICPRB staff and researchers at Johns Hopkins University, suggested that a cooperative regional supply plan could better and more cost-effectively meet the growing demand.

In 1980, the WMA Water Supply Task Force, made up of elected officials and technical and citizens advisory committees, was created to address the problem. This task force led to cost-sharing agreements between the WMA suppliers to construct, maintain, and operate water supply storage in Jennings Randolph and Little Seneca reservoirs. A call was also made for a formal cooperative regional water supply agreement.

Subsequently, the Potomac River and Reservoir Simulation Model (PRRISM) was developed and helped to show stakeholders the benefits to each utility, individually and collectively, from managing the water supply resources as a system. Using this model to run drought exercises built confidence in the system and in the ability of all the players to cooperate. Eventually, in 1982, the Water Supply Coordination Agreement (WSCA) was signed by the Baltimore District of the U.S. Army Corps of Engineers (USACE), Fairfax Water, WSSC, District of Columbia, and ICPRB. This agreement set up a more cooperative approach than the one in the LFAA for sharing available water resources when flows drop below a specified threshold. The main goals of the WSCA are to optimize the use of available water by the signatories and equitably share the costs of constructing, operating, and maintaining future jointly owned upstream reservoirs. The agreement also provides for system reliability assessments to be completed every five years. CO-OP has been conducting such assessments since the initial study in 1990.

Through these agreements, CO-OP, as a special section of ICPRB, is governed by a subset of ICPRB's commissioners. Quarterly meetings of these commissioners are held to review CO-OP's current and proposed efforts. Additionally, CO-OP is overseen by an Operations Committee set up by the WSCA. This committee is comprised of the general managers of each of the WMA suppliers and has a technical committee of utility staff that meets regularly. CO-OP's annual work plan and budget are subject to approval by the Operations Committee members, who provide the Section's funding.

## 1.2 CO-OP Functions and Responsibilities

### 1.2.1 Long-term Planning

CO-OP's daily water balance model, PRRISM, is used for long-term planning. The model simulates Potomac River flows and the various inflows and outflows that determine water availability for the WMA suppliers. The reliability of the system for the simulation period is judged on a set of metrics including daily Potomac River flow at Little Falls, which is located downstream of the WMA intakes, minimum reservoir storage levels, and the number of days during which demands could not be met.

PRRISM requires three primary datasets: temperature, precipitation, and stream flow. Hydrologic conditions in the current version of PRRISM are simulated for the 78-year period of record which extends from October 1929 through December 2007. Thus, PRRISM can be used to evaluate the reliability of the current system to meet future demands if hydrologic conditions in the future are similar to those experienced in the past. This allows CO-OP to understand how the system would perform if a drought occurred that was similar to one experienced during the period of record. Past drought periods in the historic dataset include:

- Summer and fall of 1930 – A prolonged period of low flow conditions considered the drought of record for the region.

- Summer of 1966 – A relatively brief drought in which Potomac River flow dropped to its lowest ever recorded value.
- Summer of 1999 – The first drought which required releases from the WMA's system of reservoirs.
- Summer of 2002 – The second drought requiring releases from system reservoirs.

### 1.2.2 Drought Response

Between April and October of each year – the most likely time for a drought in the basin – CO-OP distributes a monthly Water Supply Outlook (WSO). The WSO provides the suppliers and general public with the probability that releases will be needed from one or more of the system's reservoirs to meet demands.

In the event of a drought, CO-OP assists the WMA suppliers in cooperatively managing water withdrawals and reservoir releases throughout the system. The goals during a drought are to meet utility demands, maintain environmental flow-by recommendations, and balance the use of the system's reservoirs. CO-OP has developed a series of tools to guide management decisions on a daily and hourly basis, depending on the severity of the situation. Staff members communicate at a minimum of once a day to update stakeholders on recent flows, demands, and release and withdrawal recommendations.

In order to keep both CO-OP and utility staff current on drought response procedures, a drought exercise is held every year when no actual drought has occurred. These exercises allow staff at all organizations to practice working together, maintain confidence in the cooperative system, and provide an opportunity to test out new management ideas and learn about system changes at the utilities.

Since construction of Jennings Randolph in 1981, WMA suppliers through CO-OP have requested releases during three droughts periods – 1999, 2002, and 2010. The amount of additional water needed to meet demand and the 100 Mgal/d flow-by recommendation is calculated by CO-OP and translated into a flow target at the USGS gage in Luke, Maryland, for the USACE staff that manages the reservoirs. The minimum flow target at Luke for the USACE is 120 cubic feet per second (cfs) when there are no flood control releases occurring. This minimum flow target is met with releases from Jennings Randolph's water quality storage and Savage Reservoir.

The tables below are reproductions of those that appear in CO-OP reports following the three droughts that required water supply releases (**Table 1**, **Table 2**, and **Table 3**). CO-OP's ability to track and account for releases from water quality and water supply storage from Jennings Randolph and from Savage has improved over time which is why the information is more detailed for the 2010 drought operations.

**Table 1.** Releases from Jennings Randolph water supply account during 1999 drought operations. Adapted from Hagen et al. 1999.

| | Jennings Randolph | Jennings | Daily Mean |
|---|---|---|---|
| 7/9/1999 | 0 | 0 | 178 |
| 7/10/1999 | 0 | 0 | 160 |
| First | | | |
| 7/11/1999 | 3 | 557 | 445 |
| 7/12/1999 | 3 | 557 | 698 |
| 7/13/1999 | 2 | 309 | 543 |
| 7/14/1999 | 1 | 155 | 369 |
| 7/15/1999 | 1 | 155 | 288 |
| 7/16/1999 | 2 | 309 | 366 |
| 7/17/1999 | 2 | 309 | 459 |
| 7/18/1999 | 1 | 155 | 369 |
| 7/19/1999 | 1 | 155 | 287 |
| 7/20/1999 | 1 | 155 | 283 |
| 7/21/1999 | 5 | 77 | 243 |
| 7/22/1999 | 5 | 77 | 200 |
| 7/23/1999 | 5 | 77 | 198 |
| 7/24/1999 | 5 | 77 | 202 |
| 7/25/1999 | 5 | 77 | 198 |
| 7/26/1999 | 5 | 77 | 195 |
| 7/27/1999 | 3 | 48 | 184 |
| 7/28/1999 | 2 | 39 | 167 |
| 7/29/1999 | 1 | 19 | 169 |
| 7/30/1999 | 0 | 0 | 163 |
| 7/31/1999 | 0 | 0 | 165 |
| Second | | | |
| 8/10/1999 | 0 | 0 | 160 |
| 8/11/1999 | 1 | 186 | 257 |
| 8/12/1999 | 1 | 265 | 384 |
| 8/13/1999 | 1 | 232 | 384 |
| 8/14/1999 | 1 | 186 | 342 |
| 8/15/1999 | 1 | 186 | 342 |
| 8/16/1999 | 1 | 186 | 328 |
| 8/17/1999 | 6 | 93 | 261 |
| 8/18/1999 | 0 | 0 | 184 |
| Total | 3 | 4718 | - |

**Table 2.** Releases from Jennings Randolph water supply account during 2002 drought operations. Adapted from Kiang and Hagen 2003.

| | Jennings | Jennings | Daily Mean |
|---|---|---|---|
| 8/10/2002 | 0 | 0 | 365 |
| 8/11/2002 | 0 | 0 | 449 |
| 8/12/2002 | 0 | 0 | 623 |
| 8/13/2002 | 0 | 0 | 627 |
| 8/14/2002 | 0 | 0 | 625 |
| 8/15/2002 | 0 | 0 | 625 |
| 8/16/2002 | 7 | 122 | 625 |
| 8/17/2002 | 0 | 0 | 984 |
| 8/18/2002 | 0 | 0 | 916 |
| 8/19/2002 | 1 | 289 | 532 |
| 8/20/2002 | 2 | 418 | 818 |
| 8/21/2002 | 2 | 418 | 1004 |
| 8/22/2002 | 2 | 356 | 958 |
| 8/23/2002 | 2 | 356 | 859 |
| 8/24/2002 | 2 | 356 | 863 |
| 8/25/2002 | 1 | 303 | 800 |
| 8/26/2002 | 1 | 249 | 673 |
| 8/27/2002 | 1 | 249 | 617 |
| 8/28/2002 | 1 | 249 | 645 |
| 8/29/2002 | 1 | 169 | 574 |
| 8/30/2002 | 1 | 169 | 486 |
| 8/31/2002 | 1 | 169 | 476 |
| 9/1/2002 | 0 | 0 | 415 |
| 9/2/2002 | 0 | 0 | 339 |
| 9/3/2002 | 0 | 0 | 336 |
| 9/4/2002 | 0 | 0 | 334 |
| 9/5/2002 | 0 | 0 | 330 |
| 9/6/2002 | 1 | 186 | 404 |
| 9/7/2002 | 1 | 186 | 490 |

| | | | |
|---|---|---|---|
| 9/8/2002 | 1 | 186 | 476 |
| 9/9/2002 | 2 | 371 | 627 |
| 9/10/2002 | 2 | 371 | 886 |
| 9/11/2002 | 1 | 289 | 787 |
| 9/12/2002 | 1 | 289 | 674 |
| 9/13/2002 | 1 | 289 | 684 |
| 9/14/2002 | 1 | 289 | 684 |
| 9/15/2002 | 1 | 209 | 611 |
| 9/16/2002 | 1 | 209 | 538 |
| 9/17/2002 | 1 | 209 | 535 |
| 9/18/2002 | 1 | 209 | 534 |
| 9/19/2002 | 1 | 209 | 537 |
| 9/20/2002 | 1 | 209 | 538 |
| 9/21/2002 | 1 | 159 | 526 |
| 9/22/2002 | 1 | 159 | 500 |
| 9/23/2002 | 0 | 0 | 379 |

| | Jennings | Jennings | Daily Mean |
|---|---|---|---|
| 9/24/2002 | 0 | 0 | 255 |
| 9/25/2002 | 0 | 0 | 254 |
| 9/26/2002 | 0 | 0 | 280 |
| 9/27/2002 | 0 | 0 | 305 |
| 9/28/2002 | 0 | 0 | 274 |
| 9/29/2002 | 0 | 0 | 258 |
| 9/30/2002 | 0 | 0 | 254 |
| Total | 51 | 7900 | - |

**Table 3.** Water release accounting during 2010 drought operations. Adapted from Ahmed et al. 2011. (JRR – Jennings Randolph Reservoir)

| | ICPRB calculated values | | | USACE calculated volumes and allocations | | | | |
|---|---|---|---|---|---|---|---|---|
| | Estimated water | Luke target | | Luke observed | | Release from JRR water | Release from JRR water | Savage Reservoir |
| | Mgal | cfs | Mgal | cfs | Mgal | Mgal | Mgal | Mgal |
| 9/10/2010 | 170 | 435 | 281 | 419 | 271 | 176 | 62 | 36 |
| 9/11/2010 | 170 | 435 | 281 | 442 | 286 | 174 | 62 | 36 |
| 9/12/2010 | 170 | 435 | 281 | 439 | 284 | 174 | 62 | 36 |
| 9/13/2010 | 150 | 405 | 262 | 408 | 264 | 154 | 59 | 36 |
| 9/14/2010 | 115 | 351 | 227 | 354 | 229 | 123 | 57 | 36 |
| 9/15/2010 | 140 | 390 | 252 | 391 | 253 | 142 | 57 | 36 |
| 9/16/2010 | 140 | 390 | 252 | 405 | 262 | 154 | 57 | 36 |
| 9/17/2010 | 90 | 312 | 202 | 333 | 215 | 110 | 57 | 36 |
| 9/18/2010 | 45 | 243 | 157 | 323 | 209 | 53 | 110 | 36 |
| 9/19/2010 | 45 | 243 | 157 | 322 | 208 | 52 | 110 | 36 |
| 9/20/2010 | 40 | 235 | 152 | 254 | 164 | 64 | 57 | 31 |
| 9/23/2010 | 90 | 312 | 202 | 303 | 196 | 109 | 59 | 28 |
| Total | 1365 | - | - | - | - | 1485 | 809 | 419 |

The largest total withdrawal to augment natural flows occurred during the 2002 drought. But even then, the approximately 5 billion gallons that was released is less than half of the water supply storage capacity. While releases during these three drought operation periods did not come close to using all the stored water in any one season, recent CO-OP work on the reliability of the water supply system under climate change shows that the system would become more stressed under hotter and drier conditions, even causing storage in the reservoirs to drop to extremely low levels in some scenarios (Ahmed et al. forthcoming).

## 1.3 Future CO-OP Water Demands

### 1.3.1 2010 Demand and System Reliability Study – Part 1

Part one of the "2010 Washington Metropolitan Area (WMA) Water Supply Reliability Study – Demand and Resource Availability for the Year 2040" provides a long-term forecast for water managers in the WMA. Water demand forecasts estimate the amount of water required to meet customer demand for a period of time into the future. A reliability and resource availability analysis accounts for the water available to meet these demands and the ability of the system to deliver the water when and where it is needed.

Completed every five years, this iteration of the study indicates a slight upward trend in summertime water use by WMA customers, while population in the region has risen by about 10 percent from approximately 3.9 to 4.3 million people. Model simulations of the current water supply system predict that for the 2030 forecasted demands the system is likely adequate, but might become strained given estimated 2040 demands. For a 2040 scenario of high demands, model simulations indicate that if the WMA was to experience conditions similar to the worst drought on record (1930) that emergency water use restrictions would be required, portions of the system could experience water supply shortfalls, and water shortages in the system's water supply reservoirs could occur.

#### 1.3.1.1 Demand Forecasting Method

Forecasts of average annual water demand were developed by combining recent water use information derived from three data sources. These included:

1) Billing data provided by the WMA suppliers and their wholesale customers,

2) information on the current and future extent of the areas supplied with water from the WMA suppliers and local planning agencies, and

3) the most recent demographic forecasts from the Metropolitan Washington Council of Governments.

Forecasts were also made for the City of Rockville, which withdraws water from the Potomac. Water use data were disaggregated into three categories for forecasting purposes: single family households, multi-family households (apartments), and employees (including commercial, industrial, and institutional use). Two forecast scenarios were developed to address some of the uncertainty involved in forecasting water use (**Table 4**).

Table 1. Forecasted demand for both high and likely scenarios at five-year intervals for the period from 2010 to 2040 (adapted from Ahmed et al. 2010).

| Demand Scenario | Withdrawals (Mgal/d) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
| Likely Scenario - Fairfax Water | 175.2 | 186.9 | 199.4 | 210.2 | 218.2 | 223.8 | 228.9 |
| High Scenario - Fairfax Water | 187.2 | 201.7 | 217.8 | 234.2 | 247.3 | 259.0 | 269.1 |
| Likely Scenario - Washington Aqueduct | 150.9 | 157.7 | 164.8 | 168.7 | 172.2 | 174.2 | 177.8 |
| High Scenario - Washington Aqueduct | 150.9 | 158.6 | 166.6 | 171.4 | 175.5 | 178.1 | 182.4 |
| Likely Scenario – WSSC | 171.9 | 177.5 | 186.7 | 191.6 | 197.1 | 201.1 | 203.8 |
| High Scenario – WSSC | 171.9 | 179.6 | 190.4 | 196.9 | 203.5 | 208.7 | 212.5 |
| Likely Scenario - WMA Supplier Subtotal | 497.9 | 522.1 | 551.0 | 570.6 | 587.5 | 599.1 | 610.5 |
| High Scenario - WMA Supplier Subtotal | 509.9 | 540.0 | 574.8 | 602.5 | 626.3 | 645.7 | 664.0 |
| Likely Scenario - City of Rockville DPW | 4.8 | 5.0 | 5.3 | 5.6 | 5.8 | 6.1 | 6.3 |
| High Scenario - City of Rockville DPW | 4.8 | 5.0 | 5.4 | 5.7 | 6.0 | 6.3 | 6.5 |
| **Likely Scenario - TOTAL WMA Suppliers plus Rockville** | **502.7** | **527.1** | **556.3** | **576.2** | **593.3** | **605.1** | **616.8** |
| Potential additional demand from growth areas | 12 | 13 | 15 | 19 | 23 | 28 | 32 |
| Additional demand assuming constant SFH unit use | 0.0 | 4.9 | 8.9 | 13.0 | 16.0 | 18.9 | 21.7 |
| **High Scenario - TOTAL WMA Suppliers plus Rockville** | **514.7** | **545.0** | **580.2** | **608.2** | **632.3** | **652.0** | **670.5** |

Note: SFH = single family home, units are million gallons per day

#### 1.3.1.2 Resource Analysis Method

The resource analysis assessed the ability of the current WMA water supply system to meet the forecasted demand discussed above. This analysis was done using PRRISM to simulate future water availability based on forecasted demands and the historical hydrologic and meteorological record. PRRISM simulates the processes that govern water supply and demand in the WMA system on a daily basis: flows in the Potomac River; inflows, storage, and releases from the WMA reservoirs; and water withdrawals by the three main WMA suppliers.

#### 1.3.1.3 Conclusions of the Demand and Resource Availability Forecast for the Year 2040

1. The WMA's current water supply system will continue to meet demands through 2030, under a range of hydrologic conditions similar to the 78-year period of historical record, with no water supply shortfalls and no emergency water use restrictions.
2. By the year 2040, the current system may have difficulty meeting the region's demands during periods of drought without water use restrictions, and/or the development of additional supply resources.
3. Summertime outdoor water use may be increasing in some areas of the WMA, offsetting the benefits of adopting more water efficient indoor fixtures and appliances.
4. The system's largest reservoir, Jennings Randolph, appears to be losing storage capacity due to sedimentation at a higher rate than previously estimated.

### 1.3.2 2010 Demand and System Reliability Study – Part 2 Climate Change

A second part of the 2010 demand study looked at the impact a changing climate could have on the reliability of the current system. Using a variety of global climate models and greenhouse gas emission scenarios, modified precipitation, temperature, and stream flow data were used as input to the PRRISM model. The same demands from Part 1 of the study were used. The results indicate that if the climate were to change, the CO-OP system as currently designed would require more days of mandatory water use restrictions and may not be as reliable as it has been in the past.

## 1.4 Options for Meeting Future Demands

When the current water supply system was envisioned in the 1980s, it was assumed that it would provide a reliable source of drinking water for 30 years. The system has indeed been strong for more than 30 years now, but the recent reliability studies indicate that the system will become more stressed in the future. Therefore, the time to start thinking about additional storage resources or new ways of managing the system is nearing.

The 2010 reliability study cites four possible additional sources of water, one of which is in the process of being constructed. The report suggests that two new intakes could be constructed –

one in the Potomac estuary and one in the Occoquan estuary. The intake, pumping station, and distribution system that would carry water from the Potomac estuary to Washington Aqueduct's Dalecarlia Treatment Facility was constructed in the 1970s but was never used for water supply. Water quality assessments were completed that show the water in this area is essentially fresh and could be treated with conventional treatment. An intake in the Occoquan estuary would be more complicated and expensive to run because the water tends to be brackish. A costly reverse-osmosis membrane treatment plant would be required to treat the water during low flows.

The 2010 report also identifies two quarry sites as locations for additional storage, one in Fairfax County, Virginia, and one in Loudon County, Virginia. Fairfax Water owns two quarries – Lorton Quarry, currently used for solids disposal, and Vulcan Quarry. Both of these are located near one of their existing water treatment plants. Assessments of both quarries were done to gauge costs and storage capacity, but neither is set for use in the near term.

Loudoun Water, currently a wholesale customer of Fairfax Water, recently received permits for the construction of a Potomac River intake, quarry storage, and a 40 Mgal/d water treatment plant. One of four proposed quarries is scheduled to be available for storage between 2017 and 2020. This quarry would have a storage volume of over one billion gallons. Loudoun Water will construct a system to allow water to fill the quarry when flows are high and then rely on water stored in the quarry when flows drop to the threshold specified in their permit. According to Loudoun's Potomac River withdrawal permit being issued by the Virginia Department of Environmental Quality, the quarry will be managed in coordination with the WMA cooperative water supply system to the benefit of both Loudoun Water and the other CO-OP suppliers.

In addition to building new structures, alternative management guidelines might also allow the system to keep up with increasing demands. Research is currently being conducted by the consulting firm Hydrologics through a Water Research Foundation grant to investigate "dynamic reservoir operations," that is, operations that respond to changing conditions, to meet the challenges of climate change.

Through this research project, Hydrologics evaluated the effectiveness of more frequent and stricter water use restrictions during droughts and increased flexibility in production rates at WSSC. At the time of completion of this report, the report on Hydrologics' study, *Dynamic Reservoir Operations: Managing for Climate Variability and Change*, is in draft form.

Another method that has received some attention in the region is the adjustment of pricing structures to incentivize reduced water use by consumers. This approach to reducing demand has been successful in other regions of the country. According to Mehan and Kline (2012), alternative pricing structures are meant to recover the full cost of providing water to customers and/or to reduce demand in water stressed regions or during droughts[3]. Key to the success of these programs is metering water use and making this information available to customers so they can respond to the price signals. Some concerns that have been raised about these structures include increased customer bills, burdens on low- income customers, and decreasing revenue for the water suppliers. In response to these concerns, Mehan and Kline provide citations showing that customer bills often drop despite the increased rates because of reduced consumption, that alternate rate structures or direct subsidies can assist low-income customers, and that utilities can account for the lower consumption rates when developing the price structure.

### 1.4.1 Reallocation of Storage Capacity in Jennings Randolph Reservoir

The question has also been raised as to whether or not some of the water quality storage in Jennings Randolph could be reallocated to allow for additional water supply storage. The reservoir was initially authorized by the United States Congress in 1962[4] for the purpose of flood control, domestic and industrial water supply, water quality control, and recreation (USACE Baltimore District 1997a). White water recreation was added as a formal purpose in the Water Resources Development Act of 1988.

According to the USACE Master Manual for reservoir operations, about 13.4 billion gallons of water supply storage is available to the WMA suppliers in Jennings Randolph, with an additional 16.6 billion gallons allocated to water quality purposes, though sediment is known to be accumulating behind the reservoir thus decreasing total capacity (USACE Baltimore District 1997a). Additionally, Savage Reservoir has 6.3 billion gallons of storage for water quality purposes. Releases are made from Savage concurrently with water supply releases from Jennings Randolph at an approximate 20 percent match.

Originally, water quality releases were needed to offset poor water quality coming out of Jennings Randolph due to acid mine drainage and municipal and industrial wastewater, but this is no longer a concern due to Federal policies requiring increased treatment of pollution at its source (USACE Baltimore District 1997a). Authorized water quality purposes include downstream water quality, with emphasis in recent years on support of a coldwater fishery immediately below the dam; in-lake and lakeside recreation; and whitewater recreation.

While increasing the water supply storage in Jennings Randolph Reservoir could bolster the reliability of the WMA water supply system, it would be difficult to reallocate the storage. The Jennings Randolph Master Manual states that flood control will always be the highest priority, but "priorities for project purposes other than flood control are constantly re-evaluated." Multiple attempts were made in the 1990s to assess the feasibility of reallocating some of the flood control storage to water supply storage (USACE Baltimore District 1995). These efforts were suspended after a review of the maximum probable flood determined that the dam needed to be modified to increase the spillway capacity due to revised dam safety criteria. Therefore, reallocation of flood storage was no longer a possibility (USACE Baltimore District 1997b). In subsequent years, work was done to figure out the improvements that need to be made to the dam, but no physical changes have been made to date (USACE Baltimore District 2011).

In the authorized reallocation studies, one potential alternative that was to be considered was the reallocation of water quality storage to supply storage (Federal Register 1994), though in the draft reallocation study this option does not appear as a considered alternative (USACE Baltimore District unpublished).

Water quality releases are made year-round, including during low flows. Without them there would be additional need for water supply releases. During low-flow periods when CO-OP is evaluating water supply demands and the potential need for releases, the analysis accounts for the amount being released from water quality storage. If this release was not occurring, there could be more frequent and extended water supply releases. That said, a significant portion of the water quality storage is used in a typical year and sometimes these releases have to be scaled back to preserve storage.

If the stakeholders in reservoir operations and downstream uses wanted to consider reallocating some of the water quality storage to water supply storage, a number of steps would have to be taken. First, funding would have to be authorized by Congress for a reallocation study. Regulations for the USACE require a Reconnaissance Study, a Feasibility Cost Share Agreement with a non-federal partner, a Feasibility Report, and an Environmental Impact Statement. These reports would also have to go through a public comment period before any final decisions could be made.

In addition to CO-OP, another active stakeholder group is the North Branch Potomac River Advisory Committee (NBPRAC). This group was formed in 2005 by the National Park Service to provide a forum for stakeholders to provide input regarding the operations of Jennings Randolph and Savage reservoirs. Since 2008, ICPRB has taken on the role of the NBPRAC coordinator. The group developed a list of flow management recommendations for the USACE (National Park Service 2008):

- Maximize opportunities for fishing and boating in the region.
- Maximize opportunities for all types of fishing (float, bank, wading).
- Maximize opportunities for lake swimming and lake boating.
- Provide opportunities for whitewater paddling at different skill levels.
- Provide opportunities for two-day weekends of paddling.
- Maintain optimum habitat for fish population.

These objectives would have to be considered in any reallocation study. Evaluation of storage allocations could part of a comprehensive basin-wide plan that considers not only water supply needs but also water quality, the health of the basin's flora and fauna, and recreation opportunities.

Finally, given the tradition of cooperation in the basin, many stakeholders, including CO-OP, would like to see more water suppliers enter into a cooperative management agreement as a means of improving the reliability of the system. If this was done and the needed tools were developed, better use could be made of the water released from the upstream reservoirs. Currently, many utilities withdrawing from the Potomac have provisions in their permits that require them to reduce or stop withdrawals during certain low flow conditions. At the same time, it is not uncommon for releases to be made from the reservoirs only to have it rain while the water is taking the approximate nine days to make it to the WMA suppliers' intakes. This can lead to stored water being "wasted" as it is no longer needed to meet demands and the recommended flow-by. If there was a cooperative management agreement in place, more efficient use of the available water would be possible. This could become more of an issue as population and water use continues to increase in upstream areas.

# Appendix AA

Pocahontas County Water Resources Management Plan

# Pocahontas County
# Water Resources Management Plan

State planning requirements for inclusion into the West Virginia Water Resource Management Plan

Submitted to the West Virginia Department of Environmental Protection
Submitted by the Pocahontas County Water Resources Task Force
Consultant: Downstream Strategies

October 31, 2013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Downstream Strategies
building capacity for sustainability

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# ABBREVIATIONS

| | |
|---|---|
| DS | Downstream strategies |
| EQIP | Environmental Quality Incentive Program |
| GIS | Geographic Information Systems |
| GVCD | Greenbrier Valley Conservation District |
| HUC | hydrologic unit code |
| MAF | mean annual flow |
| MMF | mean monthly flow |
| NRCS | Natural Resource Conservation Service |
| SRA | Strategic Resource Area |
| TMDL | total maximum daily load |
| TDS | total dissolved solids |
| USFS | United States Forest Service |
| USGS | United States Geological Survey |
| WRMP | water resources management plan |
| WRTF | Water Resources Task Force |
| WVCA | West Virginia Conservation Agency |
| WVDEP | West Virginia Department of Environmental Protection |
| WVDNR | West Virginia Division of Natural Resources |
| WVDOF | West Virginia Division of Forestry |
| WVSP | West Virginia State Parks |

# EXECUTIVE SUMMARY

The State of West Virginia is currently creating its own water resources management plan (WRMP) as mandated by the Water Resources Protection and Management Act ("The Act") of 2008 (West Virginia Code Chapter 22, Article 26). Pocahontas County's plan ("The Plan") is being developed pursuant to West Virginia Code -§22-26-9 (f) & (g), which state that a county may enter into an agreement with the West Virginia Department of Environmental Protection (WVDEP) to develop a local plan that will be filed as part of the state water resources management plan (WRMP). It is the belief of the Pocahontas County Water Resources Task Force (WRTF) that the community will be best served by creating its own WRMP—one tailored to and created by the people of Pocahontas County (more info on the WRTF can be found in Appendix B).

A process was implemented with the WVDEP to ensure this plan will meet the WV State requirements and will be filed as part of the state WRMP. Downstream Strategies (DS) and the WRTF coordinator met with the WVDEP in 2012 to discuss Pocahontas County's approach to meeting the requirements outlined in the Act. Discussion revolved around the project timeline, presentation and approval of our methods, and the intent to share data. Presented in this document are the methods and results to meet the requirements outlined in West Virginia Code §22-26.

