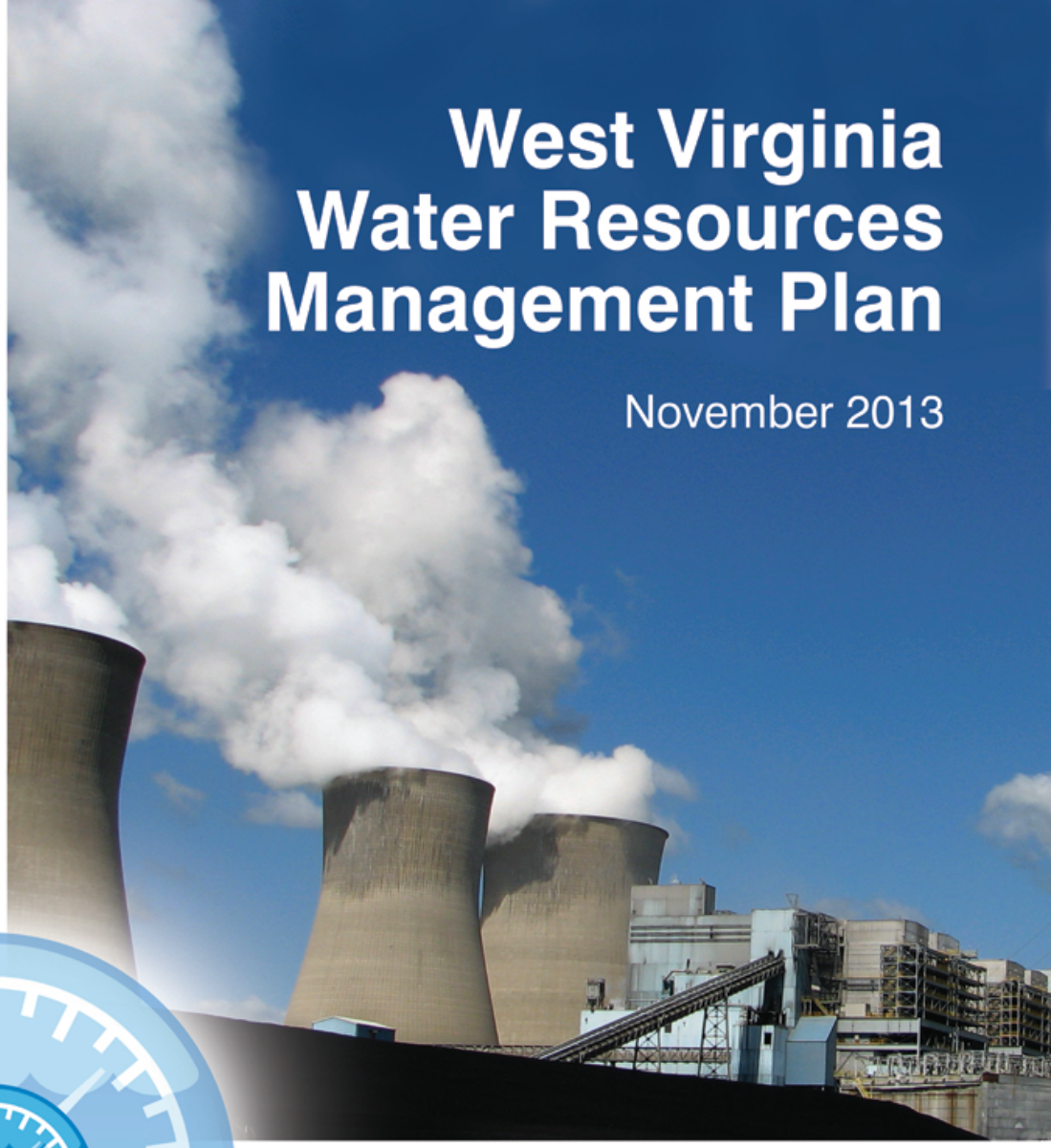


West Virginia Water Resources Management Plan

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

Contents

CONTENTS ..... **I**

FIGURES ..... **V**

TABLES ..... **XI**

ACRONYMS AND ABBREVIATIONS ..... **XVI**

DEFINITIONS ..... **XIX**

EXECUTIVE SUMMARY ..... **XXII**

SUMMARY ..... **XXII**

ACKNOWLEDGEMENTS ..... **XXXII**

INTRODUCTION ..... **XXXIII**

CHAPTER - 1 WATER RESOURCES 2

1.1 Water Resources and Population Overview *2*

1.1.1 Rain Gages 6

1.2 Surface Water *10*

1.2.1 Inventory of Streams 14

1.2.2 Stream Gaging Network 15

1.2.3 Dams 21

1.3 Groundwater *26*

1.3.1 Aquifer Characteristics 28

1.3.2 West Virginia Mine Pool Atlas 32

1.3.3 Water-well Inventory 38

1.3.4 Groundwater Monitoring Network 39

1.3.5 Geophysical Well Log Archiving Project 42

1.3.6 Spring Inventory 45

1.3.7 Dye-Tracing Database 47

1.3.8 Groundwater Conclusions 48

1.4 Interconnections of groundwater and surface water *50*

CHAPTER - 2 WATER USE 54

2.1 Comparison of Demand Tracking Programs *54*

2.1.1 Water Demand 57

2.2 Large Quantity Users (LQUs) *60*

2.2.1 Survey Testing and Annual Notification of Registration 62
2.2.2 Data Analysis 63
2.2.3 Distribution of Withdrawals 67
2.2.4 Water withdrawal trends over time 79
2.2.5 Water Sources 84
2.2.6 Interbasin Transfers 89
2.2.7 Consumptive Use 93
2.2.8 Limitations and Improvements 96
2.3 Estimating Domestic Use: Self-Supplied vs. Public Water Supply 98
2.4 Estimating Agricultural Use 101
2.5 Marcellus Shale water use 103
2.5.1 Environmental Impacts 104
2.5.2 Water Use 106
2.5.3 Out-of-state transfers 111
2.5.4 Waste Disposal 112
2.5.5 Horizontal Well Control Act 113
CHAPTER - 3 WATER BUDGET 116
3.1 Introduction 116
3.2 West Virginia's Water Budget 116
3.3 Calculation 121
3.4 Water Budget Results 123
3.5 Greenbrier Watershed Water Budget Model 128
3.5.1 Introduction 128
3.5.2 Watershed Characteristics 128
3.5.3 Historical Runoff 130
3.5.4 Large Quantity Users 131
3.5.5 Baseflow and 7Q10 132
3.5.6 Historical Precipitation and Evapotranspiration 133
3.5.7 Evapotranspiration Model 135
3.5.8 Predicted Runoff 138
3.5.9 Water Availability 140
3.5.10 Primary Data Sources Utilized 142
3.5.11 Comparison of Marshall University and DEP Water Budgets 142
CHAPTER - 4 FUTURE WATER OUTLOOK 145
4.1 Future consumptive demand 145
4.2 Review of West Virginia Water Use Survey 2006 Final Report of Consumptive Use 147
4.3 Choosing a Consumptive Use Estimation Method 149
4.4 LQU Withdrawals 150

4.5 Consumptive Use Scenarios *153*
4.6 Future Withdrawal Projections *156*
4.6.1 Withdrawal Projection Methods 157
4.6.2 Withdrawal Projection Results 166
4.7 Consumptive Use Projections *168*
4.8 Marcellus *170*
4.9 Non-consumptive water needs *171*
4.9.1 Wildlife and Associated Habitats 171
4.9.2 Public Lands 176
4.9.3 Wild and Scenic Rivers 179
CHAPTER - 5 OTHER CONDITIONS AFFECTING WATER AVAILABILITY 181
5.1 Natural Conditions Affecting Water Availability *181*
5.1.1 Flooding 181
5.1.2 Drought 187
5.1.3 Drought Response 190
5.1.4 Effect of Weather Conditions on Consumptive Use 193
5.2 Impact of Anthropogenic Activities on Low Flow in West Virginia *194*
5.2.1 Changes in Land Use 194
5.2.2 Dams 201
5.2.3 Surface Mining 204
5.2.4 Withdrawals and Discharges 206
5.3 Aging Infrastructure and Access to Public Water Supply *207*
5.3.1 Source Water Availability 207
5.3.2 Access to Public Utility 211
5.3.3 Stormwater Management 215
5.4 Water Conflicts *219*
5.5 Conservation Practices *220*
5.5.1 Agriculture and Aquaculture 221
5.5.2 Chemical, Industrial, Petroleum, and Timber 224
5.5.3 Mining 226
5.5.4 Public Water Supply 227
5.5.5 Recreation 229
5.5.6 Hydroelectric Power Generation 230
5.5.7 Thermoelectric Power Generation 230
5.5.8 Hydraulic Fracturing 231
5.5.9 Summary 232
CHAPTER - 6 REGIONAL WATERSHED MANAGEMENT AND CRITICAL PLANNING AREAS 235
6.1 Regional Watershed Management *235*

6.2 Critical Planning Areas *235*
6.2.1 Introduction 235
6.2.2 CPA Designation Process 236
CHAPTER - 7 SUMMARY, FUTURE PURSUITS AND RECOMMENDATIONS 239
7.1 Summary *239*
7.2 Future Pursuits of the Water Use Section *240*
7.3 Agency Recommendations *242*
BIBLIOGRAPHY 245
APPENDICES 258

Figures

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

Figure A-2 Rain Shadow effect xxiv

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

Figure A-4 HUC-8 Watersheds and Regional Grouping xxvii

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

Figure B-2 HUC-8 watersheds xxxviii

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 4

Figure 1-2 Average annual precipitation for West Virginia - 1981 to 2010 7

Figure 1-3 Locations of IFLOW and DCP precipitation gages in West Virginia 9

Figure 1-4 HUC-8 watersheds classified into five regions 12

Figure 1-5 The connectivity of the HUC-8 watersheds in West Virginia 13

Figure 1-6 Locations of NID Dams within the state 24

Figure 1-7 Mapped locations of Large Quantity Users who withdraw groundwater 27

Figure 1-8 Rain shadow 29

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) 31

Figure 1-10 Footprints of all documented underground mines in West Virginia and coal seam delineated areas of potential mine pools 32

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 36

Figure 1-12 Climatological zones and monitoring wells for the statewide water-level monitoring network in West Virginia (source NOAA-NWS and USGS) 40

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) 41

Figure 1-14 Documented springs of West Virginia and their flow in gallons per minute..... 46

Figure 1-15 Documented karst springs of West Virginia and their flow in gallons per minute..... 47

Figure 1-16 The DEP dye tracings locations in the karst regions of West Virginia 48

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 57

Figure 2-2 USGS estimates of total water withdrawals by state for five-year Intervals in Mgal/day. 58

Figure 2-3 USGS statewide population estimates for 1995, 2000, and 2005 59

Figure 2-4 USGS estimate of West Virginia's water withdrawals (Mgal/day) by category of use and year 60

Figure 2-5 Large Quantity Users registered with DEP after 2011 reporting year. 62

Figure 2-6 West Virginia has 32 HUC-8 watersheds and are shown divided into five regions. 65

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). 67

Figure 2-8 Distribution of Large Quantity Users as of 2011, identified by SIC code. 68

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. 69

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..... 69

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. 70

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. 71

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. 72

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. 73

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. 73

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. 74

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. 76

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. 76

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. 78

Figure 2-20 Statewide water withdraw trends over time (excluding hydroelectric). 79