This document presents the results for each state planning requirement that was presented to the WVDEP in 2012, listed in Table 1. This report brief is meant to communicate the methods and results that will be employed in the creation and implementation of the Plan. This document is not meant for public distribution or dissemination, but as a tool to communicate methods and results to the WVDEP, which will ensure that the Plan is filed as part of the statewide WRMP.

**Table 1: WV state plan requirements**

| Section reference | Water Resource Protection & Management Act reference | Description |
|---|---|---|
| Section 1 | §22-26-8 (c)(1) | Inventory surface water resources |
| Sections 1.2 and 2.10 | §22-26-8 (c)(1) and §22-26-8 (c)(3) | Estimate safe yield (for consumptive and non-consumptive uses) |
| Section 1.3 | §22-26-8 (c)(2) | Inventory consumptive large quantity users (>750,000 gal/month) |
| Section 2.1 | §22-26-8 (c)(3) | A plan for the development of the infrastructure necessary to identify groundwater resources |
| Sections 3 and 4 | §22-26-8 (c)(4) | Project existing and future non-consumptive use needs |
| Section 3 | §22-26-8 (c)(5) | Assessment & projection of existing & future consumptive use demands |
| Section 5 | §22-26-8 (c)(6) | Identify potential problems with water availability and user/use conflicts |
| Section 6 | §22-26-8 (c)(7) | Establish criteria to identify critical water planning areas |
| Section 7.1 | §22-26-8 (c)(8) | Assess public water supply capability |
| Section 7.1 | §22-26-8 (c)(9) | Flood plain & stormwater management problems |
| Sections 1.1 and 2.1 | §22-26-8 (c)(10) | Improve data collection, reporting and water monitoring where prior reports have found deficiencies |
| Section 7.4 | §22-26-8 (c)(11) | Develop a process for identifying projects & practices that encourage (water conservation) |
| Section 7.5 | §22-26-8 (c)(12) | An assessment of both structural & nonstructural alternatives to address water availability problems |
| Section 7.6 | §22-26-8 (c)(13) | A review & evaluation of statutes, rules, policies and institutional arrangements for the development, conservation, distribution & emergency management of water resources |
| Section 7.6 | §22-26-8 (c)(14) | A review & evaluation of water resources management alternatives and recommended programs, policies, institutional arrangements, projects and other provisions to meet the water resources needs of the county |
| Section 7.7 | §22-26-8 (c)(15) | Proposed methods of implementing recommendations |

# 1. SURFACE WATER RESOURCES - §22-26-8 (C)(1)

The Act requires,

> *"An inventory of the surface water resources of each region of this state, including an identification of the boundaries of significant watersheds and an estimate of the safe yield of such sources for consumptive and nonconsumptive uses during periods of normal conditions and drought."*

An inventory of surface water resource data was gathered and reported in Phase 1 of the Plan. As shown in Figure 1, the assessment inventoried and mapped all surface water resources, including the identification of the significant watershed boundaries. In addition to surface water resources, available groundwater resource data were also collected and mapped as part of the assessment, discussed further in Section 2.

Also included as part of this submission are all existing and updated datasets created during the Phase 2 planning process including an updated GIS geodatabase (Appendix A). The database includes previously developed datasets, as well as datasets created or modified during the planning process.

## 1.1 Surface water monitoring plan

The surface water quality monitoring plan was developed to be implemented by the WRTF.

The first goal of the water quality monitoring program is to collect water samples in watersheds considered impaired for fecal coliform with the following objectives:

- confirm fecal contamination issues reported in the Total Maximum Daily Load (TMDL) study performed on the Greenbrier River watershed (Tetra Tech, 2008),
- pinpoint potential sources of fecal coliform pollution in order to inform the development of programs to mitigate the pollution, and
- utilize the results to inform citizens about the issue and what can be done to minimize the pollution.

The second goal of the water quality monitoring program is to characterize surface- and groundwater in Pocahontas County, based on the following objectives:

- supplement existing baseline water quality data with new monitoring data collected by WRTF,
- provide guidelines for obtaining defensible new baseline water quality data in advance of potential industrial development such as, but not limited to horizontal hydraulic fracturing for natural gas, and
- establish defensible water quality baselines for drinking water sources for participating county residents.

Using GIS and local knowledge, sites were selected across the county from the set of sites previously established by WVDEP's Watershed Assessment Program. Using these sites allow for a direct comparison with historical data, allowing for the analysis of long-term changes. The groundwater monitoring plan is a standalone document that is presented in Appendix C. .

**Figure 1: Pocahontas County surface water resources map**

## 1.2 Safe yield

### 1.2.1 *Background*

The Act notes three components of the plan that are directly related to safe yield:

> *"An inventory of the surface water resources of each region of this state, including an identification of the boundaries of significant watersheds and an estimate of the safe yield of such sources for consumptive and nonconsumptive uses during periods of normal conditions and drought." (§22-26-8(c)(1)).*
>
> *"A plan for the development of the infrastructure necessary to identify the groundwater resources of each region of this state, including an identification of aquifers and groundwater basins and an assessment of their safe yield, prime recharge areas, recharge capacity, consumptive limits and relationship to stream base flows." (§22-26-8(c)(3)).*
>
> *"Establish criteria for designation of critical water planning areas comprising any significant hydrologic unit where existing or future demands exceed or threaten to exceed the safe yield of available water resources." (§22-26-8(c)(7)).*

This section refers to the first safe yield requirement, which applies to surface waters. The second requirement refers to groundwater (Section 2), while the third requirement refers to using the calculated safe yields to designate critical water planning areas (Section 6).

Safe yield is commonly defined as the maximum, sustainable, continuous withdrawal that can be made from a water source. The State further clarifies this definition by stating that:

- the protection of aquatic habitats should be a consideration in safe yield calculations,
- safe yield defines safety, but provides no indication of risk to the resource, and
- safe yield does not consider the cumulative impact of consumptive use.

In its original context with reservoirs, a representative definition of safe yield was "the maximum quantity of water that can be guaranteed from a reservoir during a critical dry period (1 p. 62)." After the concept was extended to apply to groundwater aquifers, a representative definition was "the attainment and maintenance of a long-term balance between the amount of ground-water withdrawn annually and the annual amount of recharge (1 p. 62)."

Streams, however, are different from reservoirs and aquifers because there is no storage. The safe yield of a stream is therefore inextricably linked to the variability of its flow and the minimum flow required to maintain the health and uses of the stream.

### 1.2.2 *Calculations*

Pursuant to requirements in the Act, surface water safe yields were calculated for each Hydrologic Unit Code (HUC)-12 based on these stream statistics. While WVDEP is not calculating safe yield in its statewide assessment, the agency has provided two methods related to its assessment of water availability. We use these WVDEP methods as springboards for calculating safe yields in this report. Further, we calculate surface water safe yields for each season, and annually, at the HUC-12 level.

The first method assumes that the minimum required flow in any stream is the 7Q10, plus an additional 10% cushion. We apply this method seasonally, using, for example, the winter 7Q10 plus 10% to represent the minimum flow required in winter. We also apply this method using annual statistics. To calculate safe yield, we compare this value against the D50, which is the flow that is exceeded 50% of the time.

The second—more protective—method assumes that the minimum flow required in any season is higher, and equal to the D75: the flow that is exceeded 75% of the time. An additional 25% cushion is provided for headwater streams, and another 25% cushion is provided for ungaged streams. The seasonal D50 is again used for comparison against this minimum flow to calculate the safe yield.

Therefore, the following stream statistics must first be calculated for each HUC-12: annual and seasonal 7Q10 flows, annual and seasonal D50 flows, and annual D75 flows.

The United States Geological Survey (USGS) has produced a series of technical reports that present methods for calculating stream statistics at any location along West Virginia streams (2; 3; 4; 5). The method for a particular stream depends on whether the location is:

- at a gaging station,
- at a partial-record station, or
- at an ungaged location.

Most of the locations of interest for this project are at ungaged locations, where the USGS reports present different methods depending on whether the location is:

- upstream from a gaging station or partial-record station,
- downstream from a gaging station or partial-record station,
- between gaging stations and (or) partial-record stations, or
- not on the same stream as a gaging station or partial-record station.

USGS provides pre-calculated stream statistics for three gages within Pocahontas County:

- 03180500: Greenbrier River at Durbin, WV;
- 03182500: Greenbrier River at Buckeye, WV; and
- 03182000: Knapp Creek at Marlinton, WV (3).

Pocahontas County is a headwaters county and its HUC-12s drain toward many different rivers outside of the county; therefore, additional gages are necessary to calculate stream statistics for the HUC-12s within the county. These additional nearby gages that are outside of Pocahontas County, for which USGS provides pre-calculated stream statistics, include:

- 03050000: Tygart Valley River near Dailey, WV;
- 03069000: Shavers Fork at Parsons, WV;
- 03183500: Greenbrier River at Alderson, WV;
- 03186500: Williams River at Dyer, WV;
- 03187500: Cranberry River near Richwood, WV; and
- 03194700: Elk River below Webster Springs, WV (3).

### 1.2.3 *Stream statistics*

As shown in Figure 2, we perform calculations for 30 HUC-12 watersheds These watersheds are either entirely within Pocahontas County or have at least 7% of their drainage area within the county. We exclude the North Fork Cherry River (050500050401), South Fork Cherry River (050500050402), and Bergoo Creek-Elk River (050500070106) watersheds because of their small watershed areas within the county.

In order to calculate stream statistics, we classify each HUC-12 into one of the categories listed above. Table 2 explains the category for each watershed. Selecting the appropriate category requires, among other things, a determination of whether the HUC-12 pour point and its potentially associated gage are on the same stream. USGS provides the following definition of being on the same stream:

> Two locations were considered to be on the same stream when the stream path from the downstream location to the basin divide followed the stream segment with the largest drainage area at each stream confluence and passed through the upstream location (4).

For these reasons, several HUC-12 pour points that flow toward a downstream gage are not considered to be "on the same stream" as the gage. For example, when traveling upstream from a gage and reaching a confluence of two headwaters streams, the headwater stream with the larger drainage area is considered to be "on the same stream" as the gage, while the headwater stream with the smaller drainage area is not.

**Figure 2:HUC-12 watersheds included in safe yield calculations**

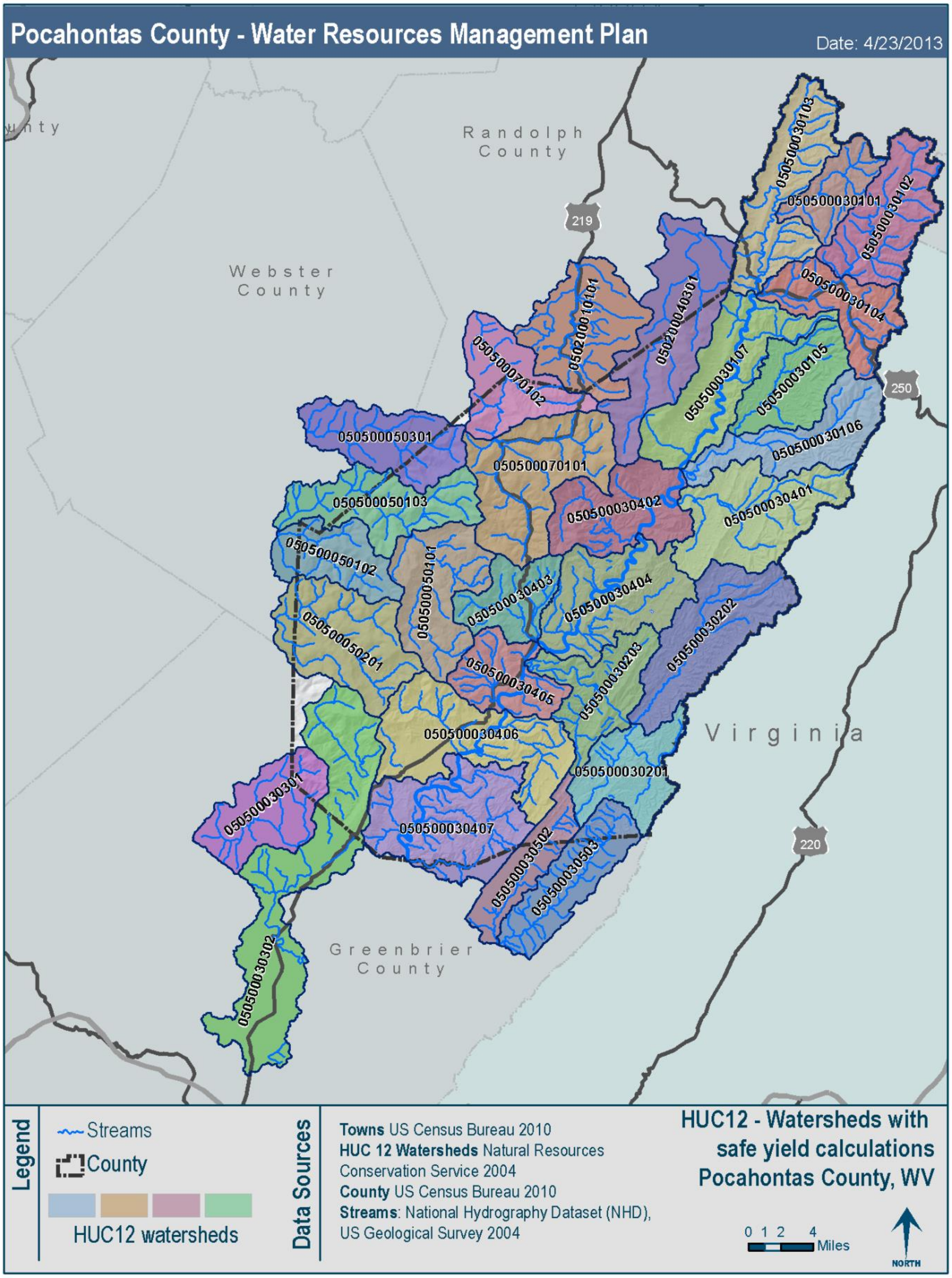


**Table 2: Categories and associated gages for each HUC-12**

| HUC-12 code | HUC-12 name | Category | Explanation | Associated gage(s) |
|---|---|---|---|---|
| **Tygart** | | | | |
| 050200010101 | Ralston Run-Tygart Valley River | Above gaging station | On stream path that follows largest drainage area to headwaters | 03050000 |
| **Shavers** | | | | |
| 050200040301 | First Fork-Shavers Fork | Above gaging station | On stream path that follows largest drainage area to headwaters | 03069000 |
| **Greenbrier** | | | | |
| 050500030101 | Little River | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500030102 | Headwaters East Fork Greenbrier River | Above gaging station | On stream path that follows largest drainage area to headwaters | 03180500 |
| 050500030103 | West Fork Greenbrier River | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500030104 | Outlet East Fork Greenbrier River | Above gaging station | On stream path that follows largest drainage area to headwaters | 03180500 |
| 050500030105 | Headwaters Deer Creek | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500030106 | Outlet Deer Creek | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500030107 | Brush Run-Greenbrier River | Between gaging stations | Between two stations and on stream path that follows largest drainage area to headwaters | 03182500 below, 03180500 above |
| 050500030201 | Douthat Creek | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500030202 | Headwaters Knapp Creek | Above gaging station | On stream path that follows largest drainage area to headwaters | 03182000 |
| 050500030203 | Outlet Knapp Creek | At gaging station | HUC-12 pourpoint is close to gage | 03182000 |
| 050500030301 | Headwaters Spring Creek | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500030302 | Outlet Spring Creek | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500030401 | Sitlington Creek | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500030402 | Clover Creek-Greenbrier River | Between gaging stations | Between two stations and on stream path that follows largest drainage area to headwaters | 03182500 below, 03180500 above |
| 050500030403 | Stony Creek | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |

| HUC-12 code | HUC-12 name | Category | Explanation | Associated gage(s) |
|---|---|---|---|---|
| 050500030404 | Thorny Creek-Greenbrier River | Between gaging stations | Between two stations and on stream path that follows largest drainage area to headwaters | 03182500 below, 03180500 above |
| 050500030405 | Swago Creek-Greenbrier River | At gaging station | HUC-12 pourpoint is close to gage | 03182500 |
| 050500030406 | Stamping Creek-Greenbrier River | Between gaging stations | Between two stations and on stream path that follows largest drainage area to headwaters | 03183500 below, 03182500 above |
| 050500030407 | Locust Creek-Greenbrier River | Between gaging stations | Between two stations and on stream path that follows largest drainage area to headwaters | 03183500 below, 03182500 above |
| 050500030502 | North Fork Anthony Creek | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500030503 | Upper Anthony Creek | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| | | | | |
| **Williams** | | | | |
| 050500050101 | Upper Williams River | Above gaging station | On stream path that follows largest drainage area to headwaters | 03186500 |
| 050500050102 | Middle Fork Williams River | Not on same stream as gaging station | Not on stream path that follows largest drainage area to headwaters | N/A |
| 050500050103 | Middle Williams River | Above gaging station | On stream path that follows largest drainage area to headwaters | 03186500 |
| | | | | |
| **Cranberry** | | | | |
| 050500050201 | Headwaters Cranberry River | Above gaging station | On stream path that follows largest drainage area to headwaters | 03187500 |
| | | | | |
| **Gauley** | | | | |
| 050500050301 | Hughes Run-Gauley River | Not on same stream as gaging station | So far from downstream station that all statistics must be calculated from regional equation | N/A |
| | | | | |
| **Elk** | | | | |
| 050500070101 | Old Field Fork | Above gaging station | On stream path that follows largest drainage area to headwaters | 03194700 |
| 050500070102 | Dry Fork-Elk River | Above gaging station | On stream path that follows largest drainage area to headwaters | 03194700 |

### 1.2.4 *Classification of HUC-12s by relationship with gaging stations*

**Watersheds at gaging stations**

Two HUC-12 watersheds are considered to be at gaging stations. As described by USGS, streamflow statistics for these watersheds are simply read from Table 11 in a previous USGS document (3).

**Watersheds above gaging stations**

Nine HUC-12 watersheds are considered to be above gaging stations. For these watersheds, stream statistics are based on the downstream gage, but the statistics are adjusted based on the ratio of the drainage area for the unknown location versus the drainage area for the known location. An exponent is also applied to this ratio, depending on the statistic.

USGS also provides a definition of "near", which is based on a ratio of the drainage area for the unknown watershed compared with the drainage area of a gage location with known streamflow statistics (4). If the watershed with unknown statistics is not sufficiently "near" the downstream gage, USGS suggests establishing a partial record station. Because it is outside of the scope of this project to establish partial record stations, we apply the regional equations for specific stream statistics for HUC12s considered to be too far from their association gage.

Note that for a single HUC12 that is above a gage, some statistics may be calculated using the "above a gaging station method" and others may be calculated using the regional equations, because the threshold for determining whether a locations is "near" varies based on the stream statistic. In addition, USGS does not include methods for calculating seasonal D75 values; therefore, seasonal D75 values are only included for HUC12s located at gaging stations, for which special methods are not needed.

**Watersheds between gaging stations**

Five watersheds are considered to be between gaging stations. These include three watersheds between the Durbin and Buckeye gages and two watersheds between the Buckeye and Alderson gages.

USGS explains situations where it is advisable to establish partial-record stations, but for reasons described above,we proceed with the USGS method even for watersheds for which the establishment of partial record stations is recommended (4).

**Not on same stream as gaging station**

The remaining 14 watersheds are too far from any gaging station, or are considered not to be on the same stream as a gaging station. As described above, while these watersheds ultimately drain to a gaging station, they do not meet the definition of being "on the same stream" as the gaging stations, and therefore a different method is used to calculate stream statistics.

The regional equations for the South-Central Region are taken from Table 1 of the appropriate USGS reports for annual statistics (4) and seasonal statistics (2).

Certain stream statistics require mean annual precipitation (4). Because these precipitation values are presented by stream gage, it was necessary to assign each HUC-12 to a gage. Five watersheds were assigned to the Greenbrier River at Durbin, WV gage (03180500)—these five watersheds include the HUC-12 that contains the gage and all upstream HUC-12s. Three watersheds were assigned to the Knapp Creek at

Marlinton, WV gage (03182000): the HUC-12 that contains the gage and all upstream HUC-12s. All remaining HUC-12s were assigned to the Greenbrier River at Buckeye, WV gage (03182500).

The stream statistics calculated for each HUC-12 are shown in Table 3.

### Table 3: Stream statistics for HUC12s in Pocahontas County (cfs)

| HUC-12 | HUC-12 Name | 7Q10 Annual | 7Q10 Winter | 7Q10 Spring | 7Q10 Summer | 7Q10 Fall | D50 Annual | D50 Winter | D50 Spring | D50 Summer | D50 Fall | D75 Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050200010101 | Ralston Run-Tygart Valley River | 0.6 | 12.4 | 4.9 | 0.6 | 1.1 | 39.8 | 94.5 | 53.6 | 10.8 | 23.8 | 12.5 |
| 050200040301 | First Fork-Shavers Fork | 0.8 | 24.0 | 12.0 | 0.8 | 1.4 | 88.9 | 150.0 | 117.5 | 35.4 | 82.0 | 40.2 |
| 050500030101 | Little River | 0.2 | 3.6 | 1.2 | 0.2 | 0.4 | 16.5 | 38.5 | 20.5 | 4.3 | 13.5 | 5.0 |
| 050500030102 | Headwaters East Fork Greenbrier River | 0.5 | 12.5 | 4.9 | 0.5 | 1.0 | 43.1 | 91.0 | 59.9 | 9.7 | 34.3 | 13.5 |
| 050500030103 | West Fork Greenbrier River | 0.9 | 14.0 | 5.3 | 0.9 | 1.6 | 54.5 | 129.0 | 71.3 | 15.7 | 41.6 | 18.0 |
| 050500030104 | Outlet East Fork Greenbrier River | 0.8 | 22.0 | 9.2 | 1.0 | 2.1 | 73.7 | 156.4 | 102.5 | 17.5 | 57.7 | 23.7 |
| 050500030105 | Headwaters Deer Creek | 0.4 | 5.0 | 2.1 | 0.3 | 0.7 | 21.9 | 53.9 | 28.8 | 6.0 | 16.3 | 6.8 |
| 050500030106 | Outlet Deer Creek | 1.0 | 12.0 | 5.6 | 0.9 | 1.7 | 48.2 | 119.5 | 65.4 | 14.1 | 34.1 | 15.8 |
| 050500030107 | Brush Run-Greenbrier River | 3.2 | 52.8 | 23.1 | 3.7 | 6.1 | 171.5 | 379.3 | 238.6 | 44.1 | 126.7 | 56.7 |
| 050500030201 | Douthat Creek | 0.4 | 3.9 | 2.1 | 0.3 | 0.7 | 18.1 | 46.8 | 24.7 | 5.0 | 12.4 | 5.6 |
| 050500030202 | Headwaters Knapp Creek | 0.7 | 8.0 | 6.8 | 1.2 | 2.3 | 28.6 | 76.6 | 39.7 | 8.2 | 18.4 | 9.7 |
| 050500030203 | Outlet Knapp Creek | 4.1 | 18.5 | 17.3 | 4.1 | 6.9 | 62.9 | 170.0 | 87.3 | 19.4 | 39.5 | 22.2 |
| 050500030301 | Headwaters Spring Creek | 0.5 | 5.7 | 2.5 | 0.4 | 0.8 | 25.0 | 61.6 | 33.0 | 6.9 | 18.4 | 7.8 |
| 050500030302 | Outlet Spring Creek | 3.2 | 37.4 | 19.0 | 3.6 | 5.2 | 131.7 | 329.5 | 185.7 | 42.1 | 87.9 | 46.3 |
| 050500030401 | Sitlington Creek | 0.7 | 8.7 | 3.9 | 0.6 | 1.2 | 36.0 | 88.9 | 48.2 | 10.3 | 25.9 | 11.6 |
| 050500030402 | Clover Creek-Greenbrier River | 6.8 | 72.0 | 37.6 | 7.6 | 10.6 | 244.5 | 587.2 | 336.5 | 65.8 | 166.3 | 79.2 |
| 050500030403 | Stony Creek | 0.3 | 3.6 | 1.5 | 0.2 | 0.5 | 16.6 | 40.8 | 21.6 | 4.4 | 12.5 | 5.1 |
| 050500030404 | Thorny Creek-Greenbrier River | 9.2 | 90.8 | 47.3 | 9.9 | 14.1 | 298.7 | 715.7 | 412.5 | 80.2 | 202.0 | 97.1 |
| 050500030405 | Swago Creek-Greenbrier River | 14.5 | 132.0 | 69.2 | 15.3 | 21.7 | 414.0 | 990.0 | 576.0 | 112.0 | 277.0 | 136.0 |
| 050500030406 | Stamping Creek-Greenbrier River | 15.3 | 144.0 | 76.8 | 17.0 | 23.0 | 442.7 | 1,064.0 | 620.4 | 121.1 | 293.2 | 145.8 |
| 050500030407 | Locust Creek-Greenbrier River | 19.9 | 154.5 | 85.5 | 21.0 | 28.1 | 491.1 | 1,188.9 | 695.3 | 136.4 | 320.6 | 162.5 |
| 050500030502 | North Fork Anthony Creek | 0.3 | 3.5 | 1.5 | 0.2 | 0.5 | 16.0 | 39.2 | 20.7 | 4.2 | 12.1 | 4.9 |
| 050500030503 | Upper Anthony Creek | 0.4 | 5.4 | 2.3 | 0.4 | 0.8 | 23.7 | 58.2 | 31.2 | 6.5 | 17.5 | 7.4 |
| 050500050101 | Upper Williams River | 0.5 | 18.4 | 4.1 | 0.5 | 0.9 | 57.5 | 111.7 | 71.5 | 15.3 | 51.0 | 20.5 |
| 050500050102 | Middle Fork Williams River | 0.3 | 4.1 | 1.8 | 0.3 | 0.6 | 18.7 | 46.0 | 24.5 | 5.0 | 14.0 | 5.8 |
| 050500050103 | Middle Williams River | 1.0 | 37.4 | 9.0 | 1.2 | 2.5 | 112.1 | 219.4 | 139.5 | 31.9 | 97.3 | 41.4 |
| 050500050201 | Headwaters Cranberry River | 1.5 | 20.8 | 4.1 | 1.8 | 5.7 | 82.5 | 145.9 | 96.0 | 27.8 | 89.3 | 32.1 |
| 050500050301 | Hughes Run-Gauley River | 0.5 | 6.0 | 2.6 | 0.4 | 0.8 | 25.9 | 63.7 | 34.2 | 7.2 | 19.0 | 8.1 |
| 050500070101 | Old Field Fork | 0.7 | 9.0 | 4.1 | 0.7 | 1.3 | 37.1 | 91.7 | 49.8 | 10.6 | 26.7 | 12.0 |
| 050500070102 | Dry Fork-Elk River | 1.3 | 44.9 | 11.2 | 1.4 | 2.3 | 134.3 | 247.4 | 157.3 | 42.2 | 141.7 | 52.8 |

**Table 4: Safe yields for HUC12s in Pocahontas County using Method 1: Protect 7Q10 flow plus 10% (cfs)**

| HUC-12 | HUC-12 Name | Annual | Winter | Spring | Summer | Fall |
|---|---|---|---|---|---|---|
| ***050200010101*** | ***Ralston Run-Tygart Valley River*** | ***39.2*** | ***80.9*** | ***48.2*** | ***10.2*** | ***9.7*** |
| | | | | | | |
| ***050200040301*** | ***First Fork-Shavers Fork*** | ***88.1*** | ***123.6*** | ***104.3*** | ***34.5*** | ***33.8*** |
| | | | | | | |
| 050500030101 | Little River | 16.2 | 34.5 | 19.2 | 4.0 | 3.8 |
| 050500030102 | Headwaters East Fork Greenbrier River | 42.5 | 77.3 | 54.6 | 9.2 | 8.7 |
| 050500030103 | West Fork Greenbrier River | 53.5 | 113.5 | 65.5 | 14.7 | 13.9 |
| 050500030104 | Outlet East Fork Greenbrier River | 72.7 | 132.2 | 92.4 | 16.4 | 15.1 |
| | | | | | | |
| 050500030105 | Headwaters Deer Creek | 21.5 | 48.5 | 26.5 | 5.6 | 5.2 |
| 050500030106 | Outlet Deer Creek | 47.2 | 106.2 | 59.2 | 13.1 | 12.2 |
| | | | | | | |
| 050500030201 | Douthat Creek | 17.7 | 42.5 | 22.4 | 4.7 | 4.2 |
| 050500030202 | Headwaters Knapp Creek | 27.9 | 67.8 | 32.2 | 6.8 | 5.6 |
| 050500030203 | Outlet Knapp Creek | 58.4 | 149.7 | 68.3 | 14.9 | 11.8 |
| | | | | | | |
| 050500030301 | Headwaters Spring Creek | 24.5 | 55.3 | 30.3 | 6.5 | 6.0 |
| ***050500030302*** | ***Outlet Spring Creek*** | ***128.3*** | ***288.3*** | ***164.8*** | ***38.2*** | ***36.5*** |
| | | | | | | |
| 050500030401 | Sitlington Creek | 35.2 | 79.3 | 43.9 | 9.5 | 8.9 |
| | | | | | | |
| 050500030403 | Stony Creek | 16.3 | 36.8 | 19.9 | 4.2 | 3.9 |
| | | | | | | |
| ***050500030502*** | ***North Fork Anthony Creek*** | ***15.7*** | ***35.4*** | ***19.1*** | ***4.0*** | ***3.7*** |
| | | | | | | |
| ***050500030503*** | ***Upper Anthony Creek*** | ***23.2*** | ***52.3*** | ***28.6*** | ***6.1*** | ***5.7*** |
| | | | | | | |
| 050500050101 | Upper Williams River | 56.9 | 91.4 | 67.0 | 14.8 | 14.3 |
| ***050500050103*** | ***Middle Williams River*** | ***111.0*** | ***178.2*** | ***129.6*** | ***30.5*** | ***29.1*** |
| | | | | | | |
| ***050500050102*** | ***Middle Fork Williams River*** | ***18.4*** | ***41.4*** | ***22.5*** | ***4.7*** | ***4.4*** |
| | | | | | | |
| ***050500050201*** | ***Headwaters Cranberry River*** | ***80.9*** | ***123.1*** | ***91.5*** | ***25.8*** | ***21.6*** |
| | | | | | | |
| ***050500050301*** | ***Hughes Run-Gauley River*** | ***25.4*** | ***57.1*** | ***31.3*** | ***6.7*** | ***6.2*** |
| | | | | | | |
| 050500070101 | Old Field Fork | 36.3 | 81.9 | 45.3 | 9.9 | 9.2 |
| ***050500070102*** | ***Dry Fork-Elk River*** | ***132.8*** | ***198.0*** | ***144.9*** | ***40.7*** | ***39.6*** |
| | | | | | | |
| 050500030107 | Brush Run-Greenbrier River | 167.9 | 321.2 | 213.2 | 40.1 | 37.4 |
| 050500030402 | Clover Creek-Greenbrier River | 237.0 | 508.0 | 295.2 | 57.4 | 54.1 |
| 050500030404 | Thorny Creek-Greenbrier River | 288.5 | 615.8 | 360.5 | 69.3 | 64.7 |
| 050500030405 | Swago Creek-Greenbrier River | 398.1 | 844.8 | 499.9 | 95.2 | 88.1 |
| 050500030406 | Stamping Creek-Greenbrier River | 425.8 | 905.6 | 535.9 | 102.4 | 95.8 |
| ***050500030407*** | ***Locust Creek-Greenbrier River*** | ***469.3*** | ***1,019.0*** | ***601.2*** | ***113.3*** | ***105.5*** |
| | | | | | | |
| | **Total** | **1,132.1** | **2,197.3** | **1386.2** | **314.8** | **295.7** |

Note: HUC-12s are grouped by watershed and are not in numerical order. Safe yields for upstream and downstream HUC-12s cannot necessarily be added together. Bold-italics HUC-12s have pour points outside of the county and are added together to calculate the total safe yield for the county.

**Table 5: Safe yields for HUC12s in Pocahontas County using Method 2: Protect annual D75 flow, plus additional protections if headwaters or ungaged (cfs)**

| HUC-12 | HUC-12 Name | Annual | Winter | Spring | Summer | Fall |
|---|---|---|---|---|---|---|
| ***050200010101*** | ***Ralston Run-Tygart Valley River*** | ***20.3*** | ***75.1*** | ***34.1*** | ***0.0*** | ***4.3*** |
| | | | | | | |
| ***050200040301*** | ***First Fork-Shavers Fork*** | ***26.2*** | ***87.3*** | ***54.8*** | ***0.0*** | ***19.3*** |
| | | | | | | |
| 050500030101 | Little River | 8.6 | 30.7 | 12.7 | 0.0 | 5.7 |
| 050500030102 | Headwaters East Fork Greenbrier River | 22.1 | 70.0 | 38.9 | 0.0 | 13.3 |
| 050500030103 | West Fork Greenbrier River | 26.4 | 100.8 | 43.2 | 0.0 | 13.5 |
| 050500030104 | Outlet East Fork Greenbrier River | 44.1 | 126.9 | 72.9 | 0.0 | 28.1 |
| | | | | | | |
| 050500030105 | Headwaters Deer Creek | 11.3 | 43.3 | 18.2 | 0.0 | 5.6 |
| 050500030106 | Outlet Deer Creek | 28.5 | 99.7 | 45.6 | 0.0 | 14.4 |
| | | | | | | |
| 050500030201 | Douthat Creek | 9.4 | 38.1 | 16.0 | 0.0 | 3.7 |
| 050500030202 | Headwaters Knapp Creek | 13.5 | 61.5 | 24.5 | 0.0 | 3.3 |
| 050500030203 | Outlet Knapp Creek | 40.7 | 147.8 | 65.1 | 0.0 | 17.3 |
| | | | | | | |
| 050500030301 | Headwaters Spring Creek | 12.8 | 49.3 | 20.8 | 0.0 | 6.2 |
| ***050500030302*** | ***Outlet Spring Creek*** | ***73.8*** | ***271.6*** | ***127.9*** | ***0.0*** | ***30.1*** |
| | | | | | | |
| 050500030401 | Sitlington Creek | 17.9 | 70.8 | 30.1 | 0.0 | 7.9 |
| | | | | | | |
| 050500030403 | Stony Creek | 8.7 | 32.8 | 13.7 | 0.0 | 4.6 |
| | | | | | | |
| ***050500030502*** | ***North Fork Anthony Creek*** | ***8.4*** | ***31.6*** | ***13.2*** | ***0.0*** | ***4.5*** |
| | | | | | | |
| ***050500030503*** | ***Upper Anthony Creek*** | ***12.1*** | ***46.7*** | ***19.6*** | ***0.0*** | ***5.9*** |
| | | | | | | |
| 050500050101 | Upper Williams River | 25.4 | 79.6 | 39.5 | 0.0 | 18.9 |
| ***050500050103*** | ***Middle Williams River*** | ***60.3*** | ***167.6*** | ***87.7*** | ***0.0*** | ***45.5*** |
| | | | | | | |
| ***050500050102*** | ***Middle Fork Williams River*** | ***9.7*** | ***37.0*** | ***15.5*** | ***0.0*** | ***5.0*** |
| | | | | | | |
| ***050500050201*** | ***Headwaters Cranberry River*** | ***32.3*** | ***95.8*** | ***45.9*** | ***0.0*** | ***39.1*** |
| | | | | | | |
| ***050500050301*** | ***Hughes Run-Gauley River*** | ***13.2*** | ***51.0*** | ***21.5*** | ***0.0*** | ***6.3*** |
| | | | | | | |
| 050500070101 | Old Field Fork | 18.5 | 73.1 | 31.1 | 0.0 | 8.0 |
| ***050500070102*** | ***Dry Fork-Elk River*** | ***51.8*** | ***164.8*** | ***74.7*** | ***0.0*** | ***59.2*** |
| | | | | | | |
| 050500030107 | Brush Run-Greenbrier River | 100.5 | 308.3 | 167.6 | 0.0 | 55.8 |
| 050500030402 | Clover Creek-Greenbrier River | 145.4 | 488.1 | 237.4 | 0.0 | 67.3 |
| 050500030404 | Thorny Creek-Greenbrier River | 177.2 | 594.3 | 291.1 | 0.0 | 80.6 |
| 050500030405 | Swago Creek-Greenbrier River | 244.0 | 820.0 | 406.0 | 0.0 | 107.0 |
| 050500030406 | Stamping Creek-Greenbrier River | 260.4 | 881.7 | 438.1 | 0.0 | 110.9 |
| ***050500030407*** | ***Locust Creek-Greenbrier River*** | ***288.1*** | ***985.8*** | ***492.2*** | ***0.0*** | ***117.5*** |
| | | | | | | |
| | **Total** | **596.3** | **2014.2** | **987.1** | **0.0** | **336.7** |

Note: HUC-12s are grouped by watershed and are not in numerical order. Safe yields for upstream and downstream HUC-12s cannot necessarily be added together. Bold-italics HUC-12s have pour points outside of the county and are added together to calculate the total safe yield for the county.

### 1.2.5 *Surface water safe yields*

Pursuant to requirements in the Act, surface water safe yields were calculated for each HUC12 based on these stream statistics. We present results for both methods described above.

As shown in Table 4 and Table 5, the safe yields calculated using the second method are generally more protective than those calculated using the first method. In summer, the safe yields calculated using the second method are all zero, meaning that the median summer flow (D50) is lower than the annual D75 flow (after appropriate adjustments for ungaged and headwater streams). It is important to recognize that these zero values do not suggest that all streams in Pocahontas County are dry in the summer. Even within a single season, flows vary significantly from day to day. Instead, these results can best be interpreted as suggesting that care should be taken if large summer water withdrawals are proposed. The methods presented in this report are appropriate at the screening level to identify potential problem areas, and more sophisticated, site-specific analyses should be undertaken to assess specific withdrawal proposals using data for the withdrawal itself and the immediate receiving stream.

There is no single precise definition of safe yield; therefore, the ranges presented here are still instructive for the management of surface water in the county.

Also, care should be taken when interpreting these numbers to recognize that many of these HUC12s are nested and flow into each other. For this reason, it would be incorrect to simply sum the safe yields to calculate a total safe yield for the county. In Table 4 and Table 5, nested subwatersheds are clustered together.

For example, using the first method, the annual safe yield for Headwaters Deer Creek is 21.5 and the annual safe yield for Outlet Deer Creek is 47.2. The safe yield for the outlet of this watershed includes the safe yield of the headwaters, and it would be inappropriate to sum these numbers.

Similarly, the safe yields calculated for the Stamping Creek-Greenbrier River HUC12 incorporate the safe yields for all upstream HUC12s and represent the total safe yield for the large part of Pocahontas County that drains to the Greenbrier River.

## 1.3 Inventory of large quantity consumptive uses - §22-26-8 (c)(2)

The Act requires,

> *"A listing of each consumptive or nonconsumptive withdrawal by a large quantity user, including the amount of water used, location of the water resources, the nature of the use, location of each intake and discharge point by longitude and latitude where available and, if the use involves more than one watershed or basin, the watersheds or basins involved and the amount transferred."*

Table 6 lists the large consumptive users in Pocahontas County. Additional information regarding watershed s and locations will be found in later versions of this document.

**Table 6: Consumption Data**

| Entity | Consumption type | Gallons per day | Water Source |
|---|---|---|---|
| Town of Marlinton | Household/commercial | 179,602 | Knapps Creek |
| Town of Hillsboro | Household/commercial | 13,276 | Wells |
| Denmar Prison | Drinking/domestic | 43,291 | Greenbrier River |
| Edray Fish Hatchery | Raising fish/drinking | Not reported | Upper spring (Mclaughlin spring) |
| Edray Fish Hatchery | Raising fish/drinking | 1,136,219 | Lower spring (Avril spring) |
| Cheat Mountain Water Company | Household/commercial | 29,894 | Multiple wells |
| Snowshoe Mountain | Recreation | 1,258,907 | Shavers Fork, Hawthorne Valley, Black Run, and wells |

| | | | | |
|---|---|---|---|---|
| Pocahontas County Public Service district | Household/commercial | 122,386 | Springs | |

# 2. GROUNDWATER RESOURCES - §22-26-8 (C)(3)

The Act requires,

> *"A plan for the development of the infrastructure necessary to identify the groundwater resources of each region of this state, including an identification of aquifers and groundwater basins and an assessment of their safe yield, prime recharge areas, recharge capacity, consumptive limits and relationship to stream base flows* (6)."

## 2.1 Groundwater monitoring plan

Developing and implementing a groundwater monitoring plan is an important step in understanding the quantity and quality of local and/or regional groundwater systems. Long-term groundwater monitoring can allow for the identification of seasonal and/or anthropogenically induced changes to water levels and water quality, and can help guide countywide planning and regional water management decisions. Pocahontas County, surrounding counties, and the State of West Virginia could all benefit from the collection of additional data within the county. This groundwater monitoring plan is designed to address the West Virginia Code *§22-26-8(c)(3).*

Developing an effective groundwater monitoring network is a long-term endeavor. Data collected from one-time sampling or monitoring events are generally of limited value in developing an understanding of local hydrogeology. Since financial support for the implementation of a groundwater monitoring plan is uncertain, three plan versions (Tiers 1 – 3) have been developed to provide options at different funding levels. The groundwater monitoring plan is a standalone document that will be submitted separately and is further available upon request.

## 2.2 Historical groundwater use

Groundwater is withdrawn for a variety of uses within the county (Table 7). Historically, groundwater has comprised approximately 29 percent of the county's yearly domestic and public supply water needs (7). Although complete groundwater use data for the county is not available, several trends in groundwater demand can be inferred from the available data. Historically, the greatest demand for groundwater within the county has been from the domestic, public supply, and agricultural sectors.

**Table 7: Description of groundwater use in Pocahontas County**

| Use Type | Description of Uses | Source |
|---|---|---|
| **Agricultural** | Irrigation of crops, livestock watering, and aquaculture | Self-supplied from private wells |
| **Commercial, Institutional, and Industrial** | Businesses, manufacturing facilities, schools, hospitals, hotels, processing facilities, industrial fire protection | Mainly self-supplied from private wells; Some supplies are provided via municipal wells (through the municipal water system) |
| **Domestic** | Potable and household uses for individual (or multi-family) residences | Self-supplied from private wells |
| **Mining** | All types of mining and extraction processes, including oil and gas (hydraulic fracturing and well construction) | Self-supplied from private wells |
| **Public Water Supply** | Mainly potable and household uses; some commercial, institutional, and industrial uses. | Municipal wells |

Note: Descriptions of uses are based on (7), and all listed uses do not necessarily exist within the Pocahontas County.

**Table 8: Groundwater use in Pocahontas County from 1985-2005**

| Year | county Population Served by Groundwater | | Self-Supplied Groundwater Use (million gallons per day) | | | | Public Water Supply |
|---|---|---|---|---|---|---|---|
| | via Public Water Systems | Via Private Domestic Wells | Agricultural | Domestic | Industrial, Commercial, and Institutional | Mining and Extractive | |
| **1985** | 2,410 | 3,940 | 0.72 | 0.28 | 0.03 | 0 | 0.15 |
| **1990** | 250 | 3,120 | 0.01 | 0.24 | 0.89 | 0.17 | 0.03 |
| **1995** | 560 | n/a | 2.87 | 0.53 | 0.19 | 0.01 | 0.16 |
| **2000** | n/a | n/a | n/a | n/a | n/a | n/a | 0.02 |
| **2005** | 788 | n/a | n/a | 0.43 | 0.01 | 0.01 | 0.16 |

Source: Adapted from (7). Note: Categories of uses are based on (7), and all listed uses do not necessarily exist within the Pocahontas County. The Mining and Extractive category may include coal mines, quarrying operations, and/or injection/storage/exploration wells.

## 2.3 Projected groundwater Use

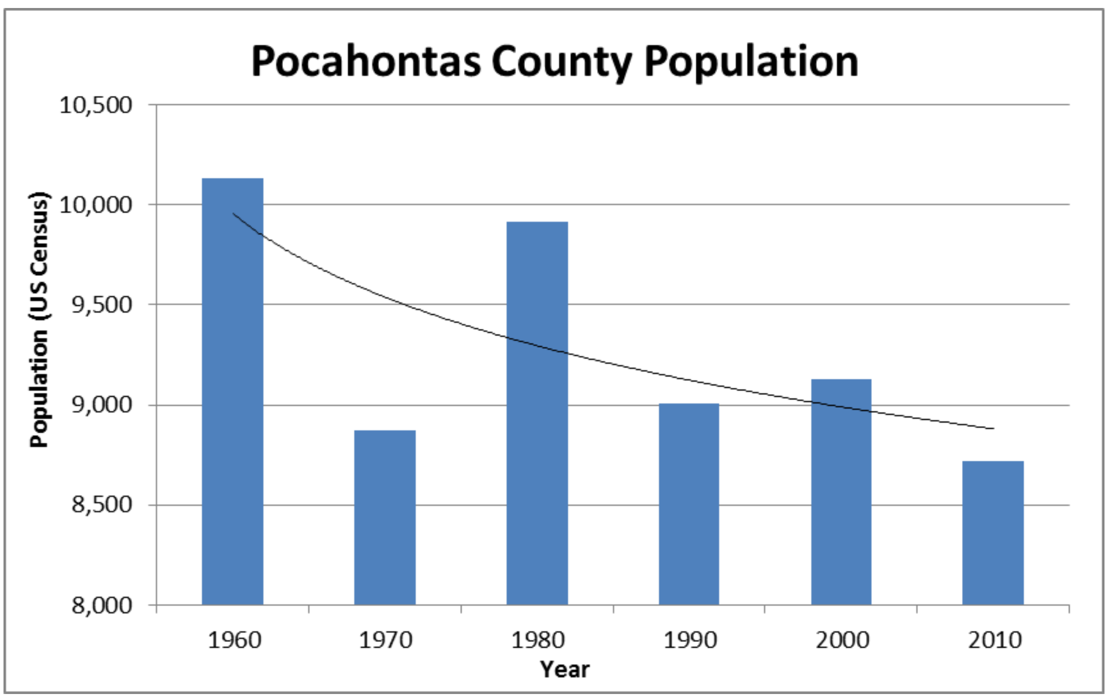
Groundwater demand projections were prepared for the county for the planning period between 2010-2035, based on historic estimated water data from the USGS (Table 9). While domestic populations are projected to decrease, domestic demand for groundwater is expected to increase slightly over the next 25 years, likely due to water use associated with vacation homes in the county. Public supply groundwater use rates in the county are projected to decrease slightly over the planning period. This is primarily due to a declining county population (Figure 3). Industrial and commercial demands also appear to be on the decline. Agricultural demand for groundwater is projected to increase based on historic estimated use, however, it is important to note that there are some data gaps in the historical agricultural groundwater demand dataset. Based on the available data, it appears that if the current population and economic trends within the county continue, the overall demand for groundwater supplies within the county may increase by 1.08 mgd over the next 25 years.

**Table 9: Projected groundwater use in Pocahontas County from 2010-2035**

| Year | Self-Supplied Groundwater Use (million gallons per day) | | | | Public Water Supply |
|---|---|---|---|---|---|
| | Agricultural | Domestic | Industrial, Commercial, and Institutional | Mining and Extractive | |
| **2010** | 3.32 | 0.53 | 0.20 | 0.07 | 0.10 |
| **2015** | 3.59 | 0.56 | 0.18 | 0.07 | 0.09 |
| **2020** | 3.82 | 0.58 | 0.17 | 0.07 | 0.09 |
| **2025** | 4.03 | 0.59 | 0.16 | 0.07 | 0.09 |
| **2030** | 4.21 | 0.61 | 0.15 | 0.06 | 0.09 |
| **2035** | 4.38 | 0.63 | 0.15 | 0.06 | 0.09 |

Note: These projections use a best-fit statistical model with input data from 1985-2005 from (7). In the Mining and Extractive sector, although 2005 may have been a lower water use year, water use in prior years may have been higher, resulting in a best-fit logarithmic trend that may be more heavily weighted toward the higher pumpage of previous years. Although water use may decline during one five-year increment, the general trend can still be an overall increase.

**Figure 3: Pocahontas County population (1960-2010)**

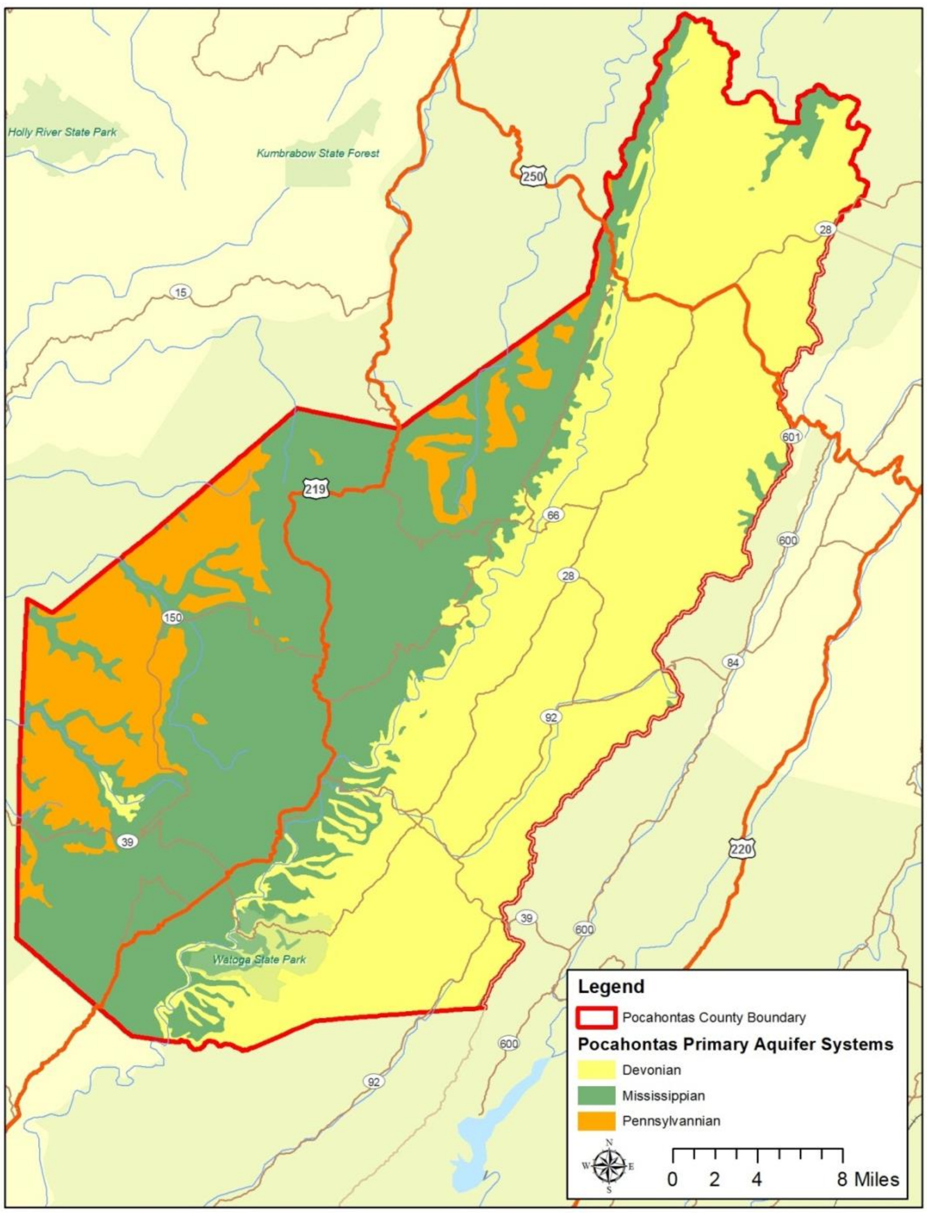


## 2.4 Identification of aquifer systems

Pocahontas County is underlain by a series of marine-origin limestone, sandstone, and shale formations, most of which were deposited from the Paleozoic era (approximately 400 million years ago) to the present. Subsequent folding, faulting, and uplift from regional tectonic activities, coupled with physical and chemical weathering formed the landscape that currently exists in the county. Groundwater occurs in and is withdrawn from each of these rock types in different areas of the county.

The hydrogeology of the county can be generally classified into several major systems (Figure 4), on the basis of their geologic age; for the purposes of this Plan, they are defined as the Quaternary, Pennsylvannian, the Mississippian, and the Devonian systems. The following sections provide an overview of the hydrogeologic framework of the county, as it pertains to groundwater supplies.

**Figure 4: Map of primary aquifer systems within Pocahontas County**



## 2.6 Hydrostratigraphy

### 2.6.1 *Quaternary system*

The Quaternary system consists mostly of alluvial materials, such as sands, silts, and gravels, and exists mainly in the stream valleys and flood plains within the county. The Quaternary system is not significant as a source of groundwater supplies, mainly due to its limited thickness and extent, and due to its highly variable composition.

### 2.6.2 *Pennsylvannian system*

The geologic units of the Pennsylvannian system consist mainly of shale, siltstone, and sandstone, interspersed with thin beds of limestone and coal. Geologic units which comprise the Pennsylvannian system outcrop mainly along ridges in the western and northwestern portions of the county, and are the chief source of groundwater supplies for rural residences and farms in these parts of the county.

### 2.6.3 *Mississippian system*

The geologic units of the Mississippian system outcrop over large areas of the county, including within the river valleys in the central portion of the county and within the western and southern portions of the county. Prominent geologic units, such as the Greenbrier Limestone and the Mauch Chunk Formation, are part of the Mississippian system, and can be observed in outcrops along streams, rivers, and road cuts in the central portion of the county. The Mississippian system is the main source of groundwater supplies for public supply, domestic, agricultural, and industrial uses for much of the county.

### 2.6.4 *Devonian system*

The Devonian system outcrops in the mountainous eastern and central portions of the county, and along the entire border with the state of Virginia. Though the Devonian system outcrops across large areas of the county, it occurs mainly within some of the lesser populated areas of the county. Groundwater from the Devonian system is used to meet domestic and farm needs, and in some of the stream valleys, is used to supply light industrial uses, commercial uses, and supply small municipalities.