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. 80

Figure 2-22 Statewide LQU water withdrawal trends for the Agriculture/aquaculture and Mining SIC categories, measured in millions of gallons per year. 81

Figure 2-23 Statewide LQU water withdrawal trends for the Public Water Supply and Industrial SIC categories, measured in billions of gallons per year. 82

Figure 2-24 Statewide LQU water withdrawal trends for the Thermoelectric and Chemical SIC categories, measured in billions of gallons per year. 83

Figure 2-25 Statewide trends in pass by flows occurring in the Hydroelectric SIC category, measured in billions of gallons per year. 83

Figure 2-26 Distribution of Large Quantity User groundwater and surface water withdrawals. 85

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. 87

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. 88

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. 88

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. 89

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. 92

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. 94

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. 95

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. 101

Figure 2-35 USGS Estimates of 2005 agriculture withdrawals for livestock and poultry. 102

Figure 2-36 Extent, depth and thickness of Marcellus Shale in West Virginia 103

Figure 2-37 Generalized horizontal drilling 104

Figure 2-38 Reported horizontal drilling source water by type per year in gallons 109

Figure 2-39 Frac water disposal data. 113

Figure 3-1 Interconnectivity of groundwater flow 120

Figure 3-2 Greenbrier Watershed 129

Figure 3-3 Comparison of Model Predicted Runoff and Actual Runoff during the study period (January 1986 – April 2013) 139

Figure 3-4 Withdrawal flow rate vs. percent of days where the 7Q10+10% flow rate would not be preserved in the stream 142

Figure 4-1 West Virginia has 32 HUC-8 watersheds and are shown divided into five regions. 146

Figure 4-2 Annual withdrawals from the LQU database for the (amended) Thermoelectric* group in billions of gallons. *Shown separately due to scale 151

Figure 4-3 Annual withdrawals from the LQU database for (amended) groups in billions of gallons 152

Figure 4-4 Average annual withdrawals occurring due to the activity of the recombined SIC groups, measured in gallons. 153

Figure 4-5 Annual high and low consumptive use scenario calculations (based on Shaffer and Runkle consumptive use coefficients) in billions of gallons. 155

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. 156

Figure 4-7 Withdrawal projection procedure 157

Figure 4-8 Procedure for apportioning county employment data to watersheds 160

Figure 4-9 Count of rare, threatened, and endangered terrestrial individuals by HUC12. Data source: DNR 174

Figure 4-10 Count of rare, threatened, and endangered aquatic individuals by HUC12. Data source: DNR 175

Figure 4-11 Location of public lands in West Virginia by type 177

Figure 5-1 WVDOH Drainage Manual 183

Figure 5-2 Percent change in Planted/Cultivated Crops (NLCD land cover database 1992 – 2006) by HUC-8 watershed. 198

Figure 5-3 Percent Change in Forest NLCD land cover database 1992 – 2006 by HUC-8 watershed..... 199

Figure 5-4 Percent Change in Development NLCD land cover database 1992 – 2006 by HUC-8 watershed. 200

Figure 5-5 Percent change in Impervious NLCD land cover database 2001 – 2006 by HUC-8 watershed. 201

Figure 5-6 Location of NID dams within the state. 203

Figure 5-7 IJDC identified areas of public water supply serviced areas. 212

Figure 5-8 IJDC identified areas of public sewage serviced areas. 213

Tables

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

Table 1-1 HUC-8 watershed average precipitation 8

Table 1-2 Total HUC-8 stream miles in West Virginia 14

Table 1-3 Numbers of U.S. Geological Survey continuous-record stations operated in West Virginia as of March 20, 2013 16

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 19

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) 19

Table 1-6 Mean annual recharge rates for the river basins of West Virginia. (Reproduced from USGS Water Resources Investigations Report 2001-4036) 29

Table 1-7 Transmissivity measurements of certain aquifers within the state as identified in USGS SIR 2001-4036 31

Table 1-8 Brief overview of the information contained within the Mine Pool Atlas 33

Table 1-9 Potentially totally flooded mines are located within these 14 major coal beds 34

Table 1-10 Coal beds that have potentially partially flooded mines 34

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) 37

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) 43

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 54

Table 2-2 Current definitions, exemptions, and requirements for border states regarding Large Quantity Users (LQU) in each state. 56

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. 63

Table 2-4 Thermoelectric (coal) plants in West Virginia 74

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. 86

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. 86

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. 90

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). 94

Table 2-9 Marcellus Shale withdrawals and consumptive use estimates by HUC. Data were provided by DEP outside of the LQU database. 96

Table 2-10 Average annual amount of water supplied by Large Quantity Users to each county and estimated annual self-supplied amounts in gallons. 100

Table 2-11 Number of reported fractured wells per year 107

Table 2-12 Statewide annual reported water withdrawals for horizontal wells (2009, 2010 and 2011) by source type in gallons 108

Table 2-13 Water use for horizontal drilling activities by watershed in gallons..... 110

Table 2-14 Transfer of water for hydraulic fracturing to neighboring states 111

Table 2-15 Transfer of water for hydraulic fracturing from neighboring states to West Virginia 112

Table 3-1 Winter and spring HUC-8 watershed precipitation totals per grid point 117

Table 3-2 Summer and fall HUC-8 watershed precipitation totals per grid point 118

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% 124

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% 126

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% 127

Table 3-6 Summary of Greenbrier Watershed characteristics 129

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..... 130

Table 3-8 Large Quantity User Water Utilization Summary 131

Table 3-9 Average Seasonal Baseflow for the Greenbrier Watershed 132

Table 3-10 Precipitation and Evapotranspiration/Other depths by month for the Greenbrier Watershed 134

Table 3-11 Unmeasured parameters incorporated into evapotranspiration model..... 136

Table 3-12 Ratio of predicted evapotranspiration (ET) to potential evapotranspiration (PET) 137

Table 3-13 Ratio of predicted evapotranspiration (ET) to potential evapotranspiration (PET) 140

Table 3-14 Comparison of water budget results 143

Table 4-1 Estimates of consumptive use coefficients used in DEP 2006 Chapter 7, a residential coefficient was not reported. 148

Table 4-2 Consumptive use factors for the Great Lakes Basin, climatically similar areas, and the world from Shaffer and Runkle 2007. 154

Table 4-3 Current average annual withdrawals and future high and low scenario estimates by watershed, in billions of gallons per year. 167

Table 4-4 Current average annual withdrawals and future high and low scenario estimates by water use category, in billions of gallons per year. 168

Table 4-5 High and low scenario consumptive use rates for each water use category. 168

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. 169

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..... 170

Table 4-8 High and low scenario Marcellus Shale withdrawals for 2020 in billions gallons per year 170

Table 4-9 Estimated water withdrawals and consumptive use projections for Marcellus Shale industry 171

Table 4-10 Total count of rare, threatened, and endangered individuals by HUC8 watershed. Data source: DNR 173

Table 4-11 Area of public lands by type for each HUC-8 (sq. mi.). 178

Table 4-12 Public lands by owner type for the state of West Virginia. 179

Table 5-1 Flood recurrence probability..... 182

Table 5-2 Changing land cover results as calculated by CEGAS from 1992 to 2006 covering the state of West Virginia 195

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. 197

Table 5-4 Total area (sqmi) of active surface mining and related activities by HUC-8 and percent of the total HUC-8 area. 204

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. 208

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?” 209

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?” 210

Table 5-8 IJDC statewide estimates of population served with public water supply and public sewage (due to data restraints, estimates may run high). 211

Table 5-9 IJDC county estimates of those served by public water supply and sewage. 214

Table 5-10 Status and location of current MS4 permits 219

Table 5-11. Number of water conservation plans by category and type. 221

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.

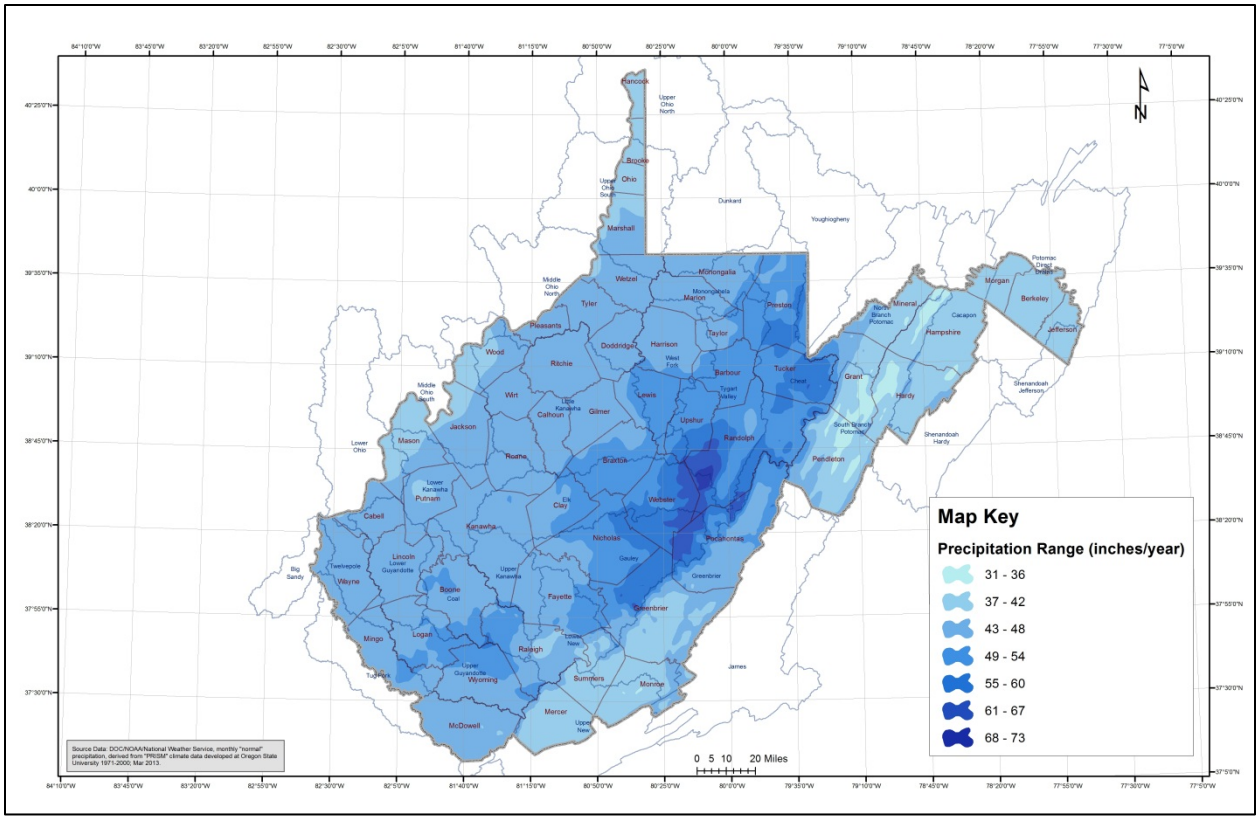


Figure A-1 Average annual precipitation across West Virginia, 1981-2010.

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.