**Table 10: Generalized hydrogeologic framework of Pocahontas County**

| System | Geologic Group Name | Geologic Sub-Unit | Description | Water Bearing Potential[1] | Groundwater Quality |
|---|---|---|---|---|---|
| **Quaternary** | Quaternary Alluvium | n/a | Undifferentiated sands, silts, and gravels of varying size. Exists mainly within stream valleys. | Low. The alluvium is generally of limited thickness and extent and closely linked to surface water bodies. | Data is inadequate to determine groundwater quality. |
| **Pennsylvannian** | Pottsville Group | Kanawha Formation | Mostly sandstone (~50%), siltstone, and shale, with some coal seams | Low. Yields are sufficient for domestic, and farm needs. In limited areas, small-scale municipal and light industrial needs are met with wells in valleys. Yields range from 0.2 to 55 gpm; most wells yield less than 15 gpm. | Data is limited. Groundwater quality appears highly variable across the county. Mostly calcium bicarbonate-type water, with elevated hardness, iron, and manganese in some areas. |
| | | New River Formation | | | |
| | | Pocahontas Formation | | | |
| **Mississippian** | Mauch Chunk Group | Bluestone & Princeton Formations | Red, green, and grey shale and sandstone. | Low to moderate for industrial and public supply needs. Generally adequate to meet domestic and farm water needs. Yields range from 3.6 to 250 gpm, with a mean reported yield of 10 gpm. Multiple productive springs present. | Calcium-bicarbonate type water with dissolved solids ranging from 23-315 mg/L. Water is slightly basic, and is generally described as "hard", with hardness ranging from 6 - 220 mg/L. |
| | | Hinton Formation | Red, green, and grey shale and sandstone with thin limestone beds. | | |
| | | Bluefield Formation | Red and green shale and siltstone with thin limestone beds. | | |
| | Greenbrier Group | | Limestone with red and grey shale, interbedded with thin beds of sandstone. Karst features and caves present. | High, especially in areas with extensive karstification. Valley and hillside wells are adequate to meet most public water system, industrial, and agricultural needs. Greatest yields reported near fracture traces. Multiple productive springs present. | Calcium bicarbonate-type water. Generally hard, with total dissolved solids (TDS) in most wells ranging from 100 - 500 mg/L. Relatively high concentrations of iron and manganese are present. Shallow wells are subject to contamination from surface waters which recharge the aquifer karst features. |
| | Maccrady Formation | | Red shale and mudstone, red and green sandstone, with minor interbedded limestone. | Good. Adequate supplies for light industrial users, small municipalities, domestic users, and farms can be obtained from valley wells. | Calcium bicarbonate-type water. Generally hard to very hard. Elevated iron present in some areas. |
| | Pocono Group | | Grey massive sandstone and some shale. | High. Valley wells provide adequate yields for small municipalities, light industrial users, domestic users, and farms. | Moderately to highly mineralized water. Sodium-chloride type water with TDS concentrations ranging from 39 mg/L TDS in shallow wells to more than 17,000 mg/L in deep wells (1,000 feet or more). |

| | | | | | |
|---|---|---|---|---|---|
| Devonian | Upper & Middle Devonian Rocks | Hampshire Formation | Predominantly shale. | Good. Adequate supplies for light industrial and commercial users, domestic users, and farms can be obtained from valley wells. Hilltop and hillside wells exhibited very low reported yields. | Generally good quality, soft to moderately hard water that is low in TDS. |
| | | Chemung Group | | | |
| | | Brallier Formation | | | |
| | | Harrell Shale | | | |
| | | Mahantango Formation | | | |
| | | Marcellus Formation | | | |
| | Lower Devonian Rocks and Older | Oriskany Sandstone | Sandstone, shale, and limestone in upper sequence. Sandstone and shale interbedded with limestone and dolostone in lower portion of sequence. | High. Valley wells provide adequate yields for small municipalities, light industrial users, domestic users, and farms. | n/a |
| | | Helderberg Group | | | |
| | | Tonoloway, Williamsport, & Wills Creek Formation | | | |
| | | McKenzie Formation & Clinton Group | | | |
| | | Tuscarora Sandstone | | | |
| | | Juniata & Oswego Formations | | | |

## 2.7 Groundwater flow and yield

Groundwater movement in the county occurs mainly within fractures, and along bedding planes. In areas where limestone units are present near land surface, karst features, including sinkholes, caverns, conduits, and sinking streams govern local groundwater flow. A detailed analysis and delineation of groundwater basins and flow directions was prepared for the karst limestone terrains of the county as part of Phase 1 of the Plan. Groundwater flow in most of the geologic units of the county likely follows topography and structural features, and can generally be characterized as slow (except in the Greenbrier Limestone and underlying units). There is certainly some degree of hydraulic communication (or leakage) between most of the geologic units within the county; however the structural complexity and areal heterogeneity of these geologic units as they extend across the county make it difficult to accurately define this relationship. As mentioned above, the Quaternary system is not significant as a source of groundwater supplies so is not further discussed.

### 2.7.1 *Pennsylvannian system*

Yields for each of the geologic units in the Pennsylvannian system are generally low, and range from less than a gallon per minute (gpm) up to 55 gpm (Table 10. These yields are generally adequate to meet domestic and farm water needs, but are not sufficient to meet most municipal or industrial water needs. Based on the geologic characteristics of the formations within the Pennsylvannian system, it is likely that the highest yields would be achieved in wells sited atop fracture zones. Fracture trace analysis and geophysical investigations would be the best methods to ensure a high-yielding well in any of the Pennsylvannian system units. Higher yields can also be expected in stream valleys and plateaus, as opposed to hilltops and slopes.

Groundwater recharge to the Pennsylvannian system occurs mainly through fractures, through localized karst features, and through infiltration within alluvial valleys. Topographic slopes, soil types, and land cover all influence local rates of groundwater recharge to the Pennsylvannian system.

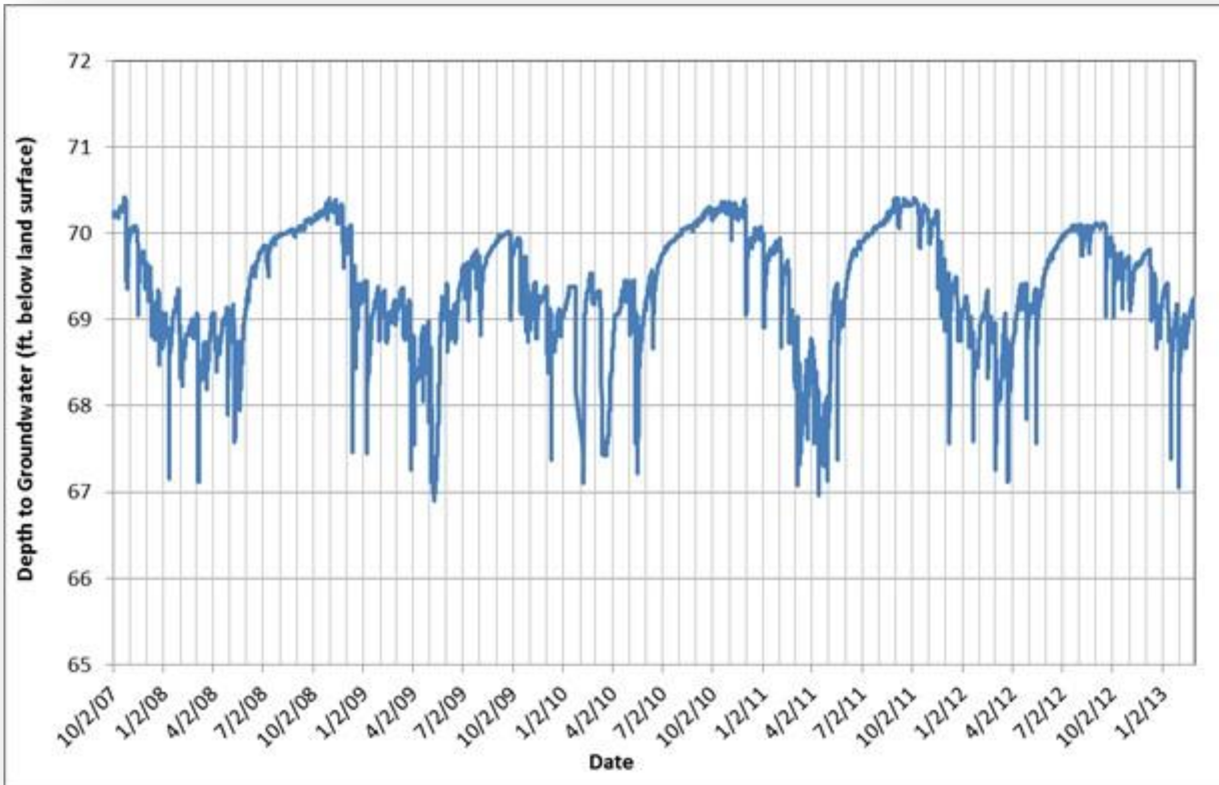
Although there are no active groundwater level monitoring wells completed within the Pennsylvannian System, well completion records and other publications (8) indicate that groundwater levels are highly variable depending on local topography. Depths to groundwater vary from approximately 15 feet (in valley wells) to 250 feet (for hillside and hilltop wells) for most of the units in the Pennsylvannian system.

### 2.7.2 *Mississippian system*

Groundwater yields from the Mississippian system are generally higher than the yields from the Pennsylvannian system (Table 10). Moderate to excellent well yields have been reported from the Mauch Chunk Formation, the Greenbrier Formation, the Maccrady Formation, and the Pocono Group, with some wells yielding in excess of 250 gpm. The highest yielding Mississippian wells are reportedly located in the valleys, especially in the western portion of the Greenbrier River valley. Yields are generally sufficient to meet local demands for all water use sectors. Though yields are generally sufficient to meet demands, concentrated groundwater pumpage in the valleys may cause detrimental drawdown in streams and wetlands.

The USGS maintains a groundwater level monitoring well (#380653080155301) in Droop Mountain State Park on U.S. Route 219. The well is completed in the Mauch Chunk Formation and is cased to a depth of 48 feet with a total depth of 86 feet. Water level data (Figure 5) have been collected continuously at the well since October of 2007. Visual analysis of the groundwater hydrograph for the well indicates that water levels fluctuate by approximately three feet seasonally, with the highest groundwater levels generally occurring from late winter to early spring.

**Figure 5: Depth to groundwater at Droop Mountain State Park**




### 2.7.3 ***Devonian System***

The units within the Devonian system generally yield adequate quantities of groundwater to meet farm, domestic, small municipal, and industrial needs. Yields are generally highest from wells completed in the Lower Devonian system. Within the Upper Devonian system, valley wells can produce appreciable quantities of groundwater, but hillside and hilltop wells reportedly exhibit low yields, which are only suitable to meet domestic and small farm needs.

Estimates of the groundwater recharge and the safe groundwater yield of each of the major river basins in the county are provided in Section 2.10.

## 2.8 Groundwater quality

Groundwater quality varies greatly across the county based on a variety of factors. Areas that are conducive to large volumes of seasonal recharge tend to exhibit better groundwater quality, with lower levels of dissolved metals and solids. Areas with low groundwater movement generally tend to exhibit poorer water quality. Although recent groundwater quality data are sparse, historical data (mainly from the 1980s) does exist for several sites in Pocahontas County. Because little or no increase in groundwater withdrawals has occurred across much of the county since the mid-1980s (7), it is likely that the historical groundwater data ( (see Groundwater section in Phase 1 of the Plan) still provides a reasonable representation of groundwater conditions across the county. Changes in groundwater quality over time are typically due to changes in the quality of water recharging the aquifer or due to the pumpage-induced movement of poorer quality groundwater.

Elevated levels of iron, sulfur, manganese, and hardness have posed groundwater quality problems in various parts of the county. Also, elevated levels of dissolved salts have been reported in groundwater in several areas of the county. Generally, groundwater quality across the county meets applicable standards. Water softeners and other affordable technology exist to treat most of the minor water quality issues that may be experienced by domestic well users. At a county-level, there do not appear to be serious groundwater quality concerns that warrant action or specialized treatment.

## 2.9 Delineation of groundwater basins

Groundwater basins are most often delineated based on visual analysis of potentiometric surfaces, triangulated water level data, or through flow path tracking tools in a groundwater modeling or GIS program. Groundwater basins can be especially difficult to delineate by visual interpretive methods in karst aquifers, highly-fractured aquifers, highly metamorphosed and folded terrain, or elsewhere where preferential subsurface flow paths exist. During Phase 1 of the Plan, groundwater basins were delineated in some of the near-surface karst terrains in the central portion of the county using data from a dye tracing study. This approach was valuable in determining localized flow patterns in the absence of potentiometric data, however, is currently not practical to implement on a countywide scale.

The data which are currently available do not allow for the delineation of additional groundwater basins in the other portions of the county. An effort is currently underway by county Water Resource Task Force staff to develop a countywide lithologic GIS-enabled database using information from the Pocahontas County Health Department well completion reports. Once complete, this dataset will be used in the development of structural maps of the aquifer units within the county, which will aid in the delineation of groundwater basins. Furthermore, groundwater level data collected as part of the groundwater monitoring plan could be used to identify groundwater basins and flow patterns within the county. WRTF staff is currently investigating funding options to establish a groundwater monitoring network and implement the groundwater monitoring plan.

For the purposes of the safe yield and water budget calculations completed in support of this Plan, and in the absence of the data needed to delineate groundwater flow patterns across the county, it is assumed that groundwater basins are concordant with surface water basins. As better data on the groundwater flow patterns and structural features in the county’s aquifer systems is developed, the yield and recharge estimates should be refined accordingly.

## 2.10 Groundwater safe yield

Groundwater safe yield estimates were developed for the HUC-12 watersheds (see Figure 2) in the county using two different methods. The estimates were developed at the HUC-12 level to maintain consistency with the surface water safe yield methods presented in Section 1.2.5. A key assumption of the groundwater safe yield calculations is that groundwater basins are roughly concordant with surface water basins. While this assumption may not hold entirely true across the county, it is the best approach available to estimating groundwater safe yields, as adequate data on groundwater basin extents across the county is not currently available. Two different safe yield methods were used, in part, to account for uncertainties associated with the safe yield estimates. It is important to note that a calibrated groundwater model is generally considered the most accurate way to determine regional and localized groundwater safe yields. Such a model does not currently exist for the county. The groundwater safe yield estimates generated for this study are planning-level estimates conducted at a large scale, which are suitable for county- and regional-level water supply planning purposes, but are not intended to be used in determining site-specific groundwater safe yields.

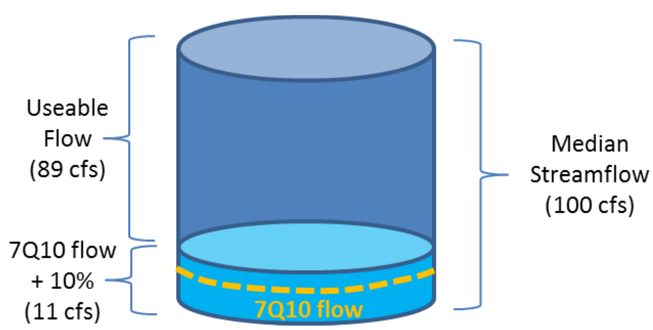
It is also important to note that some of the HUC-12 watersheds contribute flow to downstream HUC-12 watersheds. Additional calculations were required to avoid duplicity in the surface water safe yield calculations (see Section 1.2.5), but were not applied to the groundwater calculations. Travel times associated with groundwater flow are much slower than those associated with surface waters, and the focus of the groundwater safe yield analysis is only on baseflow, which is generally more seasonally consistent than the surface component of streamflow. It is important to note that, while the estimates presented herein are protective of non-consumptive uses of groundwater in each watershed, the spatial distribution of the wells in each watershed will determine whether impacts occur to baseflow. The safe yield estimates assume an even distribution of withdrawals across each watershed, and are not necessarily indicative of localized impacts to baseflow which may occur as a result of concentrated groundwater withdrawals within a given watershed.

Streamflow statistics were generated using USGS estimation methods for all of the HUC-12 watersheds in the county, as described in Section 1.2.4. These statistics, including the median annual flow and the 7Q10 flow, are the basis for the groundwater safe yield estimates. The safe yield methods are designed to protect non-consumptive groundwater uses, such as baseflow to springs and streams.

The first safe yield estimation method used was the Tessman method. The method was designed as a surface water safe yield method with an emphasis on the protection of instream flows, for the protection of aquatic habitats. Under mean annual flow conditions, the Tessman method allows for a 60% decline in surface flows (Tessman, 1980). The 60% allowable decline was applied to baseflow (the groundwater component of streamflow), to ensure that baseflow was afforded the same protection as surface water flows. Mean baseflow was calculated for each HUC-12 using the USGS Baseflow Index. The Median Annual Baseflow was then calculated by multiplying Median Annual Stream Flow for each HUC-12 by the Baseflow Index. Then, the allowable 60% decline was applied to the Median Annual Baseflow for each HUC-12, resulting in an estimated annual groundwater safe yield for each watershed (refer to Table 11) in the county. Additionally, an estimated dry season (summer) groundwater safe yield was developed using an average summer baseflow index developed from baseflow estimates from Wiley (5). The average summer baseflow index was multiplied by median summer flows for each watershed to determine the summer groundwater safe yield, which is substantially lower than the median annual groundwater safe yield (Table 11).

Based on preliminary discussions with the WVDEP regarding the assessment of water availability, Downstream Strategies employed a water availability calculation method, which involved calculating the 7Q10, plus 10 percent from the median annual stream flow for a given watershed (9). However, since these preliminary discussions, the WVDEP has decided to calculate water availability using a water budget method, as described in Chapter 3 of the West Virginia State Water Resources Management Plan (forthcoming in the fall of 2013). It is important to note that the WVDEP water budget method requires the use of 7Q10+10% statistic as an input. Due to the range of uncertainties associated with several of the variables needed to calculate the water budget using the WVDEP method, it is our opinion that the 7Q10+10% represents a reasonable estimate of the quantity of water that can be withdrawn from a watershed, while protecting minimum environmental flows.

**Figure 6 - Example of the Modified WVDEP Method**




Downstream Strategies used the discussed method to calculate groundwater safe yields by determining the percentage of the median annual flow available after subtracting the 7Q10 (plus 10 percent) flow for each watershed (Table 12). For example, in a stream with a 100 cfs median flow, and a 7Q10 flow of 10 cfs, 89 cfs of the median flow would be available for consumptive uses (see  Figure 6). In the case of the example, 89 percent of the annually available streamflow could be harvested. This percentage, , was then multiplied by median annual baseflow to result in an estimated groundwater safe yield. For example, if median baseflow for the 100 cfs example stream shown in Figure 6 is 40 cfs, then 89 percent of baseflow, or 35.6 cfs of groundwater, is available to be withdrawn within the watershed for consumptive uses. Estimated dry season (summer) groundwater safe yields were calculated in the same manner using median summer baseflows and median summer streamflows. Similar to the Tessman method, this method affords the same protection to base flows (groundwater) as surface water flows. The results of the modified WVDEP method (Table 12) indicate that this method is less protective of instream flows than the Tessman method.

## Table 11: Estimated groundwater safe yield by Tessman method

| | | | Estimated groundwater safe yield | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Median annual | | | | | Median summer | | | | |
| | | | | | Estimated groundwater safe yield | | | | | Estimated groundwater safe yield | | |
| HUC-12 number | HUC-12 name | Watershed area (AC) | Median annual baseflow (MG) | 60% median annual baseflow (MG) | MGY | MGD | GPD/ AC | Median summer baseflow (annualized, MG) | 60% median summer baseflow (annualized, MG) | MGY | MGD | GPD/ AC |
| 050200010101 | Ralston Run-Tygart Valley River | 28,343 | 3,377 | 2,026 | 1,351 | 4 | 131 | 1,064 | 638 | 426 | 1 | 41 |
| 050200040301 | First Fork-Shavers Fork | 35,929 | 7,787 | 4,672 | 3,115 | 9 | 238 | 2,453 | 1,472 | 981 | 3 | 75 |
| 050500030402 | Clover Creek-Greenbrier River | 24,722 | 22,775 | 13,665 | 9,110 | 25 | 1,010 | 7,174 | 4,304 | 2,870 | 8 | 318 |
| 050500030503 | Upper Anthony Creek | 20,952 | 2,325 | 1,395 | 930 | 3 | 122 | 732 | 439 | 293 | 1 | 38 |
| 050500030502 | North Fork Anthony Creek | 14,258 | 1,552 | 931 | 621 | 2 | 119 | 489 | 293 | 196 | 1 | 38 |
| 050500030407 | Locust Creek-Greenbrier River | 36,357 | 46,539 | 27,923 | 18,616 | 51 | 1,403 | 14,660 | 8,796 | 5,864 | 16 | 442 |
| 050500030301 | Headwaters Spring Creek | 22,326 | 2,097 | 1,258 | 839 | 2 | 103 | 660 | 396 | 264 | 1 | 32 |
| 050500030201 | Douthat Creek | 19,330 | 1,739 | 1,044 | 696 | 2 | 99 | 548 | 329 | 219 | 1 | 31 |
| 050500030302 | Outlet Spring Creek | 54,974 | 11,898 | 7,139 | 4,759 | 13 | 237 | 3,748 | 2,249 | 1,499 | 4 | 75 |
| 050500030406 | Stamping Creek-Greenbrier River | 35,987 | 40,654 | 24,392 | 16,261 | 45 | 1,238 | 12,806 | 7,684 | 5,122 | 14 | 390 |
| 050500030405 | Swago Creek-Greenbrier River | 16,209 | 37,462 | 22,477 | 14,985 | 41 | 2,533 | 11,800 | 7,080 | 4,720 | 13 | 798 |
| 050500030203 | Outlet Knapp Creek | 20,393 | 5,985 | 3,591 | 2,394 | 7 | 322 | 1,885 | 1,131 | 754 | 2 | 101 |
| 050500030202 | Headwaters Knapp Creek | 30,466 | 2,794 | 1,677 | 1,118 | 3 | 101 | 880 | 528 | 352 | 1 | 32 |
| 050500030403 | Stony Creek | 14,769 | 1,502 | 901 | 601 | 2 | 111 | 473 | 284 | 189 | 1 | 35 |
| 050500030404 | Thorny Creek-Greenbrier River | 29,988 | 28,272 | 16,963 | 11,309 | 31 | 1,033 | 8,906 | 5,343 | 3,562 | 10 | 325 |
| 050500030401 | Sitlington Creek | 31,849 | 3,413 | 2,048 | 1,365 | 4 | 117 | 1,075 | 645 | 430 | 1 | 37 |
| 050500030107 | Brush Run-Greenbrier River | 30,575 | 15,531 | 9,319 | 6,212 | 17 | 557 | 4,892 | 2,935 | 1,957 | 5 | 175 |
| 050500030104 | Outlet East Fork Greenbrier River | 19,187 | 6,582 | 3,949 | 2,633 | 7 | 376 | 2,073 | 1,244 | 829 | 2 | 118 |
| 050500030103 | West Fork Greenbrier River | 28,219 | 4,588 | 2,753 | 1,835 | 5 | 178 | 1,445 | 867 | 578 | 2 | 56 |
| 050500030106 | Outlet Deer Creek | 22,862 | 4,511 | 2,707 | 1,805 | 5 | 216 | 1,421 | 853 | 568 | 2 | 68 |
| 050500030105 | Headwaters Deer Creek | 19,666 | 2,012 | 1,207 | 805 | 2 | 112 | 634 | 380 | 254 | 1 | 35 |
| 050500030101 | Little River | 12,479 | 1,418 | 851 | 567 | 2 | 125 | 447 | 268 | 179 | - | 39 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050500030102 | Headwaters East Fork Greenbrier River | 25,254 | 3,824 | 2,294 | 1,530 | 4 | 166 | 1,204 | 723 | 482 | 1 | 52 |
| 050500050103 | Middle Williams River | 24,554 | 9,460 | 5,676 | 3,784 | 10 | 422 | 2,980 | 1,788 | 1,192 | 3 | 133 |
| 050500050301 | Hughes Run-Gauley River | 22,860 | 2,148 | 1,289 | 859 | 2 | 103 | 677 | 406 | 271 | 1 | 32 |
| 050500050201 | Headwaters Cranberry River | 30,056 | 7,064 | 4,238 | 2,825 | 8 | 258 | 2,225 | 1,335 | 890 | 2 | 81 |
| 050500050101 | Upper Williams River | 25,448 | 4,994 | 2,996 | 1,998 | 5 | 215 | 1,573 | 944 | 629 | 2 | 68 |
| 050500050102 | Middle Fork Williams River | 16,609 | 1,578 | 947 | 631 | 2 | 104 | 497 | 298 | 199 | 1 | 33 |
| 050500070101 | Old Field Fork | 34,725 | 3,275 | 1,965 | 1,310 | 4 | 103 | 1,032 | 619 | 413 | 1 | 33 |
| 050500070102 | Dry Fork-Elk River | 21,138 | 11,436 | 6,861 | 4,574 | 13 | 593 | 3,602 | 2,161 | 1,441 | 4 | 187 |

AC = Acres, MG = million gallons, MGY = million gallons per year, MGD = million gallons per year, GPD/AC = gallons per day per acre.

**Table 12: Estimated groundwater safe yield by modified WVDEP method**

| | | | Estimated groundwater safe yield | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Median annual | | | | | | Median summer | | | | | |
| | | | | | | Estimated groundwater safe yield | | | | | | Estimated groundwater safe yield | | |
| HUC-12 number | HUC-12 name | Watershed area (ac.) | (7Q10 annual + 10%)/ median annual flow | Median annual baseflow available for use | Median annual baseflow (MG) | MGY | MGD | GPD/ AC | (7q10 summer + 10%)/ median summer flow | Median summer baseflow available for use | Median summer baseflow (mG) | MGY | MGD | GPD /AC |
| 050200010101 | Ralston Run-Tygart Valley River | 28,343 | 2% | 98% | 3,377 | 3,321 | 9 | 321 | 6% | 94% | 1,064 | 1,004 | 3 | 97 |
| 050200040301 | First Fork-Shavers Fork | 35,929 | 1% | 99% | 7,787 | 7,710 | 21 | 588 | 2% | 98% | 2,453 | 2,395 | 7 | 183 |
| 050500030402 | Clover Creek-Greenbrier River | 24,722 | 3% | 97% | 22,775 | 22,080 | 60 | 2,447 | 13% | 87% | 7,174 | 6,262 | 17 | 694 |
| 050500030503 | Upper Anthony Creek | 20,952 | 2% | 98% | 2,325 | 2,279 | 6 | 298 | 6% | 94% | 732 | 686 | 2 | 90 |
| 050500030502 | North Fork Anthony Creek | 14,258 | 2% | 98% | 1,552 | 1,523 | 4 | 293 | 6% | 94% | 489 | 461 | 1 | 89 |
| 050500030407 | Locust Creek-Greenbrier River | 36,357 | 4% | 96% | 46,539 | 44,468 | 122 | 3,351 | 17% | 83% | 14,660 | 12,176 | 33 | 918 |
| 050500030301 | Headwaters Spring Creek | 22,326 | 2% | 98% | 2,097 | 2,055 | 6 | 252 | 6% | 94% | 660 | 618 | 2 | 76 |
| 050500030201 | Douthat Creek | 19,330 | 2% | 98% | 1,739 | 1,699 | 5 | 241 | 7% | 93% | 548 | 508 | 1 | 72 |
| 050500030302 | Outlet Spring Creek | 54,974 | 3% | 97% | 11,898 | 11,584 | 32 | 577 | 9% | 91% | 3,748 | 3,400 | 9 | 169 |
| 050500030406 | Stamping Creek-Greenbrier River | 35,987 | 4% | 96% | 40,654 | 39,103 | 107 | 2,977 | 15% | 85% | 12,806 | 10,834 | 30 | 825 |
| 050500030405 | Swago Creek-Greenbrier River | 16,209 | 4% | 96% | 37,462 | 36,018 | 99 | 6,088 | 15% | 85% | 11,800 | 10,027 | 27 | 1,695 |
| 050500030203 | Outlet Knapp Creek | 20,393 | 7% | 93% | 5,985 | 5,556 | 15 | 746 | 23% | 77% | 1,885 | 1,446 | 4 | 194 |
| 050500030202 | Headwaters Knapp Creek | 30,466 | 3% | 97% | 2,794 | 2,724 | 7 | 245 | 17% | 83% | 880 | 735 | 2 | 66 |
| 050500030403 | Stony Creek | 14,769 | 2% | 98% | 1,502 | 1,474 | 4 | 274 | 6% | 94% | 473 | 446 | 1 | 83 |
| 050500030404 | Thorny Creek-Greenbrier River | 29,988 | 3% | 97% | 28,272 | 27,314 | 75 | 2,495 | 14% | 86% | 8,906 | 7,693 | 21 | 703 |
| 050500030401 | Sitlington Creek | 31,849 | 2% | 98% | 3,413 | 3,341 | 9 | 287 | 7% | 93% | 1,075 | 1,001 | 3 | 86 |
| 050500030107 | Brush Run-Greenbrier River | 30,575 | 2% | 98% | 15,531 | 15,211 | 42 | 1,363 | 9% | 91% | 4,892 | 4,446 | 12 | 398 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050500030104 | Outlet East Fork Greenbrier River | 19,187 | 1% | 99% | 6,582 | 6,500 | 18 | 928 | 6% | 94% | 2,073 | 1,949 | 5 | 278 |
| 050500030103 | West Fork Greenbrier River | 28,219 | 2% | 98% | 4,588 | 4,502 | 12 | 437 | 6% | 94% | 1,445 | 1,355 | 4 | 132 |
| 050500030106 | Outlet Deer Creek | 22,862 | 2% | 98% | 4,511 | 4,411 | 12 | 529 | 7% | 93% | 1,421 | 1,316 | 4 | 158 |
| 050500030105 | Headwaters Deer Creek | 19,666 | 2% | 98% | 2,012 | 1,973 | 5 | 275 | 6% | 94% | 634 | 595 | 2 | 83 |
| 050500030101 | Little River | 12,479 | 2% | 98% | 1,418 | 1,396 | 4 | 307 | 5% | 95% | 447 | 425 | 1 | 93 |
| 050500030102 | Headwaters East Fork Greenbrier River | 25,254 | 1% | 99% | 3,824 | 3,772 | 10 | 409 | 5% | 95% | 1,204 | 1,139 | 3 | 124 |
| 050500050103 | Middle Williams River | 24,554 | 1% | 99% | 9,460 | 9,364 | 26 | 1,045 | 4% | 96% | 2,980 | 2,853 | 8 | 318 |
| 050500050301 | Hughes Run-Gauley River | 22,860 | 2% | 98% | 2,148 | 2,105 | 6 | 252 | 6% | 94% | 677 | 633 | 2 | 76 |
| 050500050201 | Headwaters Cranberry River | 30,056 | 2% | 98% | 7,064 | 6,924 | 19 | 631 | 7% | 93% | 2,225 | 2,063 | 6 | 188 |
| 050500050101 | Upper Williams River | 25,448 | 1% | 99% | 4,994 | 4,945 | 14 | 532 | 3% | 97% | 1,573 | 1,521 | 4 | 164 |
| 050500050102 | Middle Fork Williams River | 16,609 | 2% | 98% | 1,578 | 1,548 | 4 | 255 | 6% | 94% | 497 | 467 | 1 | 77 |
| 050500070101 | Old Field Fork | 34,725 | 2% | 98% | 3,275 | 3,205 | 9 | 253 | 7% | 93% | 1,032 | 960 | 3 | 76 |
| 050500070102 | Dry Fork-Elk River | 21,138 | 1% | 99% | 11,436 | 11,310 | 31 | 1,466 | 4% | 96% | 3,602 | 3,474 | 10 | 450 |

AC = Acres, MG = million gallons, MGY = million gallons per year, MGD = million gallons per year, GPD/AC = gallons per day per acre.

The results of both groundwater safe yield estimation methods are shown in Table 13 to illustrate the differences between each method. The Tessman Method should be considered more protective of non-consumptive uses of groundwater, while the modified WVDEP method is less protective. An average of the results from each method is also provided in Table 13. The average represents a middle-of-the road estimated groundwater safe yield for each watershed. It is also important to note that the estimated summer groundwater safe yields are substantially lower than the annual estimated groundwater safe yields under both estimation methods.

**Table 13: Comparison of groundwater safe yield methods**

| | | Annual Groundwater Safe Yield (MGD) | | | Summer Groundwater Safe Yield (MGD) | | |
|---|---|---|---|---|---|---|---|
| HUC-12 Number | HUC-12 Name | Tessman Method | Average of both methods | Modified WVDEP Method | Tessman Method | Average of both methods | Modified WVDEP Method |
| 050200010101 | Ralston Run-Tygart Valley River | 4 | 6 | 9 | 1 | 2 | 3 |
| 050200040301 | First Fork-Shavers Fork | 9 | 15 | 21 | 3 | 5 | 7 |
| 050500030402 | Clover Creek-Greenbrier River | 25 | 43 | 60 | 8 | 13 | 17 |
| 050500030503 | Upper Anthony Creek | 3 | 4 | 6 | 1 | 1 | 2 |
| 050500030502 | North Fork Anthony Creek | 2 | 3 | 4 | 1 | 1 | 1 |
| 050500030407 | Locust Creek-Greenbrier River | 51 | 86 | 122 | 16 | 25 | 33 |
| 050500030301 | Headwaters Spring Creek | 2 | 4 | 6 | 1 | 1 | 2 |
| 050500030201 | Douthat Creek | 2 | 3 | 5 | 1 | 1 | 1 |
| 050500030302 | Outlet Spring Creek | 13 | 22 | 32 | 4 | 7 | 9 |
| 050500030406 | Stamping Creek-Greenbrier River | 45 | 76 | 107 | 14 | 22 | 30 |
| 050500030405 | Swago Creek-Greenbrier River | 41 | 70 | 99 | 13 | 20 | 27 |
| 050500030203 | Outlet Knapp Creek | 7 | 11 | 15 | 2 | 3 | 4 |
| 050500030202 | Headwaters Knapp Creek | 3 | 5 | 7 | 1 | 1 | 2 |
| 050500030403 | Stony Creek | 2 | 3 | 4 | 1 | 1 | 1 |
| 050500030404 | Thorny Creek-Greenbrier River | 31 | 53 | 75 | 10 | 15 | 21 |
| 050500030401 | Sitlington Creek | 4 | 6 | 9 | 1 | 2 | 3 |
| 050500030107 | Brush Run-Greenbrier River | 17 | 29 | 42 | 5 | 9 | 12 |
| 050500030104 | Outlet East Fork Greenbrier River | 7 | 13 | 18 | 2 | 4 | 5 |
| 050500030103 | West Fork Greenbrier River | 5 | 9 | 12 | 2 | 3 | 4 |
| 050500030106 | Outlet Deer Creek | 5 | 9 | 12 | 2 | 3 | 4 |
| 050500030105 | Headwaters Deer Creek | 2 | 4 | 5 | 1 | 1 | 2 |
| 050500030101 | Little River | 2 | 3 | 4 | 0 | 1 | 1 |
| 050500030102 | Headwaters East Fork Greenbrier River | 4 | 7 | 10 | 1 | 2 | 3 |
| 050500050103 | Middle Williams River | 10 | 18 | 26 | 3 | 6 | 8 |
| 050500050301 | Hughes Run-Gauley River | 2 | 4 | 6 | 1 | 1 | 2 |
| 050500050201 | Headwaters Cranberry River | 8 | 13 | 19 | 2 | 4 | 6 |
| 050500050101 | Upper Williams River | 5 | 10 | 14 | 2 | 3 | 4 |
| 050500050102 | Middle Fork Williams River | 2 | 3 | 4 | 1 | 1 | 1 |
| 050500070101 | Old Field Fork | 4 | 6 | 9 | 1 | 2 | 3 |
| 050500070102 | Dry Fork-Elk River | 13 | 22 | 31 | 4 | 7 | 10 |

## 2.11 Groundwater budget

Based on the data available, it is currently not feasible to develop a detailed groundwater budget for the county. A water budget involves a full accounting of the inflows, outflows, and changes in storage in an aquifer (10). Accurate estimates of groundwater withdrawals, surface flows entering and leaving each watershed, flow accumulation between watersheds, return flows (septic, irrigation, and NPDES outflows), and estimates of groundwater underflow are currently not available for all of the HUC-12 watersheds in the county. Additionally, aquifer boundaries and characteristics are not well defined for the county. It is also important to consider that preparing a water budget would also involve developing detailed data for surrounding counties, because a number of HUC-12 watersheds extend well beyond the county boundaries. Although it is currently not possible to develop a detailed groundwater budget for the county, estimates of annual groundwater recharge, baseflow to streams and springs, and groundwater safe yield were developed in support of this Plan.

## 2.12 Criteria for the protection of non-consumptive groundwater uses

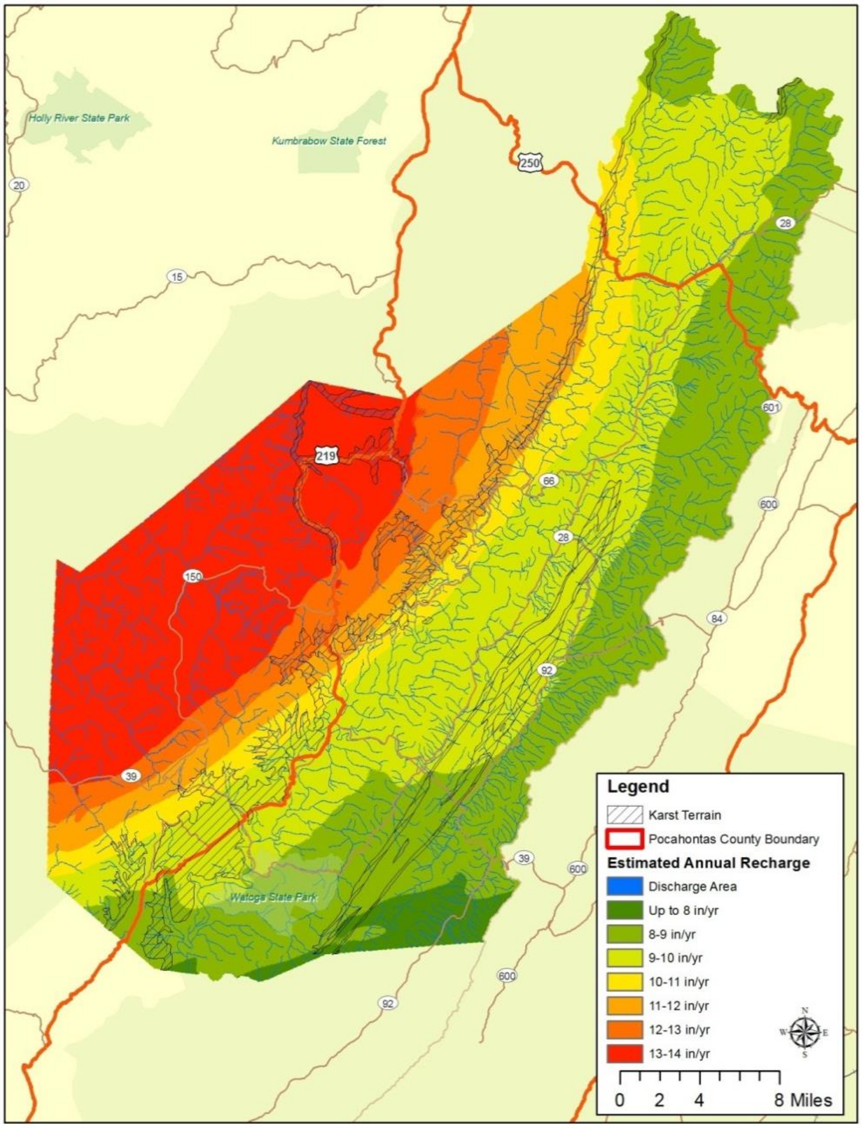
The primary nonconsumptive groundwater function in the county is baseflow to streams, rivers, and springs. Across the county, it is estimated that up to 43 percent of the total annual streamflow volume is attributable to baseflow. Declines in the groundwater table associated with groundwater pumpage can result in decreased baseflow to surface waters. Baseflow is an important component of surface water flow, and maintaining baseflow contributions will help to ensure the protection of non-consumptive surface water uses, such as recreation and the maintenance of aquatic habitat.

The groundwater safe yield methods described in this report are designed to protect nonconsumptive uses of groundwater (specifically, the maintenance of a minimum baseflow to streams). Refer to Section 2.10 for additional details on the safe yield methods used.

## 2.13 Identification of prime recharge areas

Countywide natural groundwater recharge estimates were developed using existing baseflow and runoff index maps. GIS Raster Math tools were employed to multiply the USGS baseflow index raster data (see section 2.14) by the USGS mean annual runoff raster dataset. The recharge calculation method is recommended by the USGS (11), and previous studies have indicated that the results of the calculation provide a good approximation of actual recharge at a large scale (i.e. county level). Discharge areas were identified using stream and spring boundaries from the National Hydrography Dataset for West Virginia, and were also incorporated into the recharge calculations (12).

**Figure 7: Annual groundwater recharge estimates for Pocahontas County**

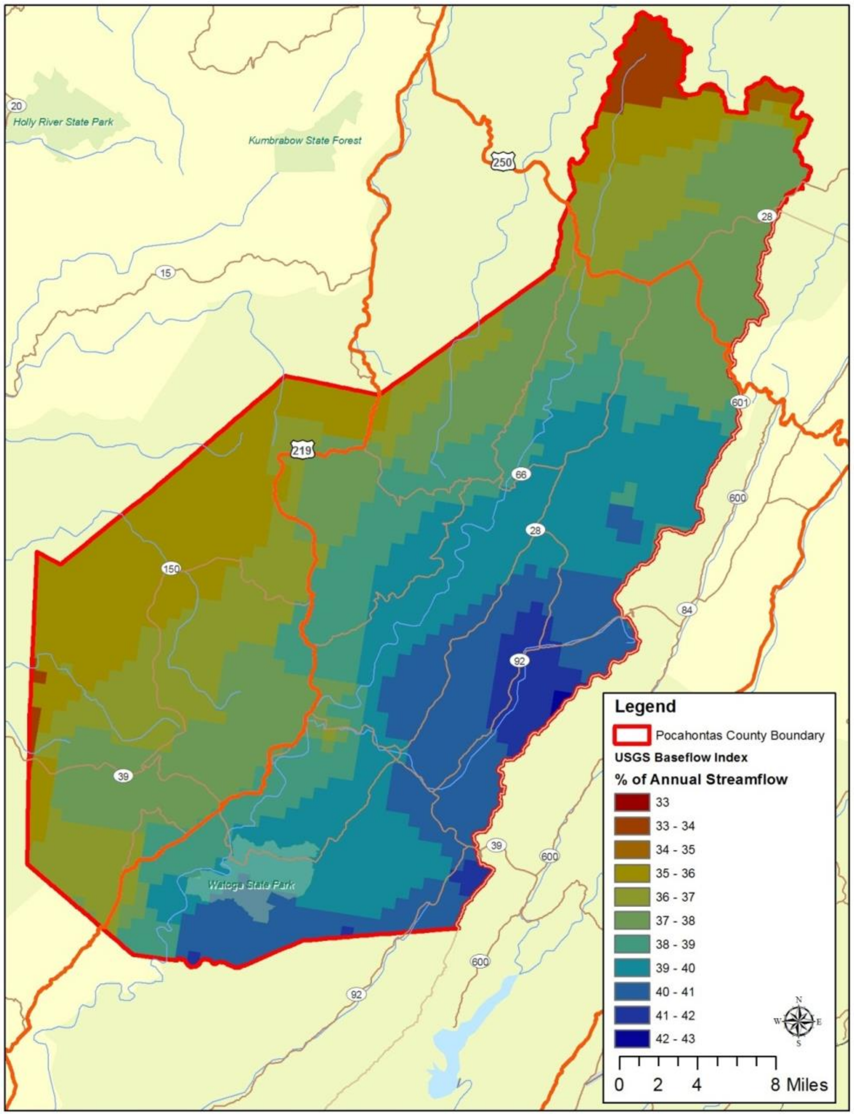



The results of the analysis (shown in Figure 77) indicate that recharge ranges from approximately 7 to 14 inches per year across the county. The western half of the county (the region west of and adjacent to Hwy. 219) constitutes a prime recharge area (shown in red and orange hues on Figure 7), with recharge rates up to twice as high as areas within the eastern half of the county. It is important to note that surface karst features (karst regions were identified in Phase 1 of the WRMP, and are shown in black hatching in Figure 7) can also act as preferential recharge features within the county.

## 2.14 Relationship to stream baseflow

The shallow groundwater systems in Pocahontas County generally have a strong influence (through baseflow) on local river and streamflow conditions. Baseflow is defined as the component of streamflow that can be attributed to groundwater discharge into streams. The USGS developed a baseflow index map for West Virginia, which shows interpolated baseflow estimates calculated using the streamflow hydrograph separation model BFI (11). For watersheds with no gages, the USGS baseflow calculations were developed using regression analyses based on drainage area and other characteristics.

**Figure 8: USGS Baseflow Index for Pocahontas County**




Source: (11)

Baseflow is expressed as a percentage of total annual streamflow and is shown in the baseflow index map (Figure 8). Monthly and seasonal baseflows may be significantly different than the annual baseflow ratio, especially during periods of high streamflow (where baseflow may account for a lower percentage of total flow) and low flow conditions (where baseflow may account for much of the total flow of a given stream). In Pocahontas County, there are few stream gaging stations with adequate periods of record to estimate baseflows. Further, there are numerous ungaged streams and tributaries within the county. Therefore, for Pocahontas County, much of the USGS baseflow index was developed using the calculations for ungaged drainage areas. Across most the county, baseflow is estimated to be responsible for 33 to 43 percent of the total annual streamflow for a given stream.

In addition to the countywide USGS baseflow index, average estimated baseflows were calculated for each of the individual HUC-12 level watersheds in the county for use in the groundwater safe yield estimates (see Section 1.2.5).

## 2.15 Groundwater conclusions & recommendations

As a result of the analyses conducted in support of this Plan, we offer the following conclusions and recommendations:

- Groundwater is withdrawn from three major aquifer units within the county; the Pennsylvannian, the Mississippian, and the Devonian systems. Each of these aquifer systems is comprised of multiple geologic units which each exhibit varying flow, yield, and water quality characteristics. Currently, the boundaries, thickness, and other physical characteristics of these units have not been thorough delineated or studied.
- In some areas of the county, the characteristics of the local geology and physiography will make it difficult to obtain the well yields necessary to support larger volume withdrawals, such as those for industrial and public supply needs. Experienced local well drillers have a good understanding of which units will produce acceptable well yields across the county, however, in some cases, it may be prudent to hire a qualified hydrogeologist or geophysicist to assist in identifying local high-yield zones.
- Elevated levels of some metals, hardness, salts, and other constituents exist in groundwater in several areas of the county, however, no major groundwater quality issues appear to be present at a countywide scale. The county and its partner agencies should make an effort to collect and analyze new groundwater quality data.
- It is recommended that the county enact the Groundwater Monitoring Plan provided as part of this Plan. The Groundwater Monitoring Plan provides a framework for the county and their partners to begin developing crucial data on the status of the county's groundwater resources.
- A full delineation of the groundwater basins across the county was not possible based on the existing hydrogeologic data available. The Groundwater Monitoring Plan, coupled with analysis of well completion data, will provide a framework to better delineate the groundwater basins in the future.
- Estimated groundwater safe yields were developed for the HUC-12 watersheds in the county using two different methods. The estimated safe yields are designed to be protective of non-consumptive uses of groundwater. The results of both safe yield estimation methods indicate that additional quantities of groundwater could be likely be withdrawn in most of the HUC-12 watersheds without impacting the non-consumptive uses of groundwater. The development of a calibrated groundwater model is recommended to analyze local impacts to non-consumptive groundwater uses associated with large volume groundwater withdrawals.
- Maps of prime recharge areas and baseflow were developed for the county. The areas with the highest recharge potential are generally in the western and northern portions of the county, however, there are many areas with a high recharge potential associated with karstification in the Greenbrier River valley. Areas with the highest annual baseflows are generally located in the southwestern portion of the county.

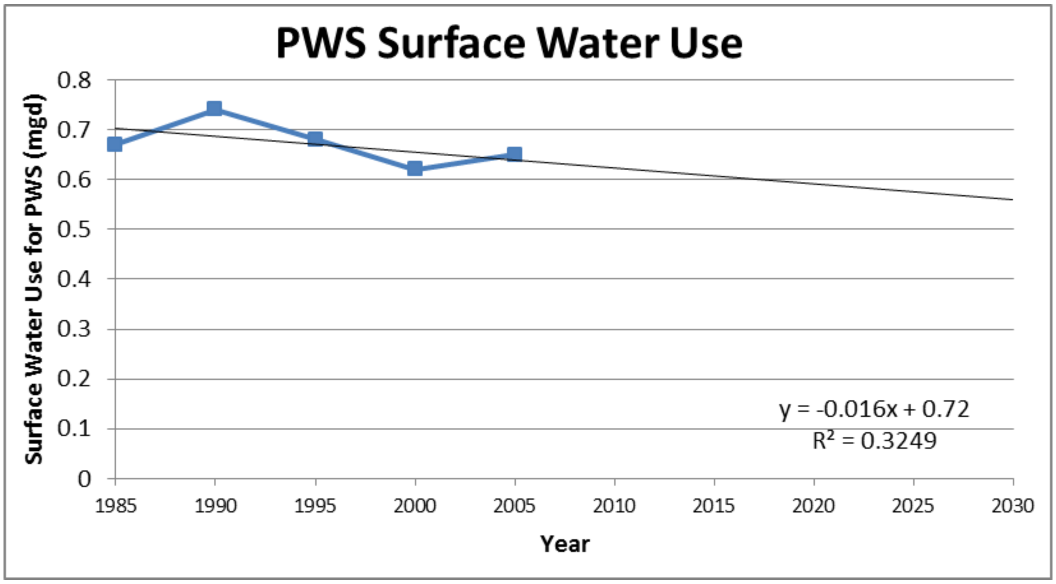
# 3. CONSUMPTIVE AND NON-CONSUMPTIVE USE DEMANDS - §22-26-8 (C)(5)

The Act requires, "Assessment and projection of existing and future consumptive use demands (6)."

In Section 2.2, we use USGS data to present historical groundwater use in Pocahontas County (7); based on these trends, we then project future groundwater use by sector in Section 2.3. Here, we use similar data and methods to project surface water use by sector through 2035.

Projections for each sector are generally based on log or linear trends—whichever best fit the historical data for that sector. Figure 9, for example, illustrates a linear projection for the Public Water Supply sector. For some sectors, best professional judgment was used if the best-fit trend line produced implausible results. Also, the Public Water Supply sector was adjusted to include a large water user that appears to have been omitted from the original USGS dataset.

**Figure 9: Example surface water use projection for the Public Water Supply sector**




As part of a stakeholder development process, WRTF surveyed agency and local government representatives as well as community members, farmers, and businesses. Analyses of survey results showed the number one water management concern to be potential horizontal hydraulic fracturing for natural gas.

Recognizing that the development of shale gas has the potential to increase water withdrawals and consumption in the future, we made one further adjustment in the Mining and Extractive sector. It would be very difficult, if not impossible, to project how many wells could be drilled and fractured in the near future in the Pocahontas County. In order to consider the potential impacts of gas development, we asked the question: How many wells might be expected should the county follow a similar development path as Wetzel County? Wetzel County was chosen because of the rapid pace of development of Marcellus wells in recent years. An average of more than five wells per year, and a maximum of 21 wells (in the year 2003) were completed in the Marcellus in Wetzel County over the past 10 years. If similar development were to occur within Pocahontas County, this could account for a maximum increase in mining-related water needs of approximately 220,000 gpd (this includes the estimated maximum amount of water used during well construction and hydraulic fracturing operations) above the current trend in mining water needs during the planning period. This potential worst-case scenario is reflected in the surface water demand projections provided in Table 14, to ensure conservative planning and stewardship of the County's water resources. By performing this calculation, we are making no judgment as to the likelihood of Marcellus development in Pocahontas County proceeding at the same pace or scale of Wetzel County. Instead, we are simply considering the potential implications if Marcellus development were to follow such a path in the future. As shown in Table 14, a continuation of past trends would result in a significant, continuing decrease in surface water withdrawn for agriculture. Domestic withdrawals, as well as withdrawals for the Industrial, Commercial, and Institutional sector, would also decline, but not as dramatically as for agriculture. Withdrawals for the Mining and Extractive sector—which includes our projection of water required for

Marcellus Shale extraction—would increase over time.[1] Withdrawals for the Public Water Supply sector are projected to stay constant. Overall, surface water withdrawals are projected to decline slightly over time. This projected decline, however, is very small.

1 Whether or not it is likely that the Marcellus will be developed extensively in Pocahontas County, our client required us to include potential Marcellus withdrawals in the projections for planning purposes. It is important to look at all possible scenarios by taking a conservative approach to planning for and protecting Pocahontas County's water resources.

**Table 14: Projected surface water withdrawals in Pocahontas County from 2010-2035 (cfs)**

| Year | Agricultural | Domestic | Industrial, Commercial, and Institutional | Mining and Extractive | Public Water Supply | Total |
|---|---|---|---|---|---|---|
| 2010 | 0.17 | 0.32 | 0.44 | 0.79 | 0.57 | 2.29 |
| 2015 | 0.13 | 0.30 | 0.43 | 0.83 | 0.57 | 2.27 |
| 2020 | 0.10 | 0.29 | 0.43 | 0.87 | 0.57 | 2.26 |
| 2025 | 0.07 | 0.27 | 0.43 | 0.90 | 0.57 | 2.24 |
| 2030 | 0.05 | 0.26 | 0.42 | 0.93 | 0.57 | 2.23 |
| 2035 | 0.02 | 0.25 | 0.42 | 0.96 | 0.57 | 2.22 |

Note: These projections use a best-fit statistical model with input data from 1985-2005 from (7). Categories of uses are based on (7), and all listed uses do not necessarily exist within the Pocahontas County. The Mining and Extractive category may include coal mines, quarrying operations, and/or injection/storage/exploration wells. The Industrial, Commercial, and Institutional category may include businesses, hotels, hospitals, schools, or similar entities.

Not all withdrawn water is consumed. As shown in Table 15, the percentage of water consumed varies considerably across sectors. The water use coefficient sectors in this table overlap with those presented in the previous table but do not match exactly.

**Table 15: Water use coefficients**

| Sector | Water use coefficient |
|---|---|
| Water supply | 7% |
| Industrial | 10% |
| Thermoelectric | 2% |
| Irrigation | 78% |
| Livestock | 76% |
| Commercial | 17% |
| Mining | 10% |
| Aquaculture | 0% |

Source: (13). Note: Irrigation coefficient is the average of crop and golf course coefficients.

For the purposes of this report, we estimate water use coefficients as follows:

- Agricultural: 77% (average of the irrigation and livestock sectors)
- Domestic: 7% (equal to the water supply sector)
- Industrial, Commercial, and Institutional: 13.5% (average of the industrial and commercial sectors)
- Mining and Extractive: 100% (While Table 15 suggests that the mining sector would consume only 10% of withdrawn water, we have included horizontal hydraulic fracturing-related withdrawals in this sector and, to be conservative, estimate that no horizontal hydraulic fracturing-related withdrawals are returned to Pocahontas County surface waters.)
- Public Water Supply: 7%

As shown in Table 16, total water consumption is projected to stay relatively constant across the county. These countywide consumption estimates are significantly smaller than the annual countywide safe yields calculated using either of the two methods presented in Table 4 or Table 5. Further, they are significantly smaller than any of the countywide seasonal safe yields calculated using either of these two methods, with the exception of the summer safe yield calculated using the most protective method (in which case surface water safe yields are zero). This suggests that care must be taken in withdrawing water from the county's surface waters during low-flows during summer.

While these projected consumption figures are small compared with the countywide safe yields, the specific streams from which surface water is withdrawn is important. If significant amounts of water are withdrawn or consumed from the county's smaller headwater streams, localized problems can be encountered.

**Table 16: Projected surface water consumption in Pocahontas County from 2010-2035 (cfs)**

| Year | Agricultural | Domestic | Industrial, Commercial, and Institutional | Mining and Extractive | Public Water Supply | Total |
|---|---|---|---|---|---|---|
| 2010 | 0.13 | 0.02 | 0.06 | 0.79 | 0.04 | 1.04 |
| 2015 | 0.10 | 0.02 | 0.06 | 0.83 | 0.04 | 1.05 |
| 2020 | 0.08 | 0.02 | 0.06 | 0.87 | 0.04 | 1.07 |
| 2025 | 0.05 | 0.02 | 0.06 | 0.90 | 0.04 | 1.08 |
| 2030 | 0.03 | 0.02 | 0.06 | 0.93 | 0.04 | 1.08 |
| 2035 | 0.02 | 0.02 | 0.06 | 0.96 | 0.04 | 1.09 |

# 4. NON-CONSUMPTIVE USE NEEDS FOR UNIQUE AREAS - §22-26-8 (C)(4)

The Act requires that

> "After consulting with the appropriate state and federal agencies, assess and project the existing and future nonconsumptive use needs of the water resources required to serve areas with important or unique natural, scenic, environmental or recreational values of national, regional, local or statewide significance, including national and state parks; designated wild, scenic and recreational rivers; national and state wildlife refuges; and the habitats of federal and state endangered or threatened species (6)."