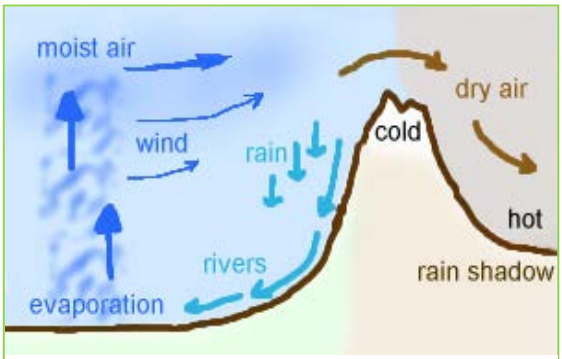


Figure A-2 Rain Shadow effect

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.

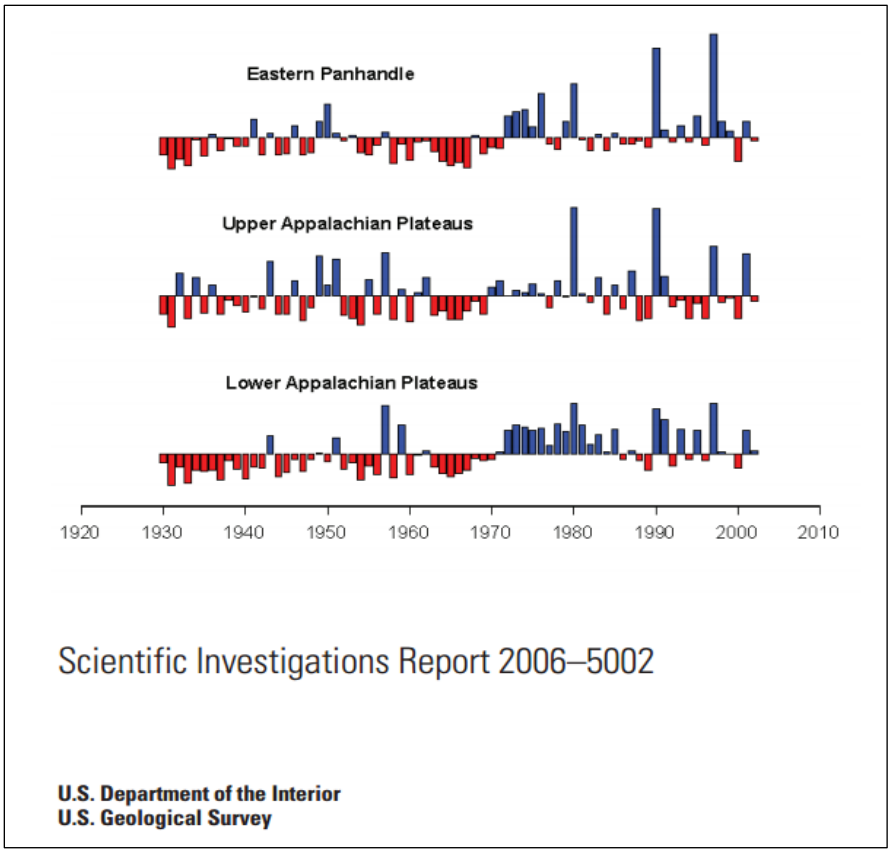


Figure A-3 Average standardized departures of the minimum flows from the record-period average for 1930-2002 for selected stations in West Virginia

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.

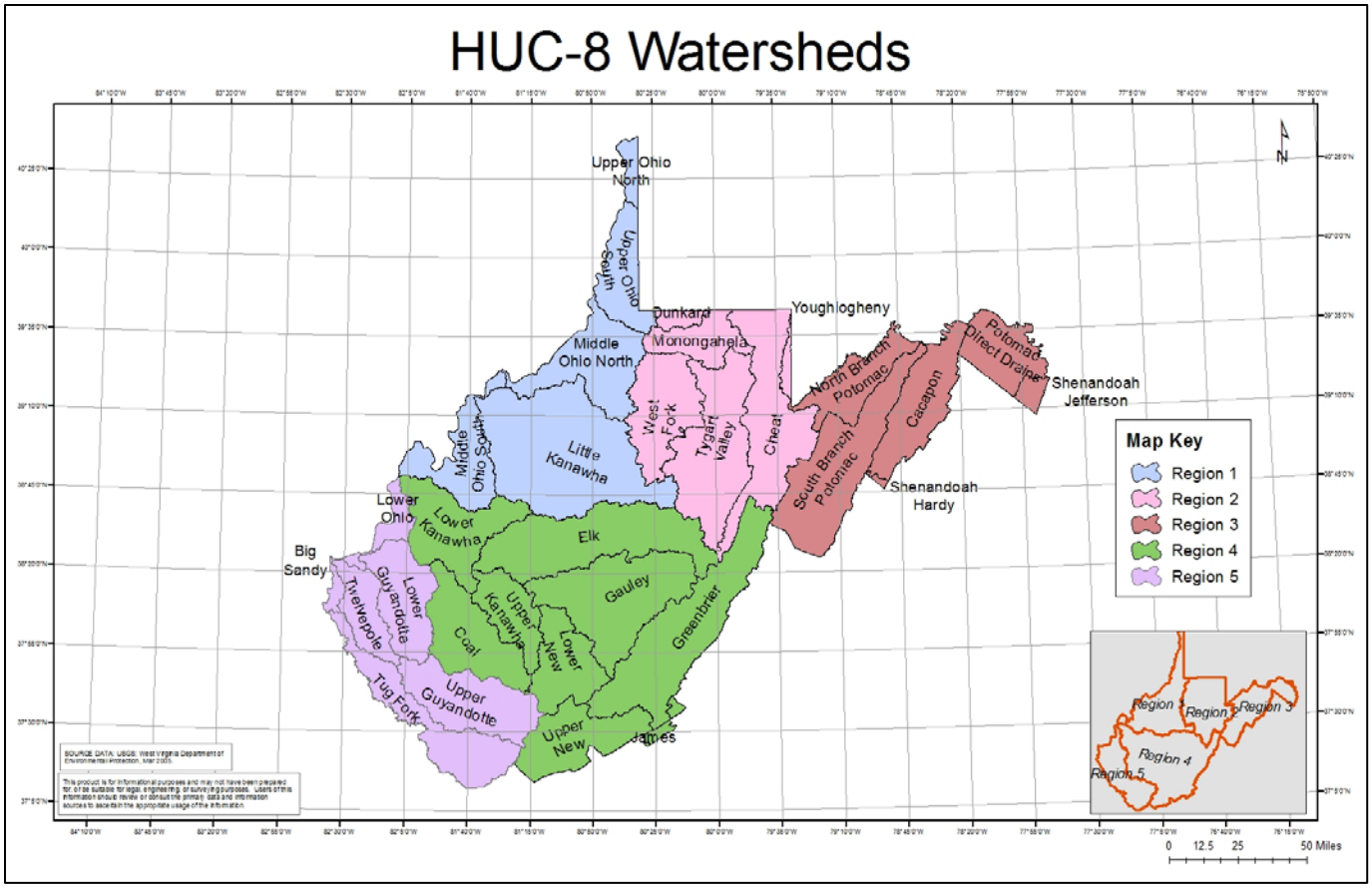


Figure A-4 HUC-8 Watersheds and Regional Grouping

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.

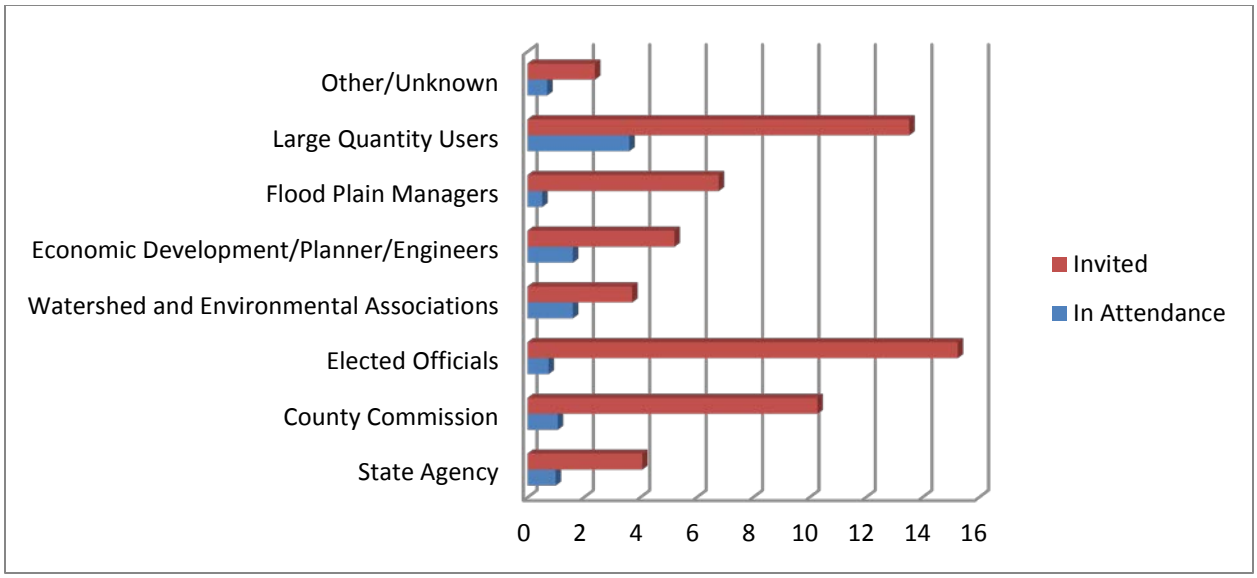


Figure B-1 Average invited vs. in attendance to each watershed meeting by group

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.

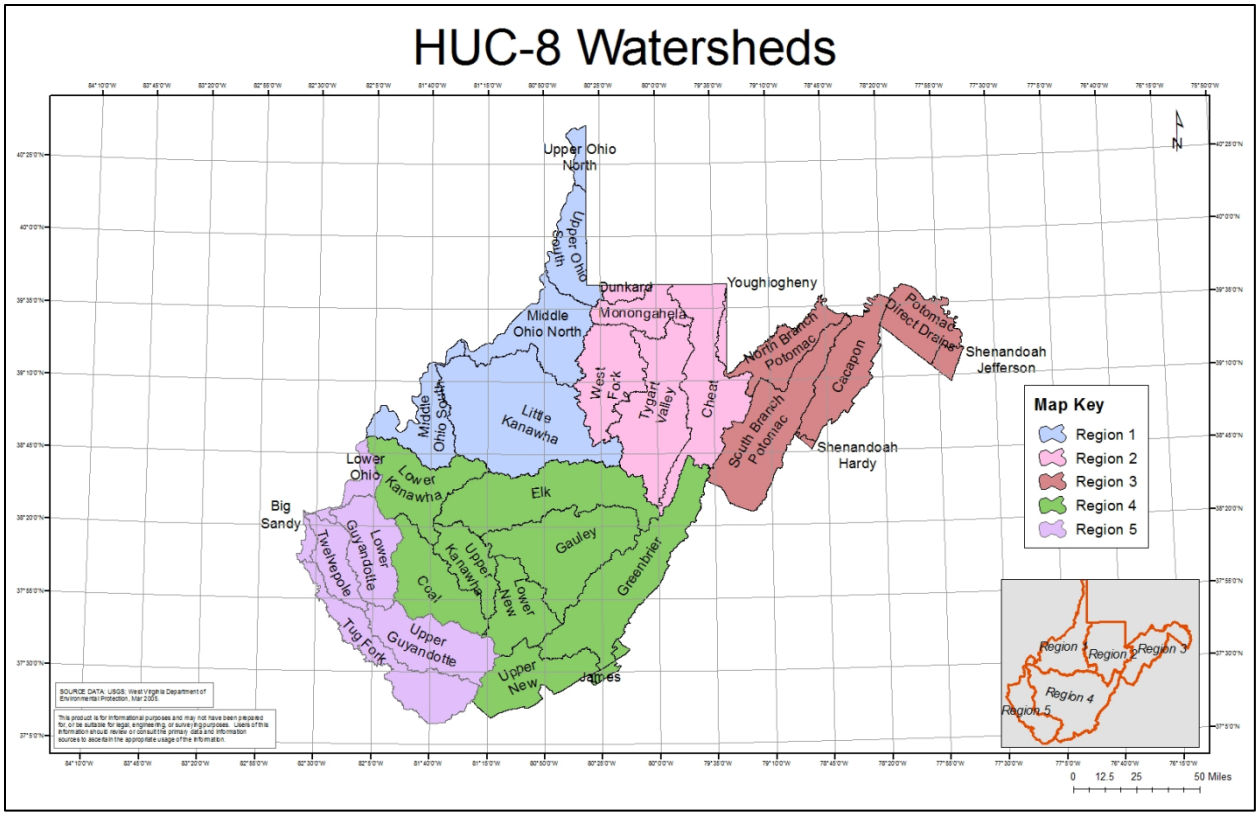


Figure B-2 HUC-8 watersheds

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.

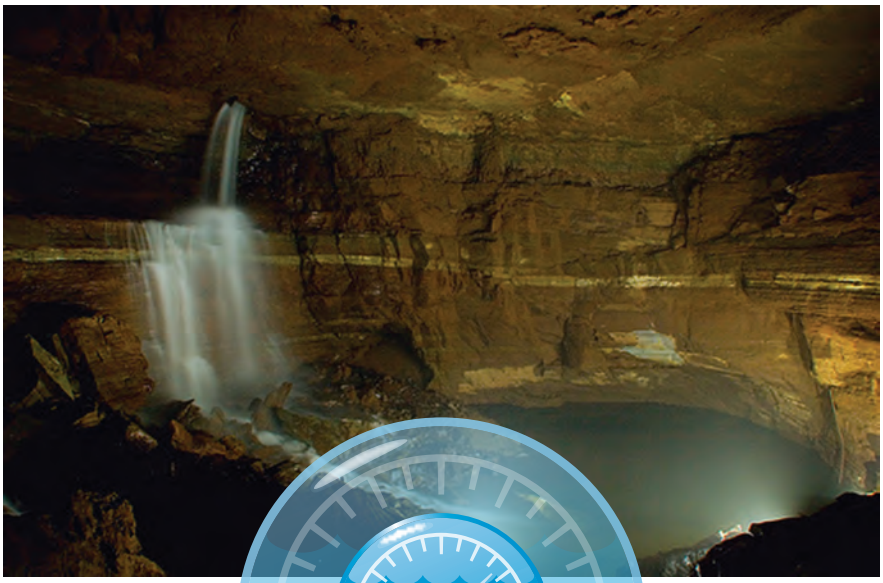
Chapter 6 describes the process necessary to declare an area a "Critical Planning Area," (CPA) which refers to an area without the resources necessary to accommodate projected needs. To that end, a process has been established to allow such areas to be nominated, evaluated, and ultimately designated 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.

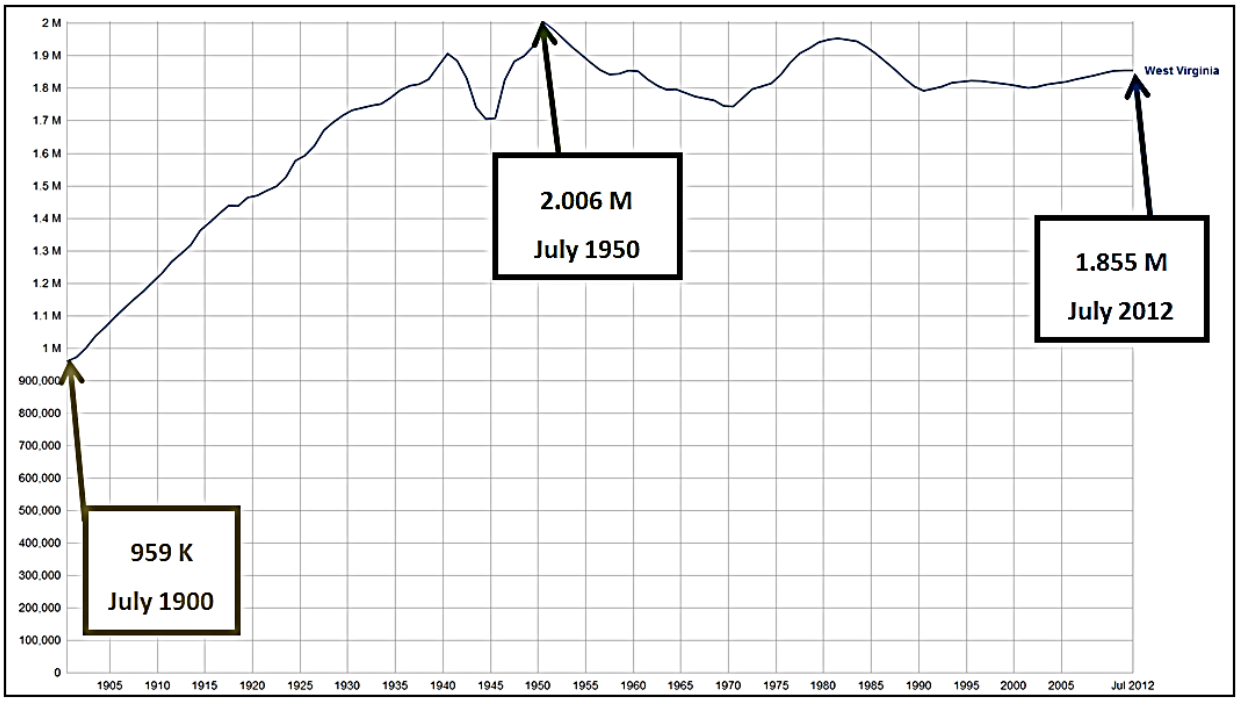


Figure 1-1 Population trend for the state of West Virginia from July 1900 to July 2012. Data Source: U.S. Census Bureau, 4/9/2013

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.