## 4.1 Definition of unique areas

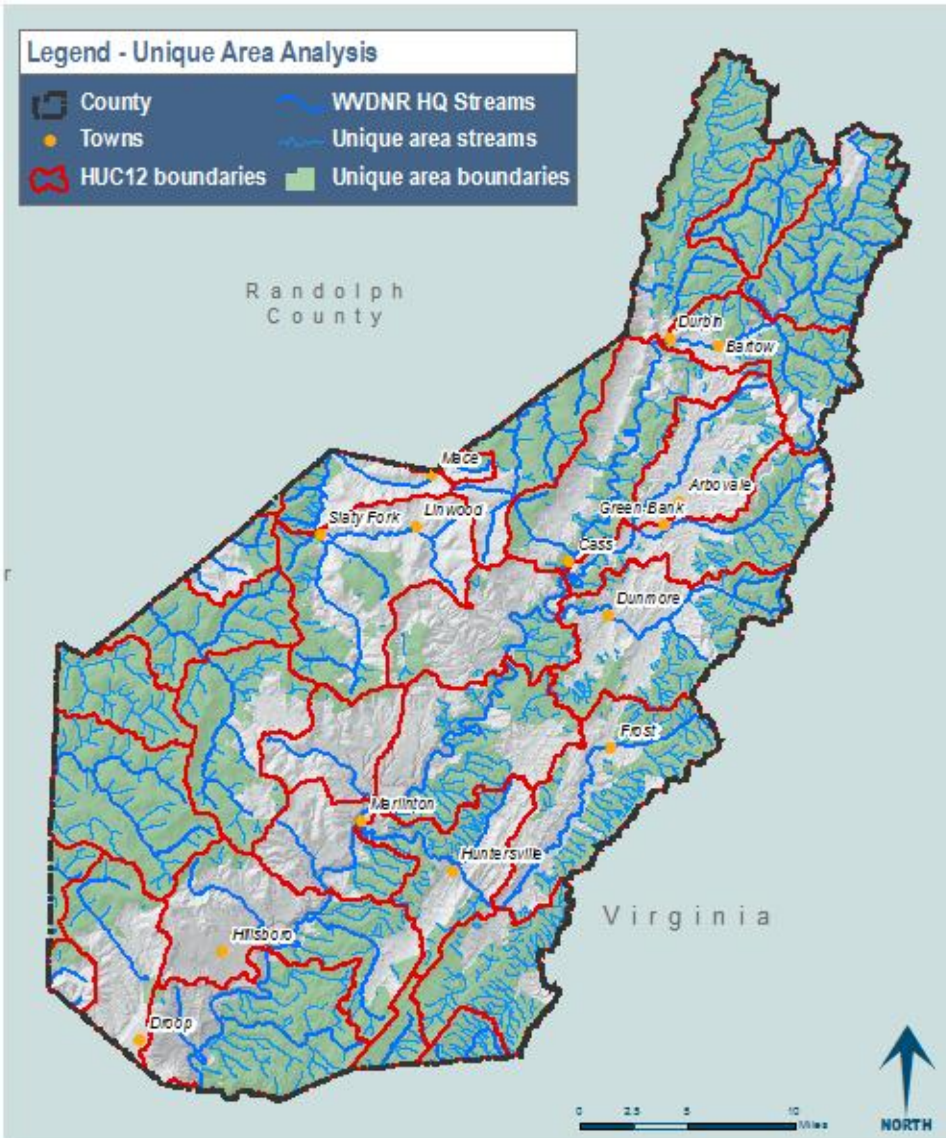
Unique areas will be identified using the following criteria:

> "natural, scenic, environmental or recreational values of national, regional, local or statewide significance, including national and state parks; designated wild, scenic and recreational rivers; national and state wildlife refuges; and the habitats of federal and state endangered or threatened species."

Unique areas will be inventoried based on publicly available datasets and coordination with local, state, and federal agencies. Areas such as designated trout streams, wild and scenic rivers, and streams within or bordering local, state, or national forest areas will be included in the inventory. In addition to agency input, non-governmental organizations and resident input will be used to identify streams not held in public ownership or management, which could identify other significant natural, scenic, environmental, an/or recreational values.

We utilized the USGS Protected Area Data (PAD) unique areas. For Pocahontas County, this database contains lands owned and managed by the United States Forest Service (USFS), the West Virginia Division of Natural Resources (WVDNR), the West Virginia Division of Forestry, West Virginia State Parks (WVSP), and one privately-owned Natural Resource Conservation Service (NRCS) easement. These areas were combined with areas on the National Historic Register and with data from the WVDNR that identified high quality streams within the county. The WVDNR considered a stream high quality if it contained stocked or native trout, or if it had a desirable warm water fishery and was greater than five miles in length. Additional unique areas may be added to this inventory if further research and feedback from local, state or federal agencies indicate additional areas, such as threatened and endangered species habitats. Figure 10 shows the area of all protected areas and identifies all streams that classify as unique areas.

**Figure 10: Locations of unique areas within Pocahontas County**




The unique areas identified were each assessed qualitatively to determine which non-consumptive uses for which each area would be utilized. Based on known recreational uses, access, and stream size, each area was assigned one or more non-consumptive use categories Table 17.

**Table 17: Inventory of unique areas within Pocahontas County**

| Unique areas name | Owner | Non-consumptive uses |
|---|---|---|
| **Calvin Price State Forest** | WVDOF | Aesthetics, ecosystem services, aquatic life, fishing |
| **Camp Bartow Historic District** | USFS | Aesthetics, ecosystem services, aquatic life, fishing |
| **Cass Historic District, Scenic Railroad and State Park** | USFS, WVSP | Aesthetics, ecosystem services, aquatic life, fishing, boating |
| **Cranberry Wilderness** | USFS | Aesthetics, ecosystem services, aquatic life, fishing, boating |
| **Droop Mountain Battlefield and State Park** | WVSP | Aesthetics, ecosystem services, aquatic life |
| **Handley Wildlife Management Area** | WVDNR | Aesthetics, ecosystem services, aquatic life, fishing, boating |
| **Monongahela National Forest** | USFS | Aesthetics, ecosystem services, aquatic life, fishing, boating |
| **Seneca State Forest** | WVDOF | Aesthetics, ecosystem services, aquatic life, fishing, boating |
| **Slaty Fork WIldlife Management Area** | WVDNR | Aesthetics, ecosystem services, aquatic life, fishing, boating |
| **Spice Run Wilderness** | USFS | Aesthetics, ecosystem services, aquatic life, fishing |
| **Upper Shavers Fork Macrosite** | USFS | Aesthetics, ecosystem services, aquatic life, fishing, boating |
| **Watoga State Park** | WVSP | Aesthetics, ecosystem services, aquatic life, fishing, boating |
| **Wetlands Reserve Program** | NRCS easement | Aesthetics, ecosystem services, aquatic life |

Note: WVDOF = West Virginia Division of Forestry

# 5. WATER AVAILABILITY OR CONFLICTS AMONG WATER USES - §22-26-8 (C)(6)

The act requires,

> *"Identification of potential problems with water availability or conflicts among water uses and users including… A) A discussion of any area of concern regarding historical or current conditions that indicate a low-flow condition or where a drought or flood has occurred or is likely to occur that threatens the beneficial use of the surface water or groundwater in the area; and B) Current or potential in-stream or off-stream uses that contribute to or are likely to exacerbate natural low-flow conditions to the detriment of the water resources* (6)*."*

This requirement is still being satisfied by applying the recently obtained results of our safe yield analyses discussed in sections 1.2 and 2.10.

## 5.1 Low flow conditions

To satisfy Paragraph (A) of this section, we will research low-flow conditions and droughts that have occurred in the past in Pocahontas County. We will use the following data sources:

- Historical data compiled and analyzed in Phase 1 of the Plan.
- Any additional historical data for Pocahontas County, including stream gage or meteorological data.
- Drought declarations made by local, state, or federal government entities in Pocahontas County.

- The WRTF will begin interviews with knowledgeable local people to identify and ensure that no information about past or current droughts or low-flow conditions was missed.

### 5.2 Current uses that exacerbate conditions

To satisfy Paragraph (B) of this section, we will integrate research on consumptive uses with the research performed on historical or current low-flow conditions. We will pay particular attention to the largest current water withdrawals and those projected to grow in the future. We will use GIS to integrate this information on withdrawals with those portions of the county with historical or current low-flow conditions.

In addition, as described above, this analysis will consider how shale gas development utilizing horizontal hydraulic fracturing at the rate experienced in Wetzel County could contribute to or exacerbate natural low-flow conditions.

## 6. CRITERIA FOR DESIGNATION OF CRITICAL PLANNING AREAS- §22-26-8 (C)(7)

The act requires that the Plan

> "Establish criteria for designation of critical water planning areas comprising any significant hydrologic unit where existing or future demands exceed or threaten to exceed the safe yield of available water resources (6)."

In addition to the requirements set forth in §22-26-8(c)(7), §22-26-9 outlines requirements and suggestions for developing regional WRMPs for critical planning areas. These requirements and suggestions are listed below.

The act also specifies the following additional requirements related to critical planning areas:

> *"(a) As part of the State Water Resources Management Plan, the secretary may designate areas of the state as regional or critical water planning areas for the development of regional or critical area WRMPs.*
>
> *(b) The secretary shall establish a timetable for completion of regional and critical area plans which may be developed.*
>
> *(c) The secretary shall identify all federal and state agencies, county commissions, municipal governments and watershed associations that should be involved in the planning process and any compacts or interstate agreements that may be applicable to the development of a regional or critical area water resource management plan.*
>
> *(d) The secretary shall establish the minimum requirements for any issues to be addressed by regional and critical area plans within twelve months of the amendment and reenactment of this article during the two thousand eight regular session of the Legislature. The plan requirements and issues to be addressed by regional and critical area plans shall be consistent with the state plan requirements of this article.*
>
> *(e) The secretary shall establish timetables for the completion of tasks or phases in the development of regional and critical area plansCounty commissions and municipal governments may recommend changes in the order in which the tasks and phases must be completed. The secretary shall have final authority to determine the schedule for development of a plan.*

*(f) Any county or municipal government may enter into an agreement with the secretary to designate a local planning area and develop a local plan which may include all or part of a region. The secretary shall assist in development of any such plan to the extent practicable with existing staff and funding.*

*(g) Plans developed by a county or municipal government shall comply with the secretary's requirements and shall be filed as part of the State Water Resources Management Plan* (6).*"*

WVDEP indicated that Critical Planning Areas are not a required component of a county water resource management plan; therefore, Pocahontas County is not under obligation to define the criteria (14). However, based on the requirements set forth by the WRTF, Strategic Resource Areas (SRA) will be identified as part of the Plan.

## 6.1 Definition of Strategic Resource Areas

The following criteria will define a Pocahontas County WRMP SRA:

"any significant HUC12 where existing or future demands exceed or threaten to exceed the safe yield of available water resources"

### 6.1.1 *Methodology for the identification of strategic resource areas and subsequent planning actions*

SRAs will be identified—if they exist—in Pocahontas County based on the safe yield calculations and the present and future consumptive and non-consumptive use need of each HUC12. HUC12's will be the planning area unit; up and downstream HUC12s can be combined to create a planning area that meets the requirements for potential planning and action. SRA HUC12s will be designated if the present or future use demand of surface or groundwater exceed safe yield.

A plan of action will be outlined that will assist the Pocahontas County Commission and/or the county WRTF in developing a process—at the county level—to identify and SRAs for any HUC12s that meet the SRA criteria. A SRA outline will be created that will first identify any state agencies, county commissions, municipal governments, and watershed associations that should be involved with the planning process. A timetable will be generated for the completion of the plan and subsequent actions.

The results of the SRA criteria implementation will be reported in the final Pocahontas County WRMP.

# 7. OTHER IMPORTANT REQUIREMENTS OF THE ACT

## 7.1 Public water supply capability - §22-26-8 (c)(8)

The Act requires, "An assessment of the current and future capabilities of public water supply agencies and private water supply companies to provide an adequate quantity and quality of water to their service areas (6)."

This requirement is pending interviews with town water supply entities.

## 7.2 Assessment of flood plain and stormwater management problems - §22-26-8 (c)(9)

The act requires, "An assessment of flood plain and stormwater management problems (6)."

The Pocahontas County flood plain manager, (Donald McNeel), was interviewed to assist in identifying any flood plain and/or storm water management problems that exist or could exist in the county. Presently, stormwater regulations are not administered by the county. Based on the interview, minimal issues related to flood plain management were noted. These issues include minimal Zone AE or measured flood zones in the county, unmapped developed areas that are prone to flooding, and the lack of education and information regarding flood plain management and regulation in the county.

Presently, only areas surrounding Slatyfork, Marlinton, Durbin, Bartow, Greenback, Frost, Huntersville, have areas designated Zone AE (see Figure 11). Zone AE usually has measured floodways which enables the flood plain manager to regulate development more strictly and require an engineering report that will satisfy the following:

> "Within any AE without Floodway area, no new construction or development shall be allowed unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the elevation of the 100-year flood more than one (1) foot at any point. This requirement can be satisfied by utilization of the floodway area where determined (15 p. 13)."

Pocahontas County's flood zone maps are primarily developed through desk-based interpretation, and delineated as Zone A. Zone A delineations usually do not have designated floodways or specific elevation requirements regarding where buildings are permitted. Thus, acceptable locations to build in Zone A are determined on a case by case basis in the field with the flood plain manager. These zones, while regulated, do not have to conform to the same standards as Zone AE—"will not increase the elevation of the 100-year flood more than one (1) foot at any point. However, the current flood plain manager is committed to ensuring buildings in Zone A also do not raise water levels during flooding events.

A quick analysis was performed to calculate the number of stream or river front parcels (with buildings) that are in or out of flood zone areas. A total of 929 stream or river front parcels (with buildings) exist in the county, only 207 of those are in Zone AE, 290 are in Zone A, and 432 parcels are not located in either Zone A or AE. Figure 11 shows the parcels that have stream frontage with and without flood plain management oversight.

A second issue noted by the flood plain manager was that some tributaries do not have flood plain maps, even though they flood. Figure 12 shows the flood plain delineations across the county. As discussed above, many parcels with buildings and stream frontage are not regulated within the flood zones.

Lastly, a third issue is the lack of information available regarding flood plain regulation and management in the county. This gap has proven to be a barrier for residents and business. Improved access to flood plain regulation and awareness information would increase the capacity of the flood plain manager.

While this plan does not have the budgetary ability to calculate new flood plains or refine existing ones, the planning effort has produced a website that will house information relevant to flood plain management for residents and businesses. This information includes permit information, additional MAPS, a guide to the regulations, and a web-mapper displaying flood plain data. Areas identified during the cursory analysis could be examined more closely and funding sought to improve the flood plain mapping system.

**Figure 11: Flood zones in Pocahontas County**

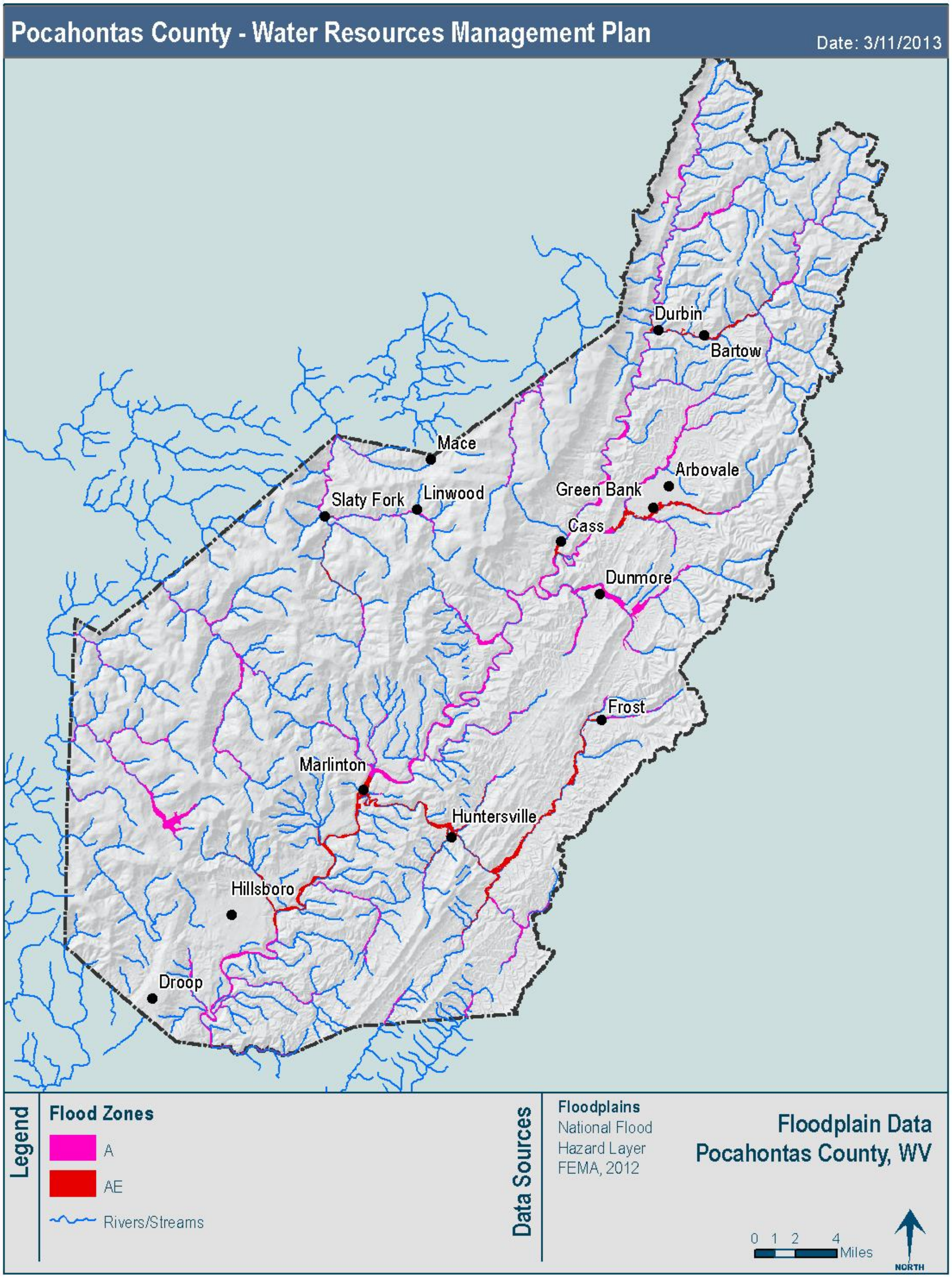
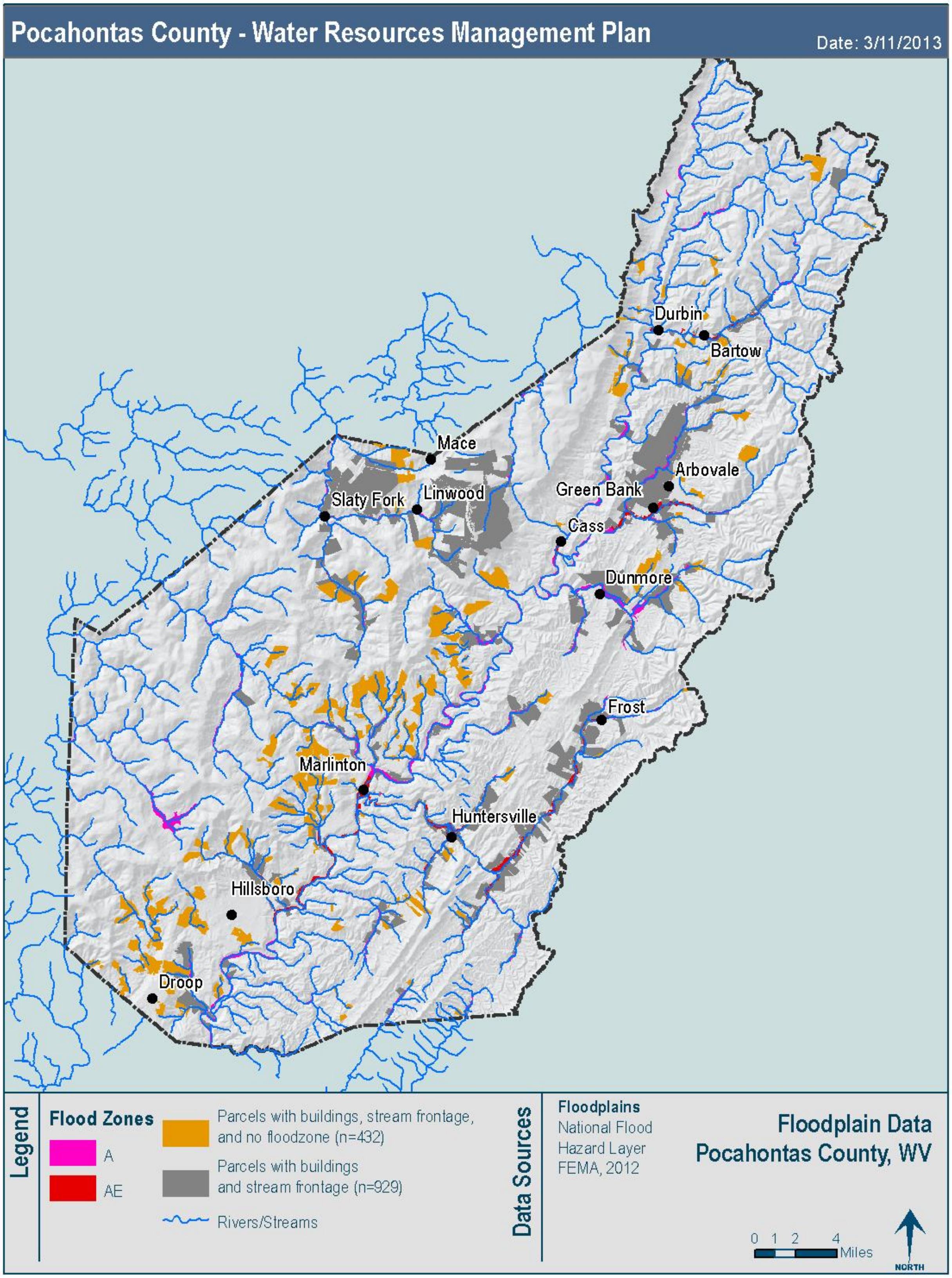


**Figure 12: Flood zones and parcels with buildings and stream frontage**



## 7.3 Improve data collection, reporting and water monitoring where prior reports have found deficiencies - §22-26-8 (c)(10)

The Act requires, "Efforts to improve data collection, reporting and water monitoring where prior reports have found deficiencies (6)."

Two documents have been prepared to fulfill this requirement, the surface water monitoring plan and the groundwater monitoring plan, previously submitted and available upon request. The WRTF is currently seeking funding to assist with the implementation of these plans.

## 7.4 Water conservation projects and practices - §22-26-8 (c)(11)

The Act requires,

> *"A process for identifying projects and practices that are being, or have been, implemented by water users that reduce the amount of consumptive use, improve efficiency in water use, provide for reuse and recycling of water, increase the supply or storage of water or preserve or increase groundwater recharge and a recommended process for providing appropriate positive recognition of such projects or practices in actions, programs, policies, projects or management activities. Actions and steps to mitigate water availability issues - §22-26-8 (c)(11)"*

The Pocahontas County WRTF gathered information from agencies regarding water conservation projects and BMPs currently being implemented in Pocahontas County. Input was received from Greenbrier Valley Conservation District (GVCD), USDA Natural Resource Conservation Service (NRCS), US Forest Service (USFS), and WVU Extension Service.

The USFS has recently implemented water conservation measures at some of their facilities in the county. All the toilets in the Cranberry Mountain Nature Center and one toilet in the warehouse at the Greenbrier Ranger Station were replaced with low flow automatic flush units. The USFS plans to replace their remaining standard toilets with low flow alternatives as they need replaced (16).

The USFS also completed replacement of the water distribution system at the Greenbrier Ranger Station in Bartow. This improvement conserves thousands of gallons of water each month. All the developed USFS recreation areas in the county have hand-pump water wells and vault toilets. Thus, there are no opportunities for further water conservation at these facilities (16).

In addition, many water conservation and restoration efforts in Pocahontas County are being implemented on private land with cost share support from NRCS and/or GVCD. GVCD, the local office of the West Virginia Conservation Agency (WVCA), awards cost share funding through its Agricultural Enhancement Program (AgEP). Thus far in FY13, AgEP has given over $60,000.00 to landowners in the Greenbrier Valley for projects which focus on soil and water conservation. The WVCA is also a partner in the Knapp Creek Watershed restoration and management project currently underway and acts as the fiscal agent for CWA Section 319 funding for the Knapp Creek project and the ongoing Elk Headwaters stream restoration project (17; 18).

NRCS also has cost share agreements with many landowners in the county for the purpose of implementing conservation and BMPs. In the last five years (2009-2013), NRCS has provided over $1,900,000.00 in cost share funding in Pocahontas County through its Environmental Quality Incentive Program (EQIP) and Wildlife Habitat Incentive Program (WHIP). Roughly $350,000 of NRCS cost share funding in FYs12 and 13 is specifically for projects in the Knapp Creek Watershed. This funding was awarded through the National Water Quality Initiative and is being used for habitat creation, erosion control, bank and channel stabilization, re-routing the stream, fencing cattle out of the stream, providing alternate water sources for cattle, installing gutters and pipes on barns to help prevent runoff, etc. The Knapp Creek Watershed restoration and management project is a partnership of NRCS, WVCA, WV DEP, the Pocahontas County Health Department and local landowners.

In addition to providing cost share funding, NRCS also provides conservation technical assistance (CTA) to landowners. Table 18shows several NRCS field performance measures relevant to water. Progress is tracked by measuring acres on which conservation practices are being implemented. Results are broken down by whether participating landowners received CTA or cost share funding through EQIP or WHIP. Specific conservation practices related to each field performance measure are listed below Table 18 (19).

**Table 18: NRCS field performance measures for conservation practices supporting water conservation in Pocahontas County**

| NRCS field performance measure | 2009 | | 2010 | | 2011 | | 2012 | | 2013* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CTA | EQIP/ WHIP | CTA | EQIP/ WHIP | CTA | EQIP/ WHIP | CTA | EQIP/ WHIP | CTA | EQIP/ WHIP |
| Acres of land with conservation applied to improve water quality[1] | 1,464 | 1,159 | 1,995 | 1,701 | 2,132 | 1,252 | 950 | 2,500 | 383 | 337 |
| Acres of Grazing land with conservation applied to protect and improve the resource base[2] | 1,146 | 1,842 | 896 | 1,322 | 1,120 | 1,290 | 1,000 | 2,000 | 430 | 285 |
| Acres of Non-Federal land with conservation applied to improve fish and wildlife habitat quality[3] | 550 | 161 | 597 | NA | 997 | 1,781 | 40 | 800 | NA | NA |

Source: (19).Note: At the time of this report, there are still over five months left in FY13, thus, the numbers for 2013 are not final. NA = not applicable. [1] conservation cover, conservation crop rotation, cover crop, critical area planning, riparian herbaceous cover, riparian forest buffer, filter strip, irrigation water management, prescribed grazing, stream crossing, stream bank and shoreline protection, nutrient management, integrated pest management, tree/shrub establishment, stream habitat improvement and management. [2] brush management, critical area planning, fence, forage harvest management, prescribed grazing, pumping plant, stream bank and shoreline protection, nutrient management, integrated pest management, watering facility, water well. [3] conservation cover, riparian herbaceous cover, riparian forest buffer, stream habitat improvement and management, access control, stream bank and shoreline protection, restoration and management of rare and declining habitats, upland wildlife habitat management, early successional habitat development and management.

## 7.5 Addressing water availability problems - §22-26-8 (c)(11)

The Act requires,

> "an assessment of both structural and nonstructural alternatives to address identified water availability problems, adverse impacts on water uses or conflicts between water users, including potential actions to develop additional or alternative supplies, conservation measures and management techniques (6)."

Countywide water availably problems will be identified (if any exist) by comparing the safe yield for both surface and groundwater with consumptive and nonconsumptive use needs. If water use conflicts exist in the county, actions to develop additional or alternative supplies, conservation measures, and management techniques will be explored and planned to mitigate any conflicts that are identified.

## 7.6 Review and evaluation of existing and recommended statutes, rules, policies, institutional arrangements, and water resources management alternatives for the development, conservation, distribution and of water resources to meet regional needs - §22-26-8 (c)(13) and §22-26-8 (c)(14)

The act requires,

1) "A review and evaluation of statutes, rules, policies and institutional arrangements for the development, conservation, distribution and emergency management of water resources," and 2) "A review and evaluation of water resources management alternatives and recommended programs, policies, institutional

arrangements, projects and other provisions to meet the water resources needs of each region and of this state (6); and

2) A review and evaluation of water resources management alternatives and recommended programs, policies, institutional arrangements, projects and other provisions to meet the water resources needs of each region and of this state (6).”

A separate document is currently being prepared to summarize existing policy as well as address policy recommended as a result of and informed by the planning process.