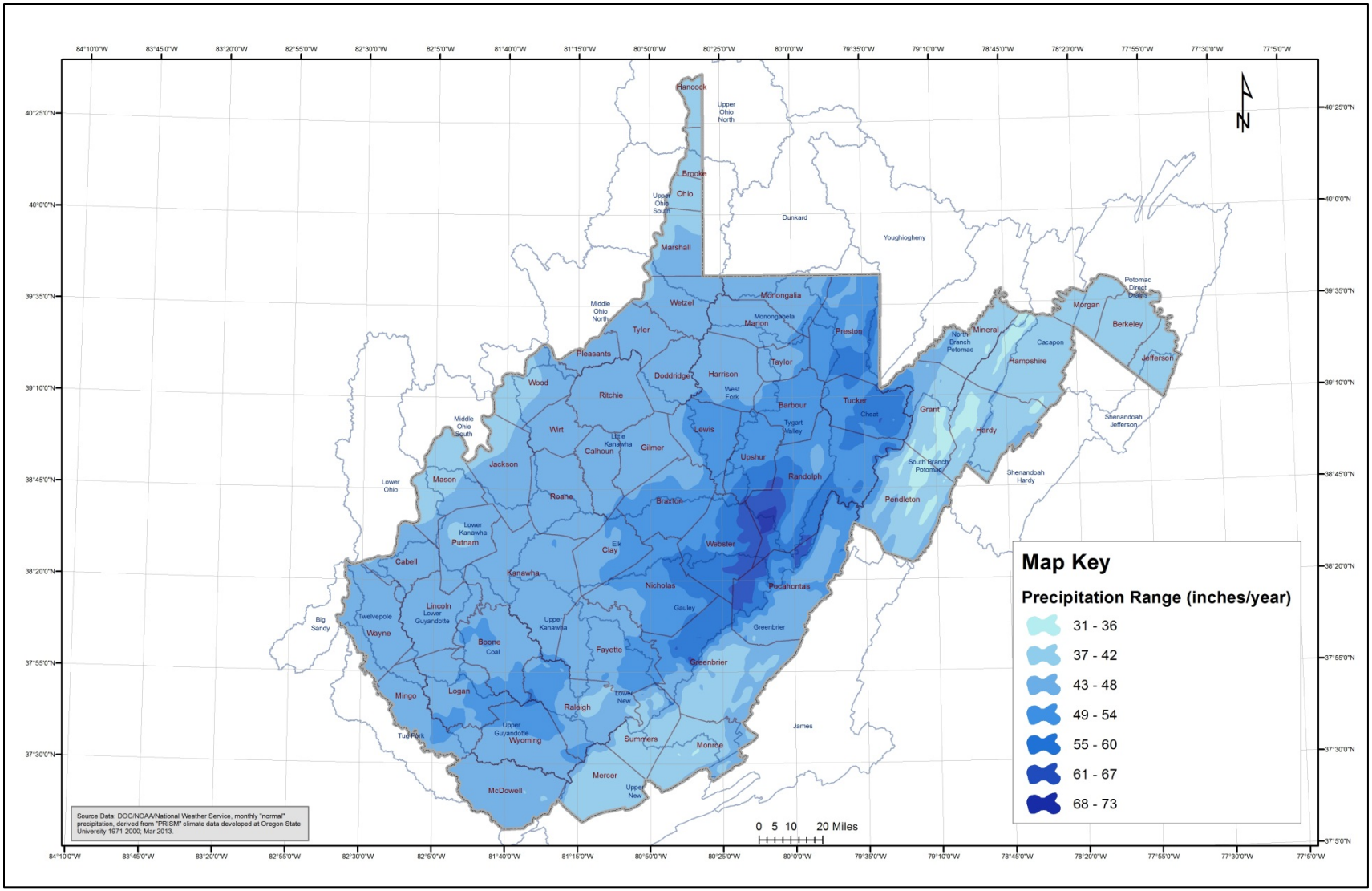


Figure 1-2 Average annual precipitation for West Virginia - 1981 to 2010

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**

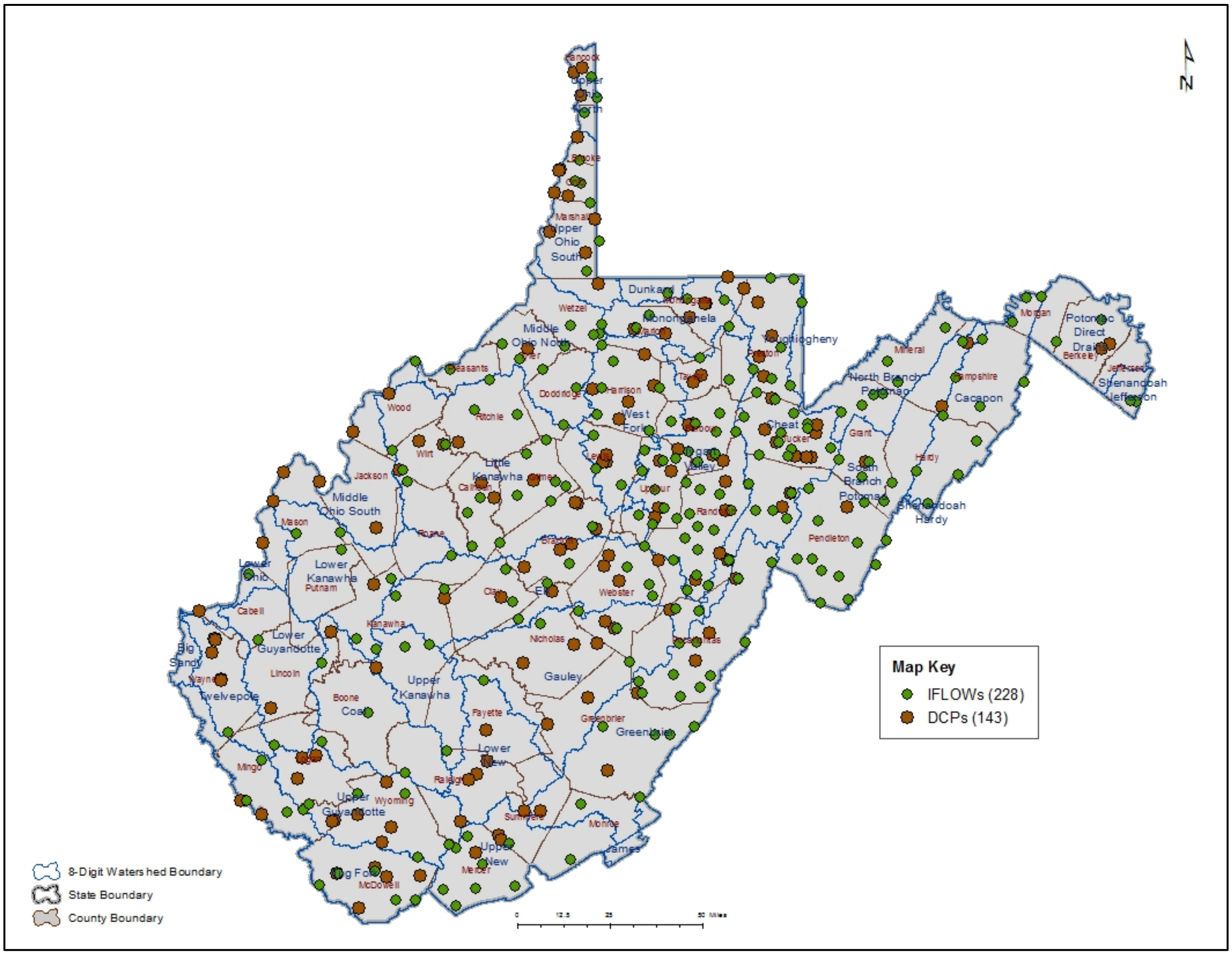


Figure 1-3 Locations of IFLOW and DCP precipitation gages in West Virginia

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.

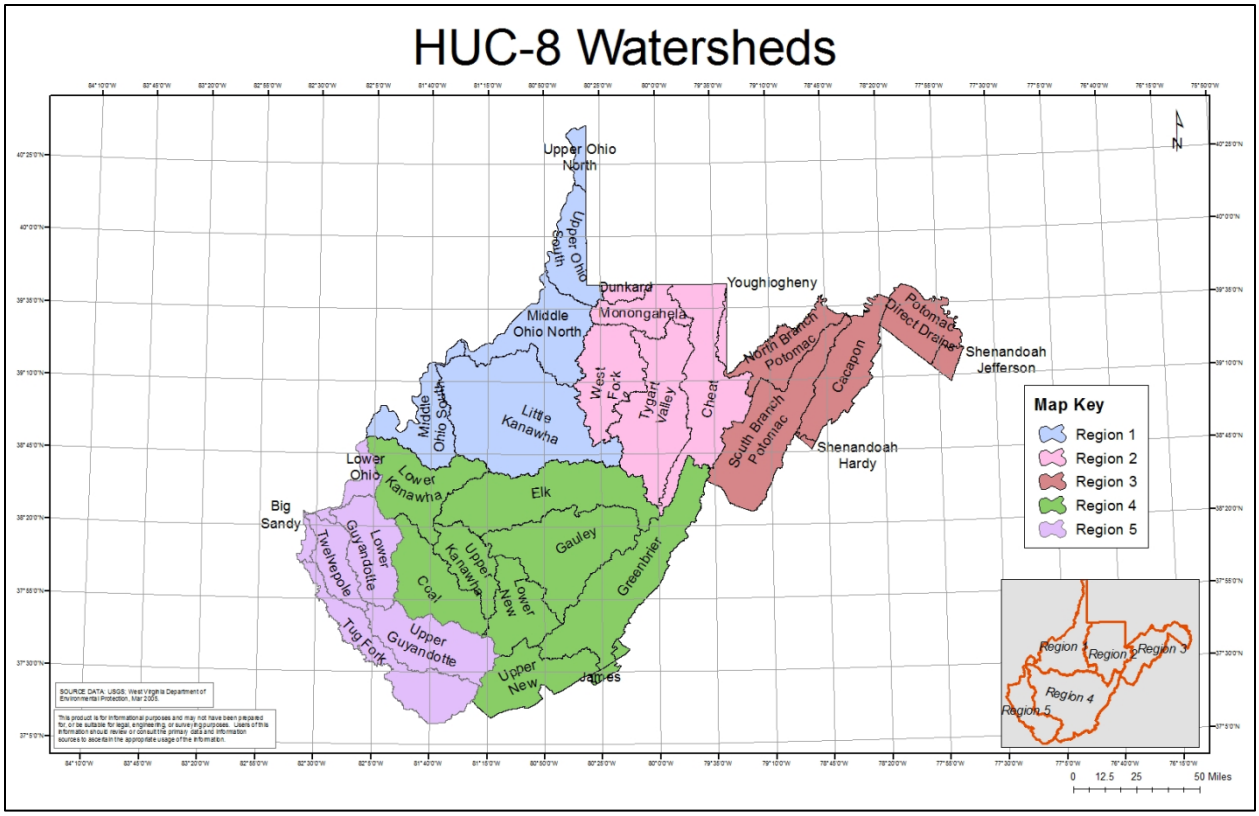


Figure 1-4 HUC-8 watersheds classified into five regions

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.

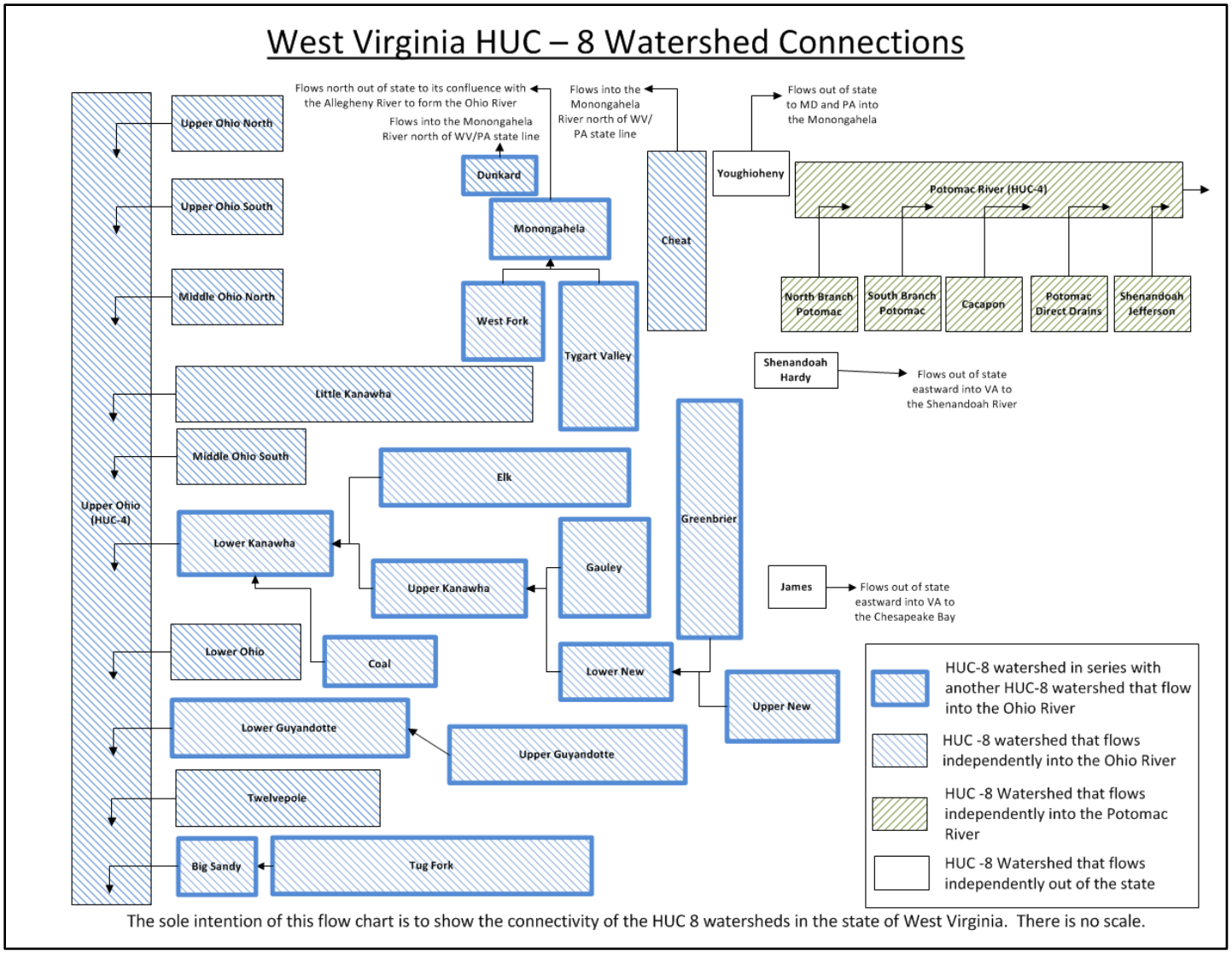


Figure 1-5 The connectivity of the HUC-8 watersheds in West Virginia

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)

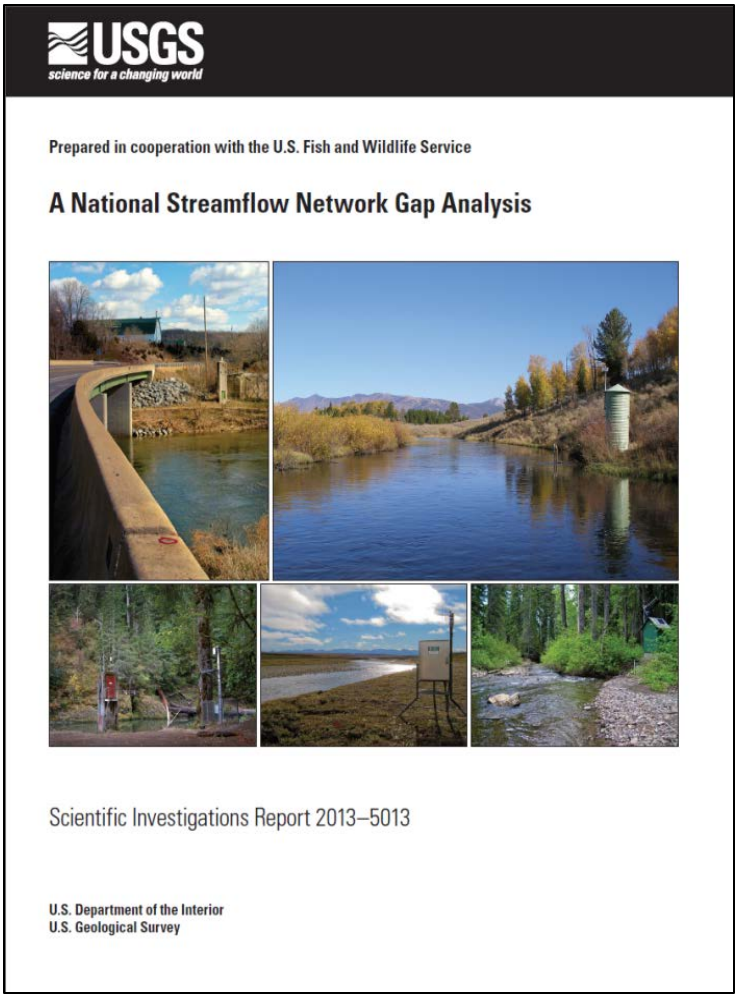
Station Type	2013 Cost
Operation and maintenance of a cableway	1,540.00
Annual peak flow at a crest-stage gage	1,900.00
Streamflow, from a stage-discharge rating	14,400.00
Streamflow, from an index-velocity-discharge rating	17,000.00
Rainfall at a stand-alone station	4,800.00
Rainfall, as an add-on to 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.


USGS
science for a changing world

Prepared in cooperation with the U.S. Fish and Wildlife Service

A National Streamflow Network Gap Analysis

Scientific Investigations Report 2013–5013

U.S. Department of the Interior
U.S. Geological Survey

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.

Selected Conversion Factors

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.

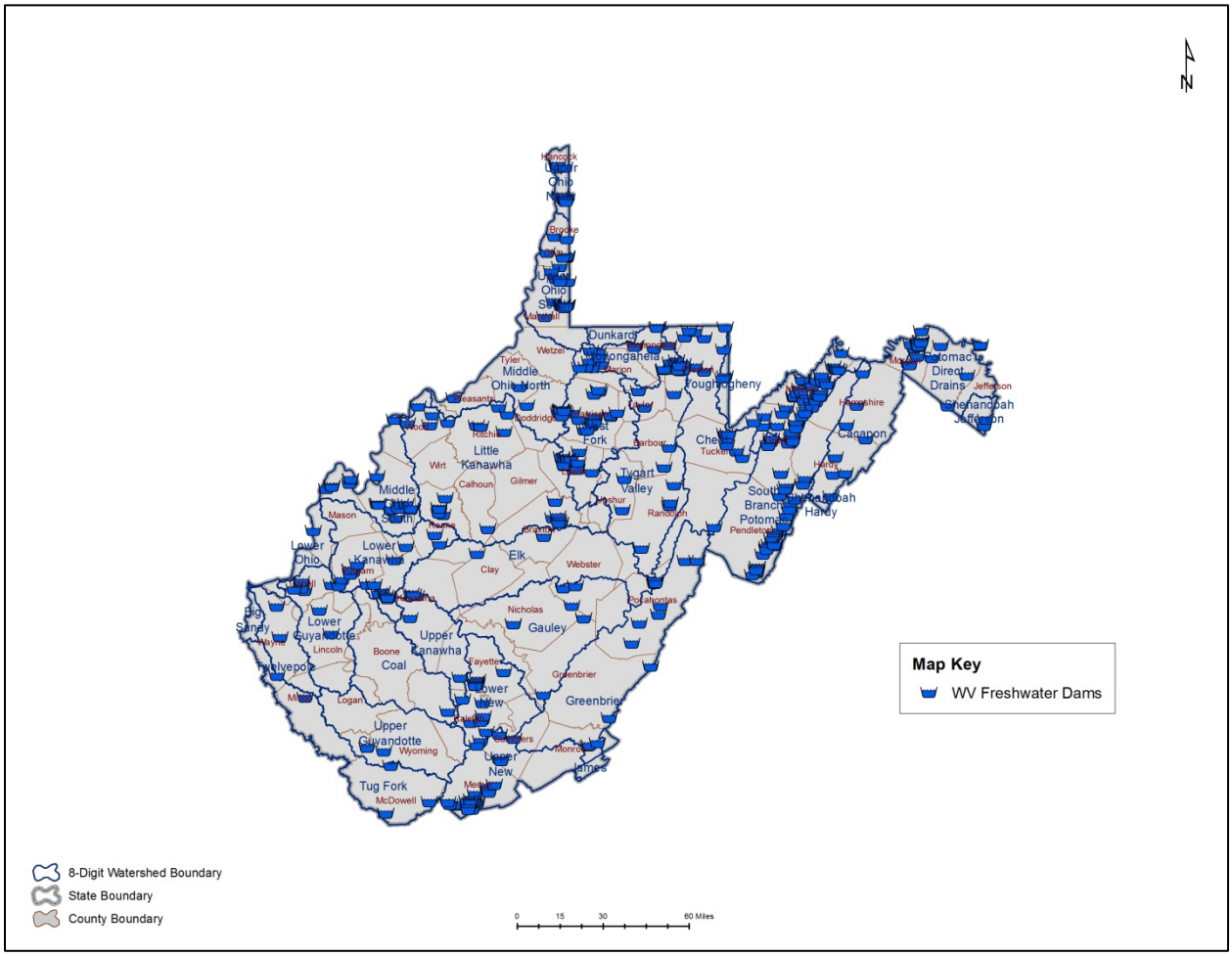


Figure 1-6 Locations of NID Dams within the state

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.