## 7.7 Implementation plan - §22-26-8 (c)(15)

This document has outlined the technical components of completing the WRMP and fulfilling the requirements for inclusion with the West Virginia state water resource management plan. The following deliverables will be submitted in fulfillment of the implementation plan requirement:

1. Written WRMP with the following components:
   a. Inventory of additional data not identified in Phase 1.
   b. Septic system and domestic well inventory (as available and with assistance from the county Health department and the WRTF).
   c. Surface and groundwater vulnerability maps that delineate protection areas.
   d. Written, step-wise action plans to respond to water resources development.
   e. Written water quality monitoring plan with procedures and protocols.
   f. Written groundwater monitoring plan with estimated costs.
   g. Summary matrix that details specific action items for both short- and long-term goals needed to successfully implement the Plan.
2. Dissemination and GIS deliverables
   a. Website to house all documents, data, and tools (to be hosted by WRTF)
   b. Google earth mapping tool hosted on the website
   c. Summary document (glossy, 4-8 pages) for public dissemination.
   d. PowerPoint presentation summarizing the Plan.
   e. Updated water quality database.
   f. Updated geodatabase.

These deliverables comprise the full Plan for Pocahontas County. Only the requirements set forth in this document are expected to be part of the state-wide water resource management plan.

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17. **Hamons, Greg.** Agriculture & Natural Resources Extension Agent, WVU Extension Service. *Email to author Knight.* March 8,11, 2013.

18. **West Virginia Conservation Agency, Greenbrier Valley District.** [Online] 2013. http://www.wvca.us/districts/?page=gvcd.

19. **Davis, Susan.** District Conservationist, USDA NRCS. *Email and in-person correspondence with author Knight.* March, April 2013.

# APPENDIX A: WATER RESOURCE MANAGEMENT PLAN GEODATABASE

| Layer name | Description | Feature class layer descriptions in geodatabase |
|---|---|---|
| Analysis | Results from various analysis and summaries developed during the water resource assessment | • Catchments with all relevant water quality information tied to the drainage area, for both trout and non-trout streams<br>• TMDL subwatersheds with load allocations calculated<br>• Catchments with all many statistics calculated per catchment, which include:<br>o Land-use<br>o Calculated groundwater consumption<br>o Wells per catchment<br>o Recharge rate, both surface and groundwater<br>o Baseflow information<br>o Climatic conditions<br>• Water quality sample locations for the study area<br>• Digitized well yield estimates for parts of Pocahontas County |
| Basemap | Cartographic representations of relevant Pocahontas County features | • county boundary<br>• Roads<br>• HUC 12 watersheds<br>• Populated places with annotation<br>• Structures |
| Consumptive and non-consumptive use | Unique areas | • Mapped area if natural, scenic, environmental or recreational values of national, regional, local or statewide significance |
| Strategic resource areas | Defined strategic resource areas based on planning process | • HUC-12 watersheds at or near safe yield<br>• Source water protection areas<br>• Impaired subwatersheds |
| Geology/karst | Geologic features of Pocahontas County, including karst and cave data provided by various institutions | • Geology of the county<br>• Groundwater vulnerability<br>• Groundwater risk<br>• Karst formations<br>• West Virginia Speological Survey (WVASS) Cave locations (CONFIDENTIAL)<br>• 8-Rivers dye trace locations<br>• Interpreted groundwater basins (part of this study and mapped in the report)<br>• Pocahontas County oil and gas wells<br>• WVDEP Sinking streams<br>• WVDEP dye trace locations |
| Hydrology | Surface water data used for both cartography and analysis | • WVDEP high resolution stream datasets, reaches<br>• WVDEP 2010 303(d)-listed stream<br>• NHD 1-100k catchments<br>• NHD 1-100k flowlines (streams)<br>• NRCS HUC-12 watershed boundaries<br>• Watershed annotation<br>• Stream gauge locations |
| Recreation | Public lands | • Monongahela National Forest boundary<br>• State forest boundaries<br>• State park boundaries<br>• Wilderness boundaries |

| | | |
|---|---|---|
| Safe Yield | Seasonal safe yield calculated for each HUC-12 in the county. Seasonal groundwater safe yield calculated for each HUC 12. Seasonal withdrawal guidelines and critical planning areas for both surface and groundwater | • HUC-12 surface water safe yield, calculated for fall, winter, spring, and summer<br>• HUC-12 surface water withdrawal guidelines, calculated for fall, winter, spring, and summer<br>• Groundwater safe yield, calculated for fall, winter, spring, and summer<br>• Groundwater withdrawal guidelines, calculated for fall, winter, spring, and summer<br>• HUC 12 critical planning areas based on safe yield guidelines |
| Social | Demographic and economic datasets | • Block population (point locations)<br>• Block population (polygons)<br>• Business and public administrative water users<br>• county parcels (2010)<br>• county structures |
| Wastewater | Datasets relevant to the wastewater situation in Pocahontas County | • Septic failure: Scoring based on WVDEP methodology using soils data based on permeability, depth to groundwater, drainage<br>• Priority parcels for septic inventory and evaluation<br>• WVDEP water service areas (polygons) |
| Other | Tables and other datasets without a specific category | • TMDL wasteload allocations<br>• Impaired streams by mile summary<br>• Land-use dataset – raster 2001<br>• Elevation dataset – raster 2001<br>• Hillshade dataset – raster 2001<br>• Water quality data and relationship with sample locations |

Note: This table lists all the geo-datasets that were used and developed for the Plan for mapping or analysis purposes. The table organization below mirrors the organization of the ESRI geodatabase scheme and provides a general description of each dataset. Proper metadata is embedded in the geodatabase for all data layers that were either created or otherwise not gathered from the public domain.

# APPENDIX B: POCAHONTAS WATER RESOURCE TASK FORCE

The Pocahontas County Water Resources Task Force (WRTF) is a volunteer entity of the Pocahontas County Commission. WRTF was formed in late 2008 when a group of citizens requested the commission create a countywide WRMP pursuant to SB 641 §22-26-1, The Water Resources Protection and Management Act. WRTF has utilized AmeriCorps VISTA members, a part time employee, and countless community volunteers in their work. All WRTF efforts have been funded by public grants from the WV DEP, the US EPA and Secure Rural Schools Title II funding.

Current members of the WRTF steering committee are:

- Dennis Egan (Greenbank)
- Alvan Gale (Marlinton)
- Joshua Hardy (Hillsboro)
- Beth Little (Lobelia)
- Donald McNeel (Hillsboro)
- Margaret Worth (Edray)

Past members of the WRTF steering committee are:

- Jo Lori Drake (Arbovale)
- Anne Smith (Greenbank)

**Purpose and goals**

The foremost goal of WRTF is the completion and implementation of a WRMP for Pocahontas County. Through this WRMP, WRTF strives to (1) integrate efficient and effective water resources management, (2) coordinate and assist a diverse group of individuals and organizations responsible for water resources management, (3) promote sustainable economic development, and (4) ensure local input.

The four-fold mission of WRTF is as follows:

1. identify, inventory, and monitor Pocahontas County's water sources and uses;
2. promote public awareness and foster wise use of Pocahontas County's water resources;
3. protect the quality of life and economic vitality of Pocahontas County; and
4. contribute to the management and protection of West Virginia's water resources

In order to serve this mission, WRTF also engages in water-related education and outreach throughout the county.

**Partnerships**

Since its inception, WRTF has enjoyed the support of many partners. Included among these partners are Elk Headwaters Watershed Association, Pocahontas County Health Department, Use Your Noodle afterschool program (sponsored by High Rocks Educational Corporation), United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), West Virginia Department of Environmental Protection (WVDEP), West Virginia Division of Natural Resources (WVDNR), West Virginia University (WVU) Extension Service, Friends of the Lower Greenbrier River Watershed Association, Greenbank Middle School, Pocahontas County Parks and Recreation, Pocahontas County Public Service District (PSD), and US Forest Service (USFS).

# APPENDIX C: GROUNDWATER MONITORING PLAN





# Pocahontas County
# Water Resources Management Plan

## Phase 2 – Groundwater Monitoring Plan

**Prepared for:**

Pocahontas County Commission
Water Resources Task Force
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Marlinton, WV 24954

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# ABBREVIATIONS

| | |
|---|---|
| CSR | Code of State Regulations |
| DWWM | Division of Water and Waste Management |
| GPS | global positioning system |
| HUC | Hydrologic unit code |
| mg/L | Milligrams per liter |
| WRMP | Water Resources Management Plan |
| WVDEP | West Virginia Department of Environmental Protection |

# 1. INTRODUCTION

Implementing a groundwater monitoring plan is an important step in developing an understanding of the quantity and quality of local and/or regional groundwater systems. Long-term groundwater monitoring can allow for the identification of seasonal and/or anthropogenically- induced changes to water levels and water quality, and can help guide county-wide planning and regional water management decisions. Pocahontas County, surrounding counties, and the state of West Virginia could all benefit from the collection of additional data within the county. This groundwater monitoring plan is designed to address the West Virginia Code of State Rules (WV CSR) §22-26-8(c)(3), that requires the development of a "plan for the development of the infrastructure necessary to identify the groundwater resources of each region of this state…"

Developing an effective groundwater monitoring network is a long-term endeavor. Data collected from one-time sampling or monitoring events are generally of limited value in developing an understanding of local hydrogeology. Since financial support for the implementation of a groundwater monitoring plan is uncertain, three plan versions (Tiers 1 – 3) have been developed to provide options at different funding levels. The following sections describe the proposed objectives, design, methods, and costs for three different versions of the county-wide groundwater monitoring plan.

## 1.1 Monitoring plan objectives

The primary objectives of the groundwater monitoring plan are to:

- Develop a water level monitoring network with an adequate distribution of wells to understand water level conditions across each aquifer which is currently or reasonably anticipated to be utilized as a drinking water resource.
- Develop a water quality monitoring network with a strategic distribution of wells to monitor groundwater conditions across multiple watersheds.

Secondary objectives of the groundwater monitoring plan are to:

- Gather additional data on the hydrostratigraphy of the county.
- Gather additional data on the aquifer parameters of the county.
- Work cooperatively with other agencies and stakeholders to collect and share groundwater data for the county.

The data collected from the monitoring network will allow the county (and any teaming partners) to develop a baseline understanding of groundwater characteristics and to analyze long-term trends in groundwater quality and levels.

In the long term, data collected from the monitoring network could be used in the development of a county-wide groundwater protection and management plan. Prior to the development of such a plan, several years of background data will need be collected and analyzed to determine whether groundwater conditions are changing due to anthropogenic activities. It is possible that additional monitoring stations will be needed to make such a determination. If warranted by observations from the monitoring program or major changes in land use, the county could then develop and implement official policies and strategies to ensure the protection of groundwater quality and quantity.

## 1.2 Preliminary considerations

This monitoring plan in intended to be used as a flexible, preliminary planning document for the county that can be adjusted as needed to fit budgetary, logistical, and legal constraints. It is currently not possible to determine whether certain aspects of the plan can be successfully implemented without further planning on the county's behalf. There are several important issues that should be carefully considered prior to making any decisions on the implementation of this plan. Each of these issues has the potential to impact the successful implementation of the plan. Refer to Table 1 for an overview of some of the important considerations. Additionally, other sections of this plan provide recommendations on how the county might address the identified issues.

**Table 1: Important monitoring plan considerations**

| Issue | Preliminary Considerations | Potential Solutions |
|---|---|---|
| Property Ownership and Access | Does the county own any lands that would be suitable for the installation of new monitoring wells?<br><br>For wells installed on or (existing wells) accessed on private properties, the county may need to establish a right of entry agreement or an easement. | Inventory county-owned lands or lands owned by municipalities or other potential partners (i.e. Forest Service) that could be used in the project.<br><br>Develop a simple legal access agreement between the county and potential landowners that address liability concerns. Identify and use pro-bono legal services to help draft a legally-sound agreement. |
| Identifying Existing Wells | How will the county identify existing private (or municipal) wells that can be used for groundwater monitoring?<br><br>What type of outreach to landowners can the county conduct to interest land owners in allowing access to their private wells for groundwater monitoring?<br><br>Can the county offer any type of incentive to property or business owners who allow access to their property and/or well(s)? | Analyze the well completion reports to identify existing wells.<br><br>Contact large public/private landowners, industrial facilities, and agricultural operations. Large operations may have unused wells that could be used in the monitoring network. Another option may be to install monitoring wells on school properties, which could also be an educational tool.<br><br>Investigate incentives for land owners who assist in the plan. Land owners could also be recognized on the county's website or elsewhere for their involvement. |
| Cooperation with Other Agencies / Parties | Can the county facilitate cost / labor sharing agreements with partners to implement the plan?<br><br>What other agencies or non-profits have a vested interest in, or a stated goal of monitoring the county's water resources?<br><br>What technical, financial, or other cooperation will the county seek from potential partnering agencies?<br><br>What can the county offer potential partners as part of a cooperative monitoring agreement (labor, funding, property access, etc.)? | Begin by contacting USGS, WVDEP, and the USFS. Other potential partners may include universities, K-12 county schools, and local watershed organizations. Determine the potential goals of each organization.<br><br>It is likely that the county will need technical, financial, and logistic assistance in implementing the plan. The county should develop an itemized list of what assistance they plan to solicit from partners.<br><br>Prepare a list of what the county can offer potential partnering entities. |
| Funding | What funding can the county allocate for the development and monitoring of the network?<br><br>If funding is currently not available, does the county have any mechanism that would allow the collection of revenues to support the monitoring network in the future?<br><br>What agencies or partners would be likely to contribute funding to the project? | Examine current and potential funding sources.<br><br>Begin searching for grant opportunities.<br><br>Obtain funding from partner agencies (refer to Table 6) where possible. |
| Internal Resources and Staffing | What personnel resources can the county bring to the project (the project could require field staff, data processing and interpretation experts, laboratory staff, surveyors, administrative staff, and possibly legal assistance)?<br><br>What assets does the county possess that could be used in the implementation of the plan? | Identify and inventory county staff who would participate in the monitoring plan, and what role they would play.<br><br>Inventory scientific equipment, vehicles and other equipment that could be used in the monitoring plan. |

## 2. MONITORING NETWORK DESIGN

The monitoring network will initially include a minimum of 12 wells, distributed between the four major watersheds within the county (based on 8-digit HUCs); the Gauley, Greenbrier, Cheat, and Elk watersheds (Table 2).

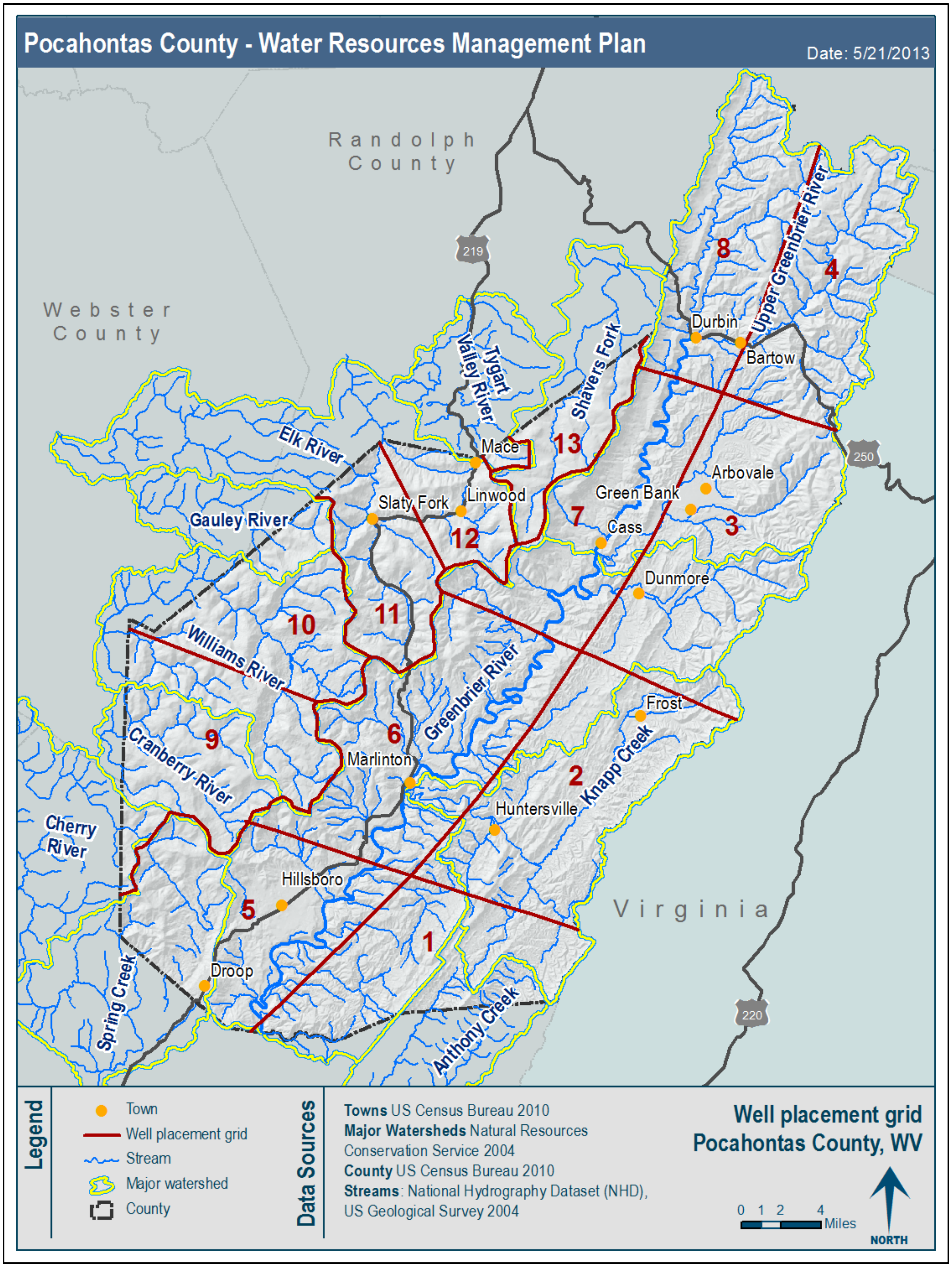
**Table 2: Number of proposed monitoring wells by HUC watershed**

| Watershed (8-digit HUC) | Number of Wells | Index Map Numbers[2] |
|---|---|---|
| Greenbrier | 7[1] | 1-8 |
| Gauley | 2 | 9-10 |
| Elk | 2 | 11-12 |
| Cheat | 1 | 13 |

[1] A USGS monitoring well is already installed in the Greenbrier watershed, in grid cell #5. Currently, only water levels are monitored continuously in this well.
[2] Refer to Figure 1 for the grid cell index map

The number of monitoring wells in each watershed is based upon the size and orientation of the portion of each watershed located within the county boundaries. Watersheds were divided into a series of cells designed to provide a reasonable distribution of monitoring wells (commensurate with expected funding constraints) across the county. Actual well locations were not determined as part of this plan, and will need to be determined by the county prior to the implementation of the plan. To obtain an even distribution of monitoring wells across the county, one monitoring well should be installed in each of the grid cells identified in Figure 1. Because the goal of the plan is to monitor potential drinking water resources in different locations across the county, specific aquifers are not identified for monitoring. Wells should be installed into the aquifer within each grid cell that is locally used to meet domestic and municipal supply needs. Multiple aquifer units are used for water supply purposes across the county, dependent on elevation and location within the county.

**Figure 1: County-wide monitoring well placement grid map**



Specifications for the three proposed tiers of monitoring, designed to meet different budgetary constraints, are provided in Table 3.

**Table 3: Three tiers of the groundwater monitoring plan**

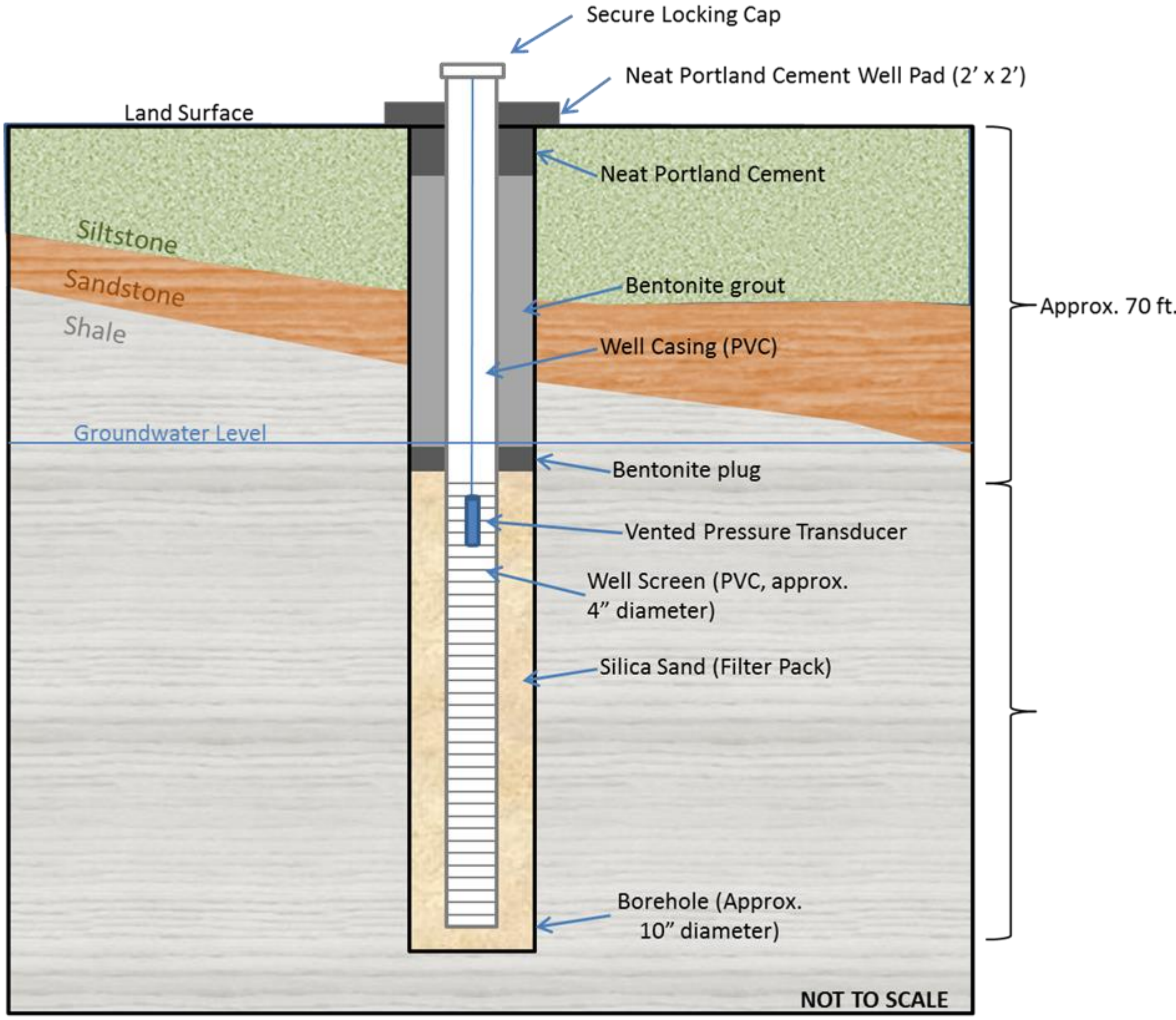
| Monitoring Plan | Proposed New Infrastructure | Number of Monitoring Stations | Water Level Monitoring Frequency | Water Quality Monitoring Frequency |
|---|---|---|---|---|
| Tier 1 | 12 dedicated monitoring wells | 12 new wells<br>Any available existing wells<br>+1 existing USGS well<br>**13+ wells** | Continuous | Bi-annually for first 3 years; Annually thereafter |
| Tier 2 | 6 dedicated monitoring wells | 6 new wells<br>6 existing wells (minimum)<br>+1 existing USGS well<br>**13+ wells** | Continuous for new wells; quarterly in existing wells | Bi-annually for first 3 years; Annually thereafter |
| Tier 3 | No new infrastructure | 12 existing wells (minimum)<br>+1 existing USGS well<br>**13+ wells** | Quarterly | Bi-annually for first 3 years; Annually thereafter |

## 2.1 Installation of new wells

The Tier 1 and 2 monitoring options both entail the construction of new, dedicated monitoring wells. Tier 3 assumes no new infrastructure and that existing public or private drinking water wells and the existing USGS well will be used. County staff will need to coordinate with USGS to discuss the implementation of the plan and to discuss potential water quality sampling activities at the well (currently only water levels are monitored at the USGS well). Because the exact future location of the wells is not currently known, precise construction details for the proposed wells cannot be provided. As previously discussed, since the purpose of the monitoring program is to monitor the quality of groundwater in zones that are (or may be) used for drinking, the monitoring wells should be installed into the same hydrogeologic unit (at roughly the same depth) as nearby domestic or municipal wells. Well depths should be determined based on the local knowledge of the well driller (for new wells), based on a physical inspection (for existing wells) and onsite depth measurements, or based on data interpreted from well completion logs for nearby wells (Appendix 1). A 500-foot electronic water level indicator can be used to measure the depths of existing wells.

For the purposes of this plan, it is assumed that the average monitoring well will consist of a 4-inch diameter poly-vinyl chloride (PVC) casing, installed from approximately two feet above land surface down to 70 feet below land surface. Four-inch diameter wells are recommended to facilitate potential use in aquifer performance testing, geophysical logging, and for ease of access when sampling with standard submersible pumps. Total well depths will be approximately 250 feet, with an open borehole or screened interval (dependent on the local geology) from 70 to 250 feet below land surface (Figure 2). Actual well construction specifications may vary based on local conditions, and should be similar to the specifications used in the construction of local domestic wells. Wells should be finished with a two-foot square cement pad and a secure locking cap. All well construction, cementing, and well development procedures will be conducted according WV CSR 64 (sections 19 and 46). The wells will be installed by a West Virginia Certified Monitoring Well Driller using mud rotary or air rotary methods. Well construction cost estimates are provided in Tables 7 and 8.

**Figure 2: Example well schematic-construction details are approximate and subject to change based on local conditions**




During the construction of the wells, lithologic samples (cuttings) should be collected every five feet, or during significant changes in drilling progress or changes in the appearance of the cuttings. An accredited geologist or engineer should describe the cuttings and develop a lithologic log for each well constructed in support of the project. The well logs provide valuable information for hydrogeologic interpretation and it is very important that the County maintain a copy of the well logs in their records (Appendix 2).

At least 24 hours after the installation and development of the wells, vented pressure transducers should be programmed, calibrated, and deployed in each of the new wells. Depending on the brand of transducers selected for the project, some modifications of the casing riser and/or well cap may be needed. Additional detail on the deployment and operation of the transducers is provided in the section 3.2 Water Level Monitoring.

Each of the new wells should ultimately be surveyed by a West Virginia licensed land surveyor. Horizontal and vertical specifications (top of casing, land surface, XY coordinates) of each of the wells should be used to accurately determine groundwater levels with respect to an established datum. Although this is not a crucial part of the monitoring plan, the county should eventually seek to identify funding to have the wells surveyed so that gradients and groundwater flow direction can be determined. Surveying costs are not included in the cost estimates provided in this plan.

## 2.2 Selection of existing wells

Tiers 2 and 3 depend on identifying existing (used or unused) wells within the county for use in a monitoring plan. The county will need to develop agreements with public and/or private landowners within the county to access their wells for monitoring. Some existing wells will have characteristics that are more favorable for use in monitoring than others. Table 4 presents criteria which shall be considered when selecting existing wells for use in the monitoring program. Each of the criteria are important, however, minimally, the well construction specifications need to be ascertained for any well used in the monitoring program.

**Table 4: Favorable criteria for the selection of existing wells for use in monitoring plan tiers 2 and 3**

| Description of Criteria |
|---|
| **Wells are currently unused (backup or emergency wells) or seasonally used**. Some knowledge of the water use patterns is needed for pumping wells which are used in the monitoring program. |
| **No pumps installed.** If pumps are installed, wells will need a sampling tap available and /or adequate space available between the pump apparatus and casing to sample and monitor water levels. |
| **Well casing, appurtenances, and mechanical components are in good condition.** Damaged wells can only be used under limited circumstances, and will need to be inspected by a driller first, potentially increasing project costs. |
| **Horizontal and vertical surveys have already been conducted on the well.** Preference should be given to wells which already have had surveys conducted on them. |
| **Well construction specifications (depth, etc.) and log are available.** Well permits, construction logs and/or other construction documentation provide important information on the hydrogeologic characteristics of the well site and the specifications of the well. |
| **Year-round well access is possible.** Wells included in the monitoring program must be accessed at least four times yearly. |

## Monitoring of springs (optional)

Upon selection of an existing well site for use in the monitoring plan, a site visit should be conducted to meet with the land owner, ascertain well construction details, collect GPS coordinates and photos, and collect other relevant site information. It may not be possible to determine the feasibility of using an individual well in the program until a preliminary site visit is conducted by the county (or their representatives) to the prospective well site. Each of the existing wells should ultimately be surveyed by a West Virginia licensed land surveyor.