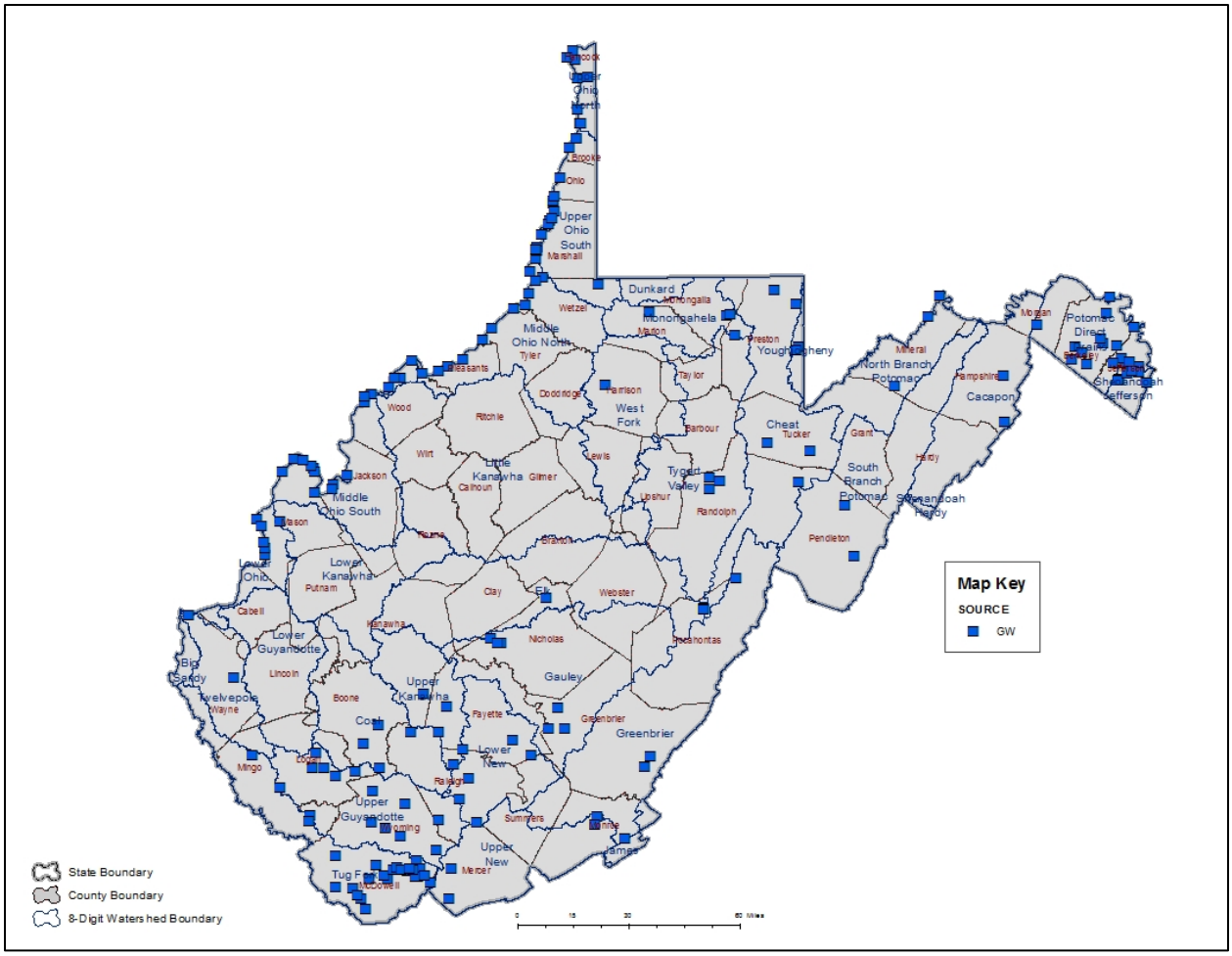


Figure 1-7 Mapped locations of Large Quantity Users who withdraw groundwater

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**)**

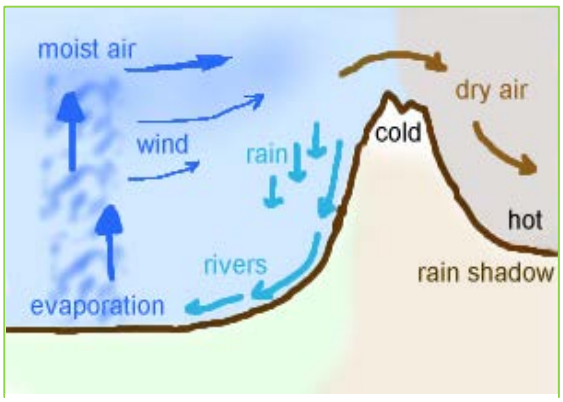


Figure 1-8 Rain shadow

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

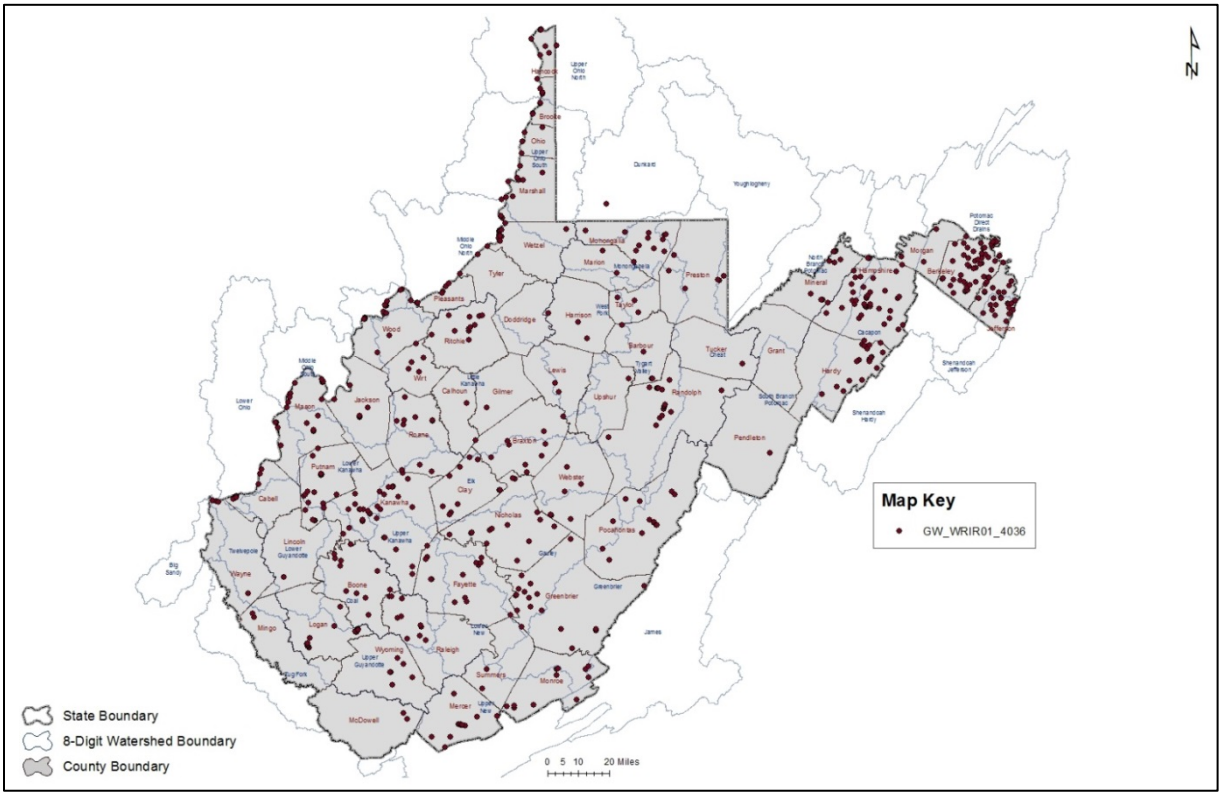


Figure 1-9 Sample locations in examining aquifer characteristics of West Virginia. (The DEP produced map using data provided in USGS, Water-Resources Investigations Report 2001-4036)

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.

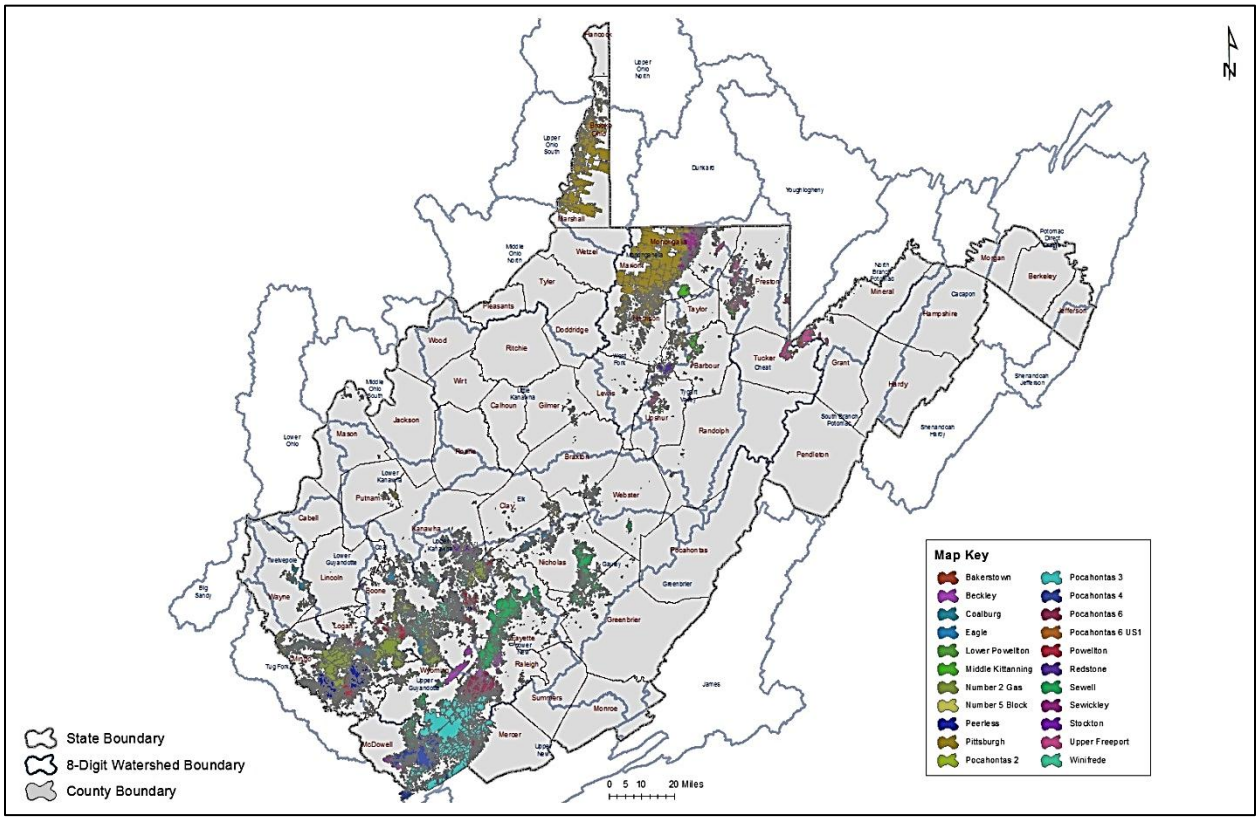


Figure 1-10 Footprints of all documented underground mines in West Virginia and coal seam delineated areas of potential mine pools

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** • **Stratigraphic columns showing the position of all coal beds within each formation** • **Tables showing the distribution of potential totally and partially flooded mines in each seam by mine footprint area and position with respect to drainage** • **Tables showing the distribution of potential partially flooded areas of above and near drainage underground mines by coal bed** • **Maps of coal beds in which potential partial and/or total flooding was present in mines that had areas of 500 acres or greater** • **Structural contours of the coal beds** • **Isopach maps (total bed thickness)** • **Seam overview** • **Extent of potential total flooding** • **Extent of potential partial flooding** • **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

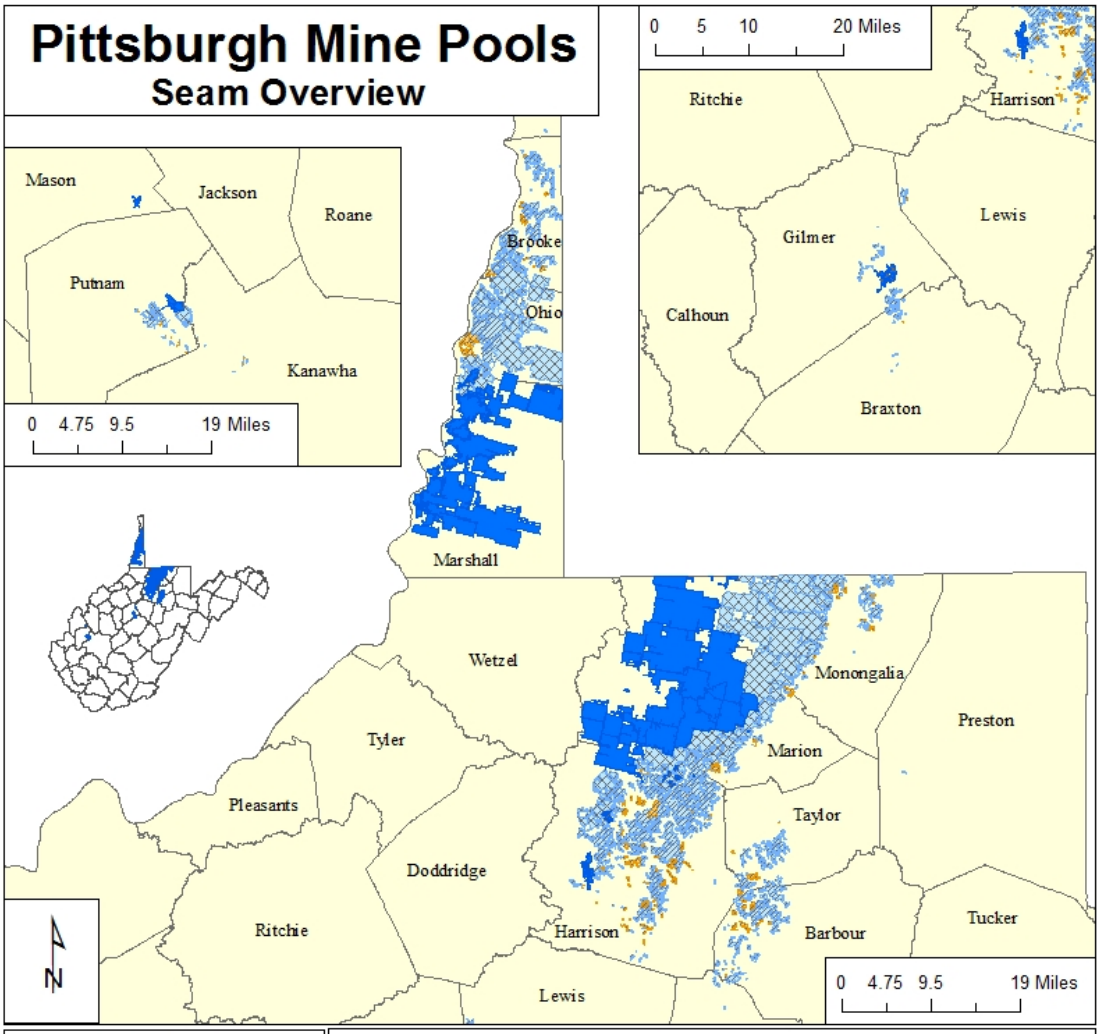
Coal beds that have potentially partially flooded mines:
• **Sewickley coal in Monongalia and Marion counties**
• **Bakerstown coal in Preston, Grant and Tucker counties**
• **Number 5 Block coal in Braxton, Nicholas, Clay, Kanawha, Boone, Lincoln, Mingo and Wayne counties**
• **Stockton coal in Braxton,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

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.

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

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.