There are at least 68 known springs within Pocahontas County. Springs are representative of groundwater conditions, but also typically directly contribute to surface water, and as such, can have an important bearing on surface water quality and quantity. Collecting data from springs would aid in the overall understanding of groundwater conditions within the county.

For the purposes of this plan, a springs monitoring option is included with each of the proposed Tiers of monitoring (Table 7-9). The proposed costs for the springs monitoring program are presented in a manner where they can be added to either the county groundwater or surface water monitoring plan, based on budgetary constraints, and logistical considerations. The same suite of water quality parameters collected from the monitoring well network should be collected from the springs, at the same frequency as the sampling of the well network. Gaging of springflow should be conducted using the same procedures as outlined for the streamflow gaging in the surface water monitoring plan.

A reasonable approach to monitoring the springs might be to select 10 percent of the total known springs across the county, which would equal seven springs. At least one spring should be selected for monitoring within each significant HUC 8-digit watershed within the county. One spring in each the Gauley, Elk, and Cheat River watersheds should be monitored, and four springs within the Greenbrier watershed should be monitored. Springs should be selected based on accessibility and magnitude, with preference given to readily-accessible springs with the greatest flow volumes. Within the Greenbrier watershed, two springs should be selected on either side of the Greenbrier River, with one set of springs in the southern half of the watershed, and one set in the northern half of the watershed. The county should identify the springs to be monitored using local knowledge and through outreach to landowners or land managers.

**ESTIMATED COST $36,700 for 3 years of baseline monitoring**

# 3. MONITORING PROTOCOLS

## 3.1 Water quality sampling

For all three Tiers of monitoring (Table 3), the first three years of the monitoring program should be considered the baseline monitoring period. Data from the baseline monitoring period should be used to characterize the background groundwater quality in different hydrogeologic units across the county. Water quality samples should be collected twice yearly at each monitoring well site during the baseline monitoring period. After the three-year baseline monitoring period, the monitoring frequency can be reduced to annually.

The water quality parameters which will be sampled for include a number of parameters which will indicate both the basic geochemistry of different hydrogeologic units across the county and potential influences from surface activities (Table 5). The levels of these constituents will provide an indication of the suitability of groundwater in various areas of the county for consumption. Additionally, after the monitoring network is established, additional water quality parameters can be added to the monitoring plan if desired, to monitor the impacts of different land uses (e.g. gas drilling/hydraulic fracturing, mining, agricultural) on groundwater quality.

Groundwater samples shall be collected in accordance with WVDEP-DWMM-PP-GW-001 – Quality Assurance/Quality Control Plan, and Standard Operating Procedures for Groundwater Sampling, which is the State of West Virginia's guidance document for obtaining and handling groundwater samples (Appendix 3). WVDEP-DWMM-PP-GW-001 provides procedures for purging, sampling, and monitoring water levels and quality in wells.

All water quality samples shall be handled and preserved according to WVDEP-DWMM-PP-GW-001 and transported to a National Environmental Laboratory Accreditation Program (NELAP) accredited analytical laboratory under a secure chain of custody (Refer to Appendix 4 for a list of WVDEP-certified laboratories). For quality assurance purposes, duplicate water quality samples will be collected for every 10 groundwater samples and submitted to the laboratory. The sampling location (well) and sampling time for the duplicate samples should not be identified to the analytical laboratory. Upon receipt of the sampling results, the duplicate results can be compared with the initial set of samples from the same well to determine the accuracy of the laboratory analytical results.

**Table 5: Proposed groundwater monitoring parameters**

| Analyte | EPA Method | WV Drinking Water Quality Standard |
|---|---|---|
| Arsenic | 200.7 | 0.01 mg/L |
| Cadmium | 200.7 | 0.005 mg/L |
| Calcium | 200.7 | n/a |
| Chloride | 300.0 | 250 mg/L |
| Chromium | 200.7 | 0.1 mg/L |
| Copper | 200.7 | 1.3 mg/L[1] |
| Dissolved Oxygen | n/a – field parameter | n/a |
| Fluoride | 340.2 | 4.0 mg/L |
| Iron | 200.7 | 0.3 mg/L |
| Lead | 200.7 | 0.015 mg/L[1] |
| Magnesium | 200.7 | n/a |
| Manganese | 200.7 | 0.05 mg/L |
| Mercury | 245.1 | 0.002 mg/L |
| Ortho-phosphate-phosphorous | 365.2 | n/a |
| pH | n/a – field parameter | n/a |
| Potassium | 200.7 | n/a |
| Sodium | 200.7 | 20 mg/L[2] |
| Sulfate | 300.0 | 250 mg/L |
| Specific Conductance | n/a – field parameter | n/a |
| Temperature | n/a – field parameter | n/a |
| Total Dissolved Solids | 160.1 | 500 mg/L |
| Total Nitrate + Nitrite | 353.2 | 10 mg/L[3] |
| Total phosphorus | 365.2 | n/a |
| Turbidity | n/a – field parameter | n/a |
| Zinc | 200.8 | 5.0 mg/L |
| Carbonate Alkalinity ($CO_3$-) | n/a - State Method | n/a |
| Bicarbonate Alkalinity ($HCO_3$) | n/a - State Method | n/a |

[1] West Virginia Action Level
[2] American Heart Association Maximum Recommended Level2
[3] Nitrate = 10 mg/L, Nitrite = 1 mg/L

## 3.2 Water level monitoring

Water level monitoring is an important part of each Tier of the monitoring plan. Depending of which Tier of this plan is implemented, water level data will be collected either manually with a handheld electronic water level indicator, or automatically using pressure transducers.

New, dedicated wells constructed for the project, as specified for Tiers 1 and 2 (Table 3), should be instrumented with vented pressure transducers to continuously monitor changes in groundwater levels over time. At a minimum, data from the pressure transducers will be downloaded quarterly over the duration of the project. The pressure transducers need to be properly calibrated and maintained according to the manufacturer’s guidance, and need to be accurate to at least 0.1 inches.

Water levels in existing wells which are incorporated into the network may be measured quarterly using a handheld electronic water level indicator, accurate to 0.1 inches. Some of the existing wells used in the monitoring program may be wells which are seasonally used for other purposes or wells with pumps installed in them, so the installation of pressure transducers may not be feasible. While quarterly monitoring is not generally preferable to continuous data, it can usually be done at a lower cost, and still provides data sufficient to determine seasonal changes in groundwater levels.

Although not included in this plan, it would also be valuable for the county to proceed with additional groundwater level and flow studies, especially in the karst areas of the county. Additional dye trace studies (similar to those presented in Phase I of the WRMP) could be conducted to monitor groundwater movement and delineate groundwater basins, in karst areas adjacent to those studied in Phase I of the WRMP. Dye tracing can provide data on preferential groundwater flow pathways that is difficult to ascertain from monitoring groundwater levels in wells.

# 4. DATA STORAGE AND MANAGEMENT

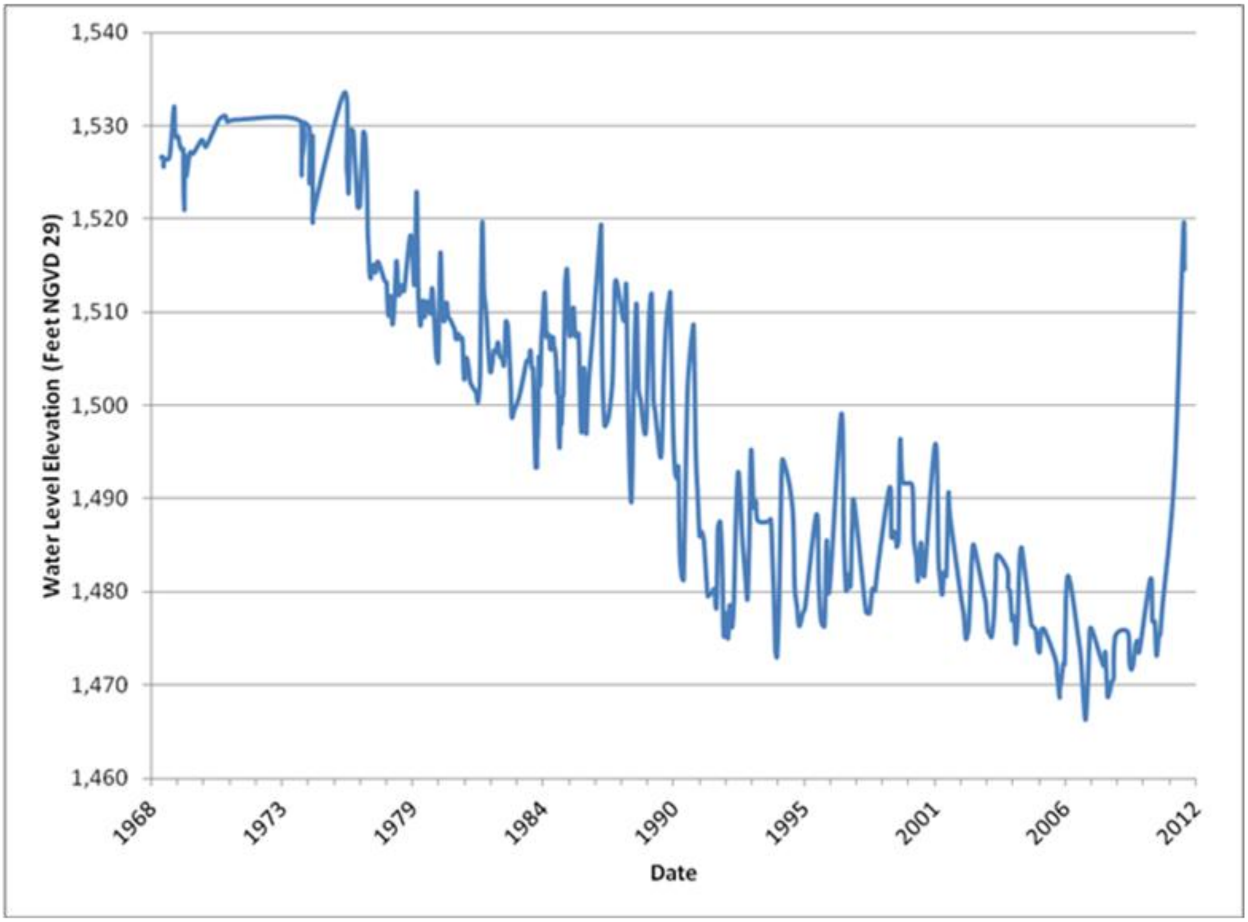
As data is collected over the duration of the plan, the county should store the data in Microsoft Excel or Access databases. The data could be integrated into the existing water quality database provided to the county as part of Phases I of the WRMP. Appending new data into the existing database would save time and ensure a consistent format for all of the water quality data managed by the county. Water level and water quality data should be added continuously to the database as it is collected, so that a chronological record of all data collected exists in the same database. This will enable graphical and statistical analysis of data for the entire monitoring period, and will reduce costs for the county during the analysis of the data. It is anticipated that the county will need some assistance in the analysis and processing of the data, either from an outside contractor, or a partnering agency.

The baseline data collected in the first three years of the program should be used to establish minimum, maximum, and mean water quality and water level values. Data collected after the baseline period can be compared to the range of values and means established during the baseline period. Deviations from the normal baseline range of water quality and levels might entail investigations of changing climatic or environmental conditions in the vicinity of the monitoring well. Graphical and statistical trend analysis should be performed to examine any long-term changes in groundwater conditions that may be occurring within the county over the period of the monitoring plan. Additionally, precipitation data should be obtained (there are several state rain gages within the county) and correlated with the groundwater data, where possible. Other valuable analyses might include correlating groundwater levels with stream flow and surface water elevations (for well sites which are in close proximity to surface water resources). Minimally, the groundwater level data should be used to develop hydrographs for each well (Figure 3), and if possible based on the well locations and hydrogeologic units monitored in the program, potentiometric surface maps may be constructed periodically.

# 6. COST ESTIMATES

Cost estimates were developed for each Tier of the monitoring plan (Table 7-9). The cost estimates include all of the major components of work for each Tier.

**Figure 3: Example groundwater hydrograph**




Yearly technical memoranda detailing the data collected and any relevant trends should be developed over the duration of the plan. It is anticipated that the memoranda will be a joint effort between the county and either an outside contractor, or a partnering agency. The memoranda should also provide recommendations to improve or update the monitoring plan or network, if warranted.

# 5. INTER-AGENCY COOPERATION

Where possible, the county should seek to partner with other agencies and stakeholders in monitoring the groundwater conditions across the county. Developing partnerships may lead to cost-sharing or labor-sharing agreements between the county and other agencies, and could also result in other benefits, such as educational opportunities for the public. Table 6 provides a list of potential teaming partners for the county.

In some cases, potential teaming partners may be able to help provide funding or technical expertise to expand the scope and objectives of the monitoring network. Where possible, the county should work with partners to accomplish both the primary and secondary objectives of this plan (see the Monitoring Plan Objectives section), and to analyze and present the data collected over the duration of monitoring activities.

**Table 6: Potential groundwater monitoring plan teaming partners**

| Potential Partner | Potential Partnering Benefits to County | Potential Contact | Additional Partnering Information |
|---|---|---|---|
| U.S. Geological Survey | Co-funding/co-management of projects, technical expertise in collecting and interpreting data, assistance during field work, may be able to help with secondary plan objectives (such as aquifer testing and geophysical logging) | **Randall Conger**<br>Hydrologist<br>USGS Northeast Area<br><br>215 Limekiln Road<br>New Cumberland, PA 17070<br>Phone: 717-730-6947<br>Fax: 717-730-6997<br>rwconger@usgs.gov | Randall Conger is in charge of a regional project to perform geophysical logging on water wells across WV. USGS may be able to provide geophysical logging support during the construction of new monitoring wells. |
| | | **Mark D. Kozar**<br>Hydrologist<br>USGS Northwest Area<br>934 Broadway,<br>Ste. 300<br>Tacoma, WA 98402<br>Phone: 253-552-1683<br>Fax: 253-552-1581<br>mdkozar@usgs.gov | Mark Kozar is the lead on a regional study to identify the extent of Mississippian and Pennsylvannian aquifers within WV and Virginia. USGS may be interested in working cooperatively during the construction of the wells to assist in determining the hydrogeologic units encountered at each well site. |
| | | **John T. Atkins, Jr.**<br>Engineering Hydrologist<br>Hydrologic Investigations and Surveillance Section<br><br>**Melvin V. Mathes, Jr.**<br>Hydrogeologist<br>Hydrologic Investigations and Surveillance Section<br><br>**Gary R. Crosby**<br>Lead Hydrologic Technician<br>Hydrologic Networks Unit<br><br>USGS West Virginia Water Science Center Office<br>11 Dunbar Street<br>Charleston, West Virginia, 25301<br>Phone: 304-347-5130 | John Atkins, Melvin Mathes, and Gary Crosby are in charge of hydrogeologic investigations and monitoring for WV at USGS. USGS may be interested in additional groundwater monitoring or cost-share opportunities in Pocahontas County. Also, they may be able to provide assistance interpreting data collected from the groundwater monitoring network. |

| Potential Partner | Potential Partnering Benefits to County | Potential Contact | Additional Partnering Information |
|---|---|---|---|
| WV Department of Environmental Protection | Co-funding/co-management of projects, technical expertise in collecting and interpreting data, assistance during field work, may be able to help with secondary plan objectives (such as aquifer testing and geophysical logging) | **Brian A. Carr, P.G.**<br>WV DEP<br>Program Manager, Water Use Section<br>601 57th Street SE<br>Charleston, WV 25304<br>304.926.0499 x 1757 | During Project meetings, WVDEP has expressed interest in potentially working with the County on co-funding future monitoring projects. WVDEP needs to collect groundwater data across the State to support their state-wide groundwater modeling efforts. |
| Local or Regional Watershed or Citizens Environmental Groups | Co-funding of projects, assistance during field work, assistance in promotion and public outreach of the program, involvement of community members in the plan | Potentially interested groups might include: Upper Monongahela River Association, WV Sierra Club, WV Highlands Conservancy, The Wilderness Society, Friends of the Allegheny Front, WV Citizen Action Group, Appalachian Lands Conservation Cooperative, and others to be determined through further outreach by the County | Multiple environmental and citizens groups have expressed interest in shale gas drilling and hydraulic fracturing that may occur within the County. Some of these groups may be interested in being involved in monitoring efforts. |
| Local K-12 Schools | Potential lands for well installations, involvement of the community in the plan, educational opportunities for students | To be determined through further outreach by the County | n/a |
| U.S. Forest Service and National Park Service | Co-funding/co-management of projects, technical expertise in collecting and interpreting data, assistance during field work | **Clyde N. Thompson**<br>USDA Forest Service, Monongahela Forest Supervisor<br>200 Sycamore Street<br>Elkins, WV 26241<br>(304) 636-1800 | USDA has provided previous funding for the WRMP, and has expressed interest in any monitoring projects that could benefit the region. |
| Universities | Co-funding/co-management of projects, technical expertise in collecting and interpreting data, assistance during field work, educational opportunities for students | To be determined through further outreach by the County | n/a |

**Table 7: Tier 1 estimated costs**

| Task Description | Number of Events per Year | Number of Years | Estimated Labor Hours | Estimated Costs | | |
|---|---|---|---|---|---|---|
| | | | | Labor[1] | Subcontractors[2] | Equipment |
| **Identification of New Well Sites for Groundwater Monitoring -** This will be accomplished through dialogue with the Forest and Park Services and other landowners within the County. Also, it is anticipated that research on well characteristics will need to be conducted using the County well database or individual landowner records. This includes all coordination and the drafting of access agreements between landowners and the County (if legal assistance required for this task, additional funding for legal fees will be needed). | 1 | n/a | 80 | $4,000 | - | - |
| **Initial Well Site Visits** - Perform initial site visits to up to 12 new well sites. Perform recon of new well sites. Also includes acquisition of well construction permits. | 1 | n/a | 32 | $1,600 | $2,250[3] | $850[4] |
| **Well Construction** – Includes the construction, development, and instrumentation of six new dedicated monitoring wells by an experienced local driller. Also includes the preparation of lithologic logs by a qualified geologist and coordination of drilling activities, site visits, and transducer installation by County staff. | n/a | n/a | 160 | $8,000 | $158,000[5] | $9,600[6] |
| **Biannual (baseline) Groundwater Quality Sampling and Data Collection -** Includes purging and sampling 12 wells and preserving the samples. Also includes travel to each well site. | 2 | 3 | 40 | $12,000 | $3,450[7] | $6,000[8] |
| **Groundwater Level Data Collection** - Groundwater level monitoring will take place four times per year at 12 wells. Two events (annually) will occur during the water quality sampling. Includes data collection and travel to well sites. | 2 | 3 | 16 | $4,800 | - | - |
| **Data Entry, Interpretation, and Management** - Includes coordination with lab, entry of data into database, coordination with partners, preparation of technical memos, and general project management. | 1 | 3 | 120 | $18,000 | $8,250[9] | - |
| | | | **Sub Totals** | **$48,400** | **$171,950** | **$16,450** |
| | | | **+10% Contingency Fee** | | **$23,680**[10] | |
| | | **Tier 1 Monitoring Plan Total** | | **$260,480** | | |

Table 7 Notes

1) This plan assumes that County staff will be performing the majority of the Project labor hours at $50/hr. This cost includes staff salaries, benefits, use of a personal vehicle, office supplies, and communications expenses.
2) Either subcontractors or partnering agencies will meet subcontracting needs.
3) Assumes that a well driller visit new well sites along with County staff.
4) An electronic water level indicator will be purchased for the project. It is assumed that the County already has the other items needed for this task, which include a camera, a GPS unit, a tape measure, and a basic set of hand tools.
5) Includes well construction costs (approximately $12,000 per well = $144,000) and costs for lithologic analysis, construction and lithologic log preparation by a geologist, an initial meeting between a geologist from a partner agency or subcontractor and the project well driller, and the cost to ship lithologic samples if needed. Geologic oversight for the construction of each well is not included in this cost estimate.
6) Includes the purchase of 12 pressure transducers at approximately $800 apiece.
7) Includes one full day in the field for groundwater sampling training from a subcontractor or partner agency. Also includes costs for laboratory water quality analyses.
8) Each sampling event has approximately $1,000 of equipment costs. Costs include rental of pumps/pump drive and water quality meters (approximately $800 for a week - U.S Environmental Rental Corp); purchase of tubing, gloves, ice, soap, buckets, fuel and other expendables. This assumes that the County has a small gas generator that can be used for the project.
9) This is an estimate of costs to prepare an annual groundwater monitoring technical memo, which summarizes trends at the end of each year of monitoring. The report will be a cooperative effort between County staff and a subcontractor or partnering agency.
10) A 10% contingency is included to account for the uncertainty of the costs presented in this table. If the contingency funding is not needed to accomplish the tasks outlined in the table, it could be used to add more parameters or wells to the network, extend the monitoring period beyond three years, or to perform additional analyses in support of the project.

**Table 8: Tier 2 estimated costs**

| Task Description | Number of Events per Year | Number of Years | Estimated Labor Hours | Estimated Costs | | |
|---|---|---|---|---|---|---|
| | | | | Labor[1] | Subcontractors[2] | Equipment |
| **Identification of Existing Wells and New Well Sites for Groundwater Monitoring -** This will be accomplished through dialogue with the Forest and Park Services and other landowners within the County. Also, it is anticipated that research on well characteristics will need to be conducted using the County well database or individual landowner records. This includes all coordination and the drafting of access agreements between landowners and the County (if legal assistance required for this task, additional funding for legal fees will be needed). | 1 | n/a | 80 | $4,000 | - | - |
| **Initial Well Site Visits** - Perform initial site visits to up to 6 selected existing well sites and 6 new well sites. Record well diameters, depths, riser height, material, GPS coordinates, relevant notes, and collect photos. Perform recon of new well sites. Also includes acquisition of well construction permits. | 1 | n/a | 32 | $1,600 | $1,500[3] | $850[4] |
| **Well Construction –** Includes the construction, development, and instrumentation of six new dedicated monitoring wells by an experienced local driller. Also includes the preparation of lithologic logs by a qualified geologist and coordination of drilling activities, site visits, and transducer installation by County staff. | n/a | n/a | 80 | $4,000 | $79,500 | $4,800[6] |
| **Biannual (baseline) Groundwater Quality Sampling and Data Collection** - Includes purging and sampling 12 wells and preserving the samples. Also includes travel to each well site. | 2 | 3 | 40 | $12,000 | $3,450[7] | $6,000[8] |
| **Groundwater Level Data Collection** - Groundwater level monitoring will take place four times per year at 12 wells. Two events (annually) will occur during the water quality sampling. Includes data collection and travel to well sites. | 2 | 3 | 16 | $4,800 | - | - |
| **Data Entry, Interpretation, and Management** - Includes coordination with lab, entry of data into database, coordination with partners, preparation of technical memos, and general project management. | 1 | 3 | 120 | $18,000 | $8,250[9] | - |
| | | | **Sub Totals** | **$44,400** | **$92,700** | **$11,650** |
| | | | **+10% Contingency Fee** | | **$14,875[10]** | |
| | | | **Tier 2 Monitoring Plan Total** | | **$163,625** | |

Table 8 Notes

1) This plan assumes that County staff will be performing the majority of the Project labor hours at $50/hr. This cost includes staff salaries, benefits, use of a personal vehicle, office supplies, and communications expenses.
2) Either subcontractors or partnering agencies will meet subcontracting needs.
3) A subcontractor will be needed for a full day in the field to train County staff about how to identify and measure well specifications. Also assumes that a well driller visit new well sites along with County staff.
4) An electronic water level indicator will be purchased for the project. It is assumed that the County already has the other items needed for this task, which include a camera, a GPS unit, a tape measure, and a basic set of hand tools.
5) Includes well construction costs (approximately $12,000 per well = $72,000) and costs for lithologic analysis, construction and lithologic log preparation by a geologist, an initial meeting between a geologist from a partner agency or subcontractor and the project well driller, and the cost to ship lithologic samples if needed. Geologic oversight for the construction of each well is not included in this cost estimate.
6) Includes the purchase of 6 pressure transducers at approximately $800 apiece.
7) Includes one full day in the field for groundwater sampling training from a subcontractor or partner agency. Also includes costs for laboratory water quality analyses.
8) Each sampling event has approximately $1000 of equipment costs. Costs include rental of pumps/pump drive and water quality meters (approximately $800 for a week - U.S Environmental Rental Corp); purchase of tubing, gloves, ice, soap, buckets, fuel and other expendables. This assumes that the County has a small gas generator that can be used for the project.
9) This is an estimate of costs to prepare an annual groundwater monitoring technical memo, which summarizes trends at the end of each year of monitoring. The report will be a cooperative effort between County staff and a subcontractor or partnering agency.
10) A 10% contingency is included to account for the uncertainty of the costs presented in this table. If the contingency funding is not needed to accomplish the tasks outlined in the table, it could be used to add more parameters or wells to the network, extend the monitoring period beyond three years, or to perform additional analyses in support of the project.

**Table 9: Tier 3 estimated costs**

| Task Description | Number of Events per Year | Number of Years | Estimated Labor Hours | Estimated Costs | | |
|---|---|---|---|---|---|---|
| | | | | Labor[1] | Subcontractors[2] | Equipment |
| **Identification of Existing Wells for Groundwater Monitoring -** This will be accomplished through dialogue with the Forest and Park Services and other landowners within the County. Also, it is anticipated that research on well characteristics will need to be conducted using the County well database or individual landowner records. This includes all coordination and the drafting of access agreements between landowners and the County (if legal assistance required for this task, additional funding for legal fees will be needed). | 1 | n/a | 80 | $4,000 | - | - |
| **Initial Well Site Visits** - Perform initial site visits to up to 12 selected well sites. Record well diameters, depths, riser height, material, GPS coordinates, relevant notes, and collect photos. | 1 | n/a | 32 | $1,600 | $750[3] | $850[4] |
| **Biannual (baseline) Groundwater Quality Sampling and Data Collection -** Includes purging and sampling 12 wells and preserving the samples. Also includes travel to each well site. | 2 | 3 | 40 | $12,000 | $3,450[5] | $6,000[6] |
| **Groundwater Level Data Collection** - Groundwater level monitoring will take place four times per year at 12 wells. Two events (annually) will occur during the water quality sampling. Includes data collection and travel to well sites. | 2 | 3 | 16 | $4,800 | - | - |
| **Data Entry, Interpretation, and Management** - Includes coordination with lab, entry of data into database, coordination with partners, preparation of technical memos, and general project management. | 1 | 3 | 120 | $18,000 | $8,250[7] | - |
| | | | **Sub Totals** | **$40,400** | **$12,450** | **$6,850** |
| | | | **+10% Contingency Fee** | | **$5,970[8]** | |
| | | | **Tier 3 Monitoring Plan Total** | | **$65,670** | |

Table 9 Notes

1) This plan assumes that County staff will be performing the majority of the Project labor hours at $50/hr. This cost includes staff salaries, benefits, use of a personal vehicle, office supplies, and communications expenses.
2) Either subcontractors or partnering agencies will meet subcontracting needs.
3) A subcontractor will be needed for a full day in the field to train County staff about how to identify and measure well specifications.
4) An electronic water level indicator will be purchased for the project. It is assumed that the County already has the other items needed for this task, which include a camera, a GPS unit, a tape measure, and a basic set of hand tools.
5) Includes one full day in the field for groundwater sampling training from a subcontractor or partner agency. Also includes costs for laboratory water quality analyses.
6) Each sampling event has approximately $1000 of equipment costs. Costs include rental of pumps/pump drive and water quality meters (approximately $800 for a week - U.S Environmental Rental Corp); purchase of tubing, gloves, ice, soap, buckets, fuel and other expendables. This assumes that the County has a small gas generator that can be used for the project.
7) This is an estimate of costs to prepare an annual groundwater monitoring technical memo, which summarizes trends at the end of each year of monitoring. The report will be a cooperative effort between County staff and a subcontractor or partnering agency.
8) A 10% contingency is included to account for the uncertainty of the costs presented in this table. If the contingency funding is not needed to accomplish the tasks outlined in the table, it could be used to add more parameters or wells to the network, extend the monitoring period beyond three years, or to perform additional analyses in support of the project.