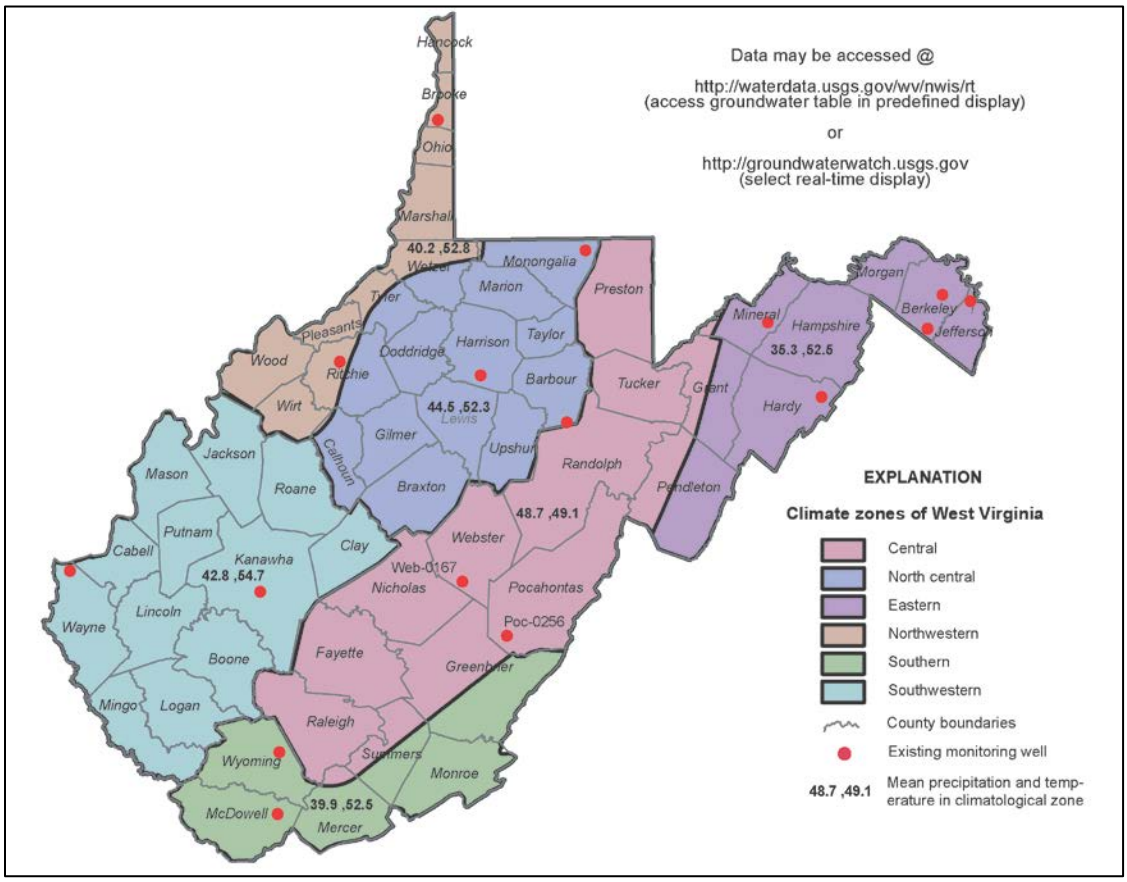
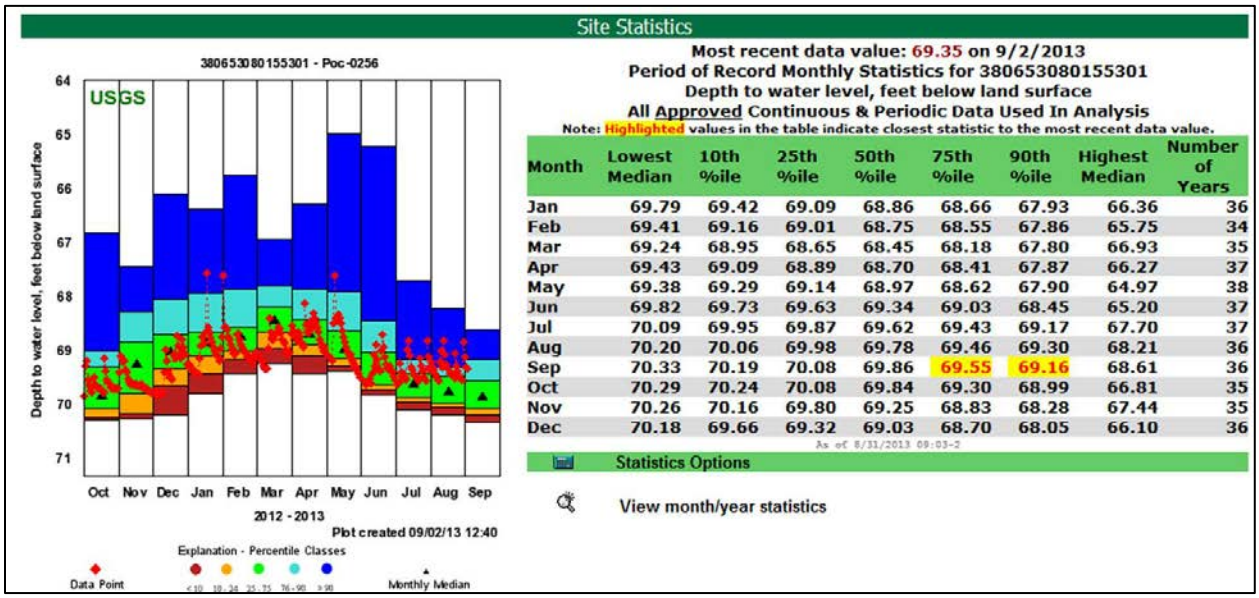


Figure 1-12 Climatological zones and monitoring wells for the statewide water-level monitoring network in West Virginia (source NOAA-NWS and USGS)

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).



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

As of 8/31/2013 09:03-2

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/

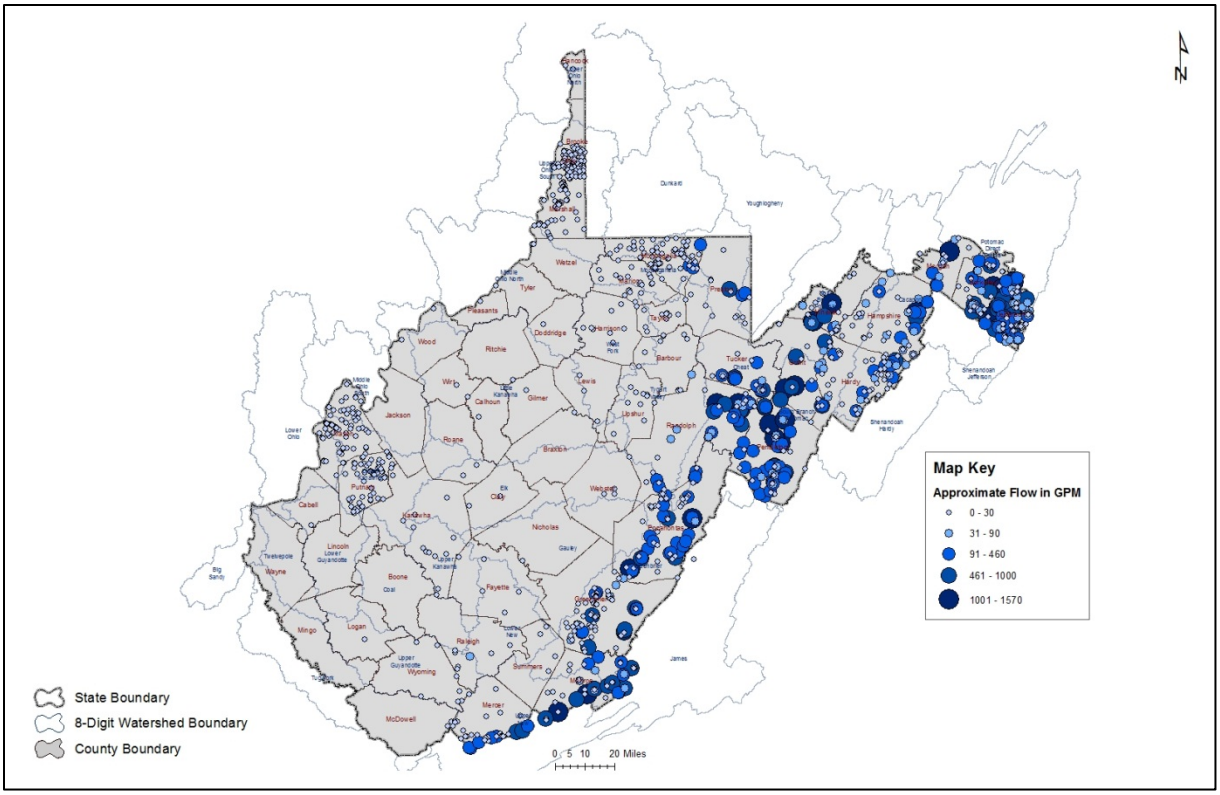


Figure 1-14 Documented springs of West Virginia and their flow in gallons per minute

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.

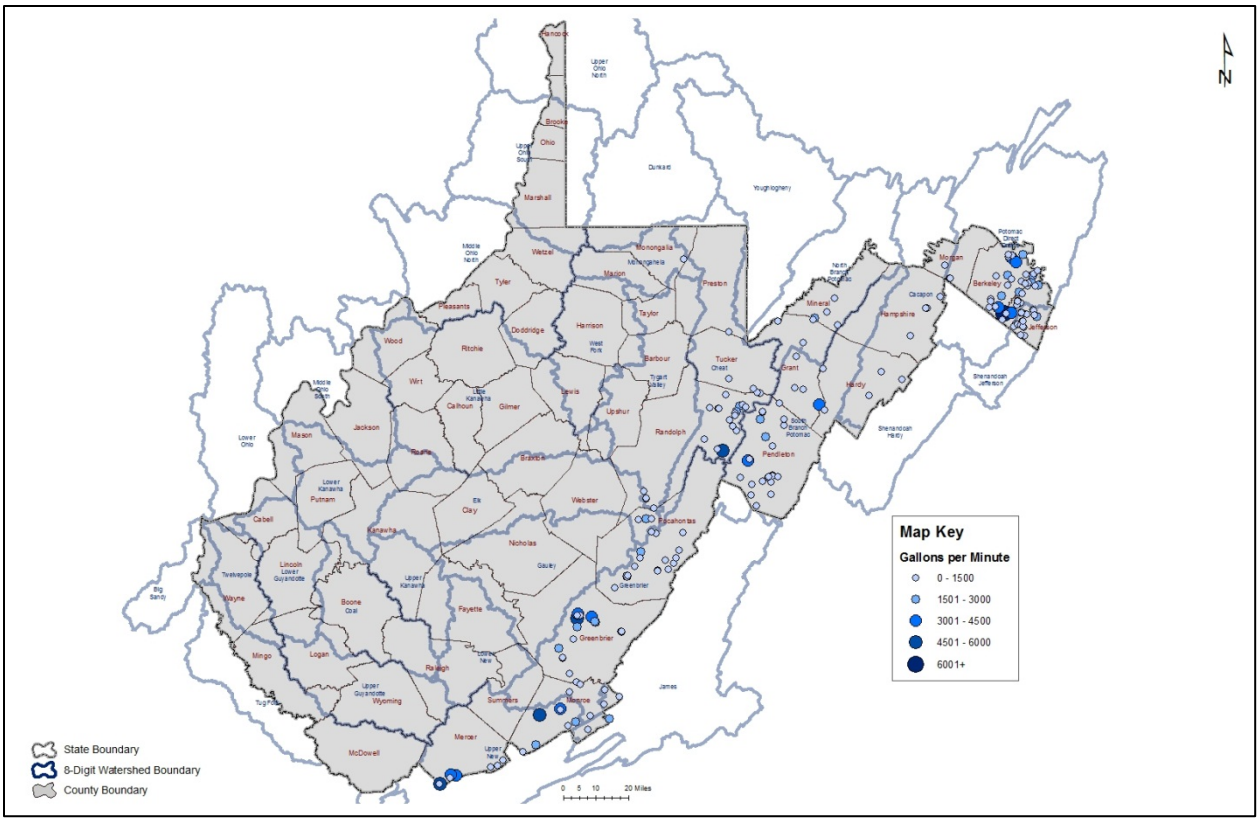


Figure 1-15 Documented karst springs of West Virginia and their flow in gallons per minute

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.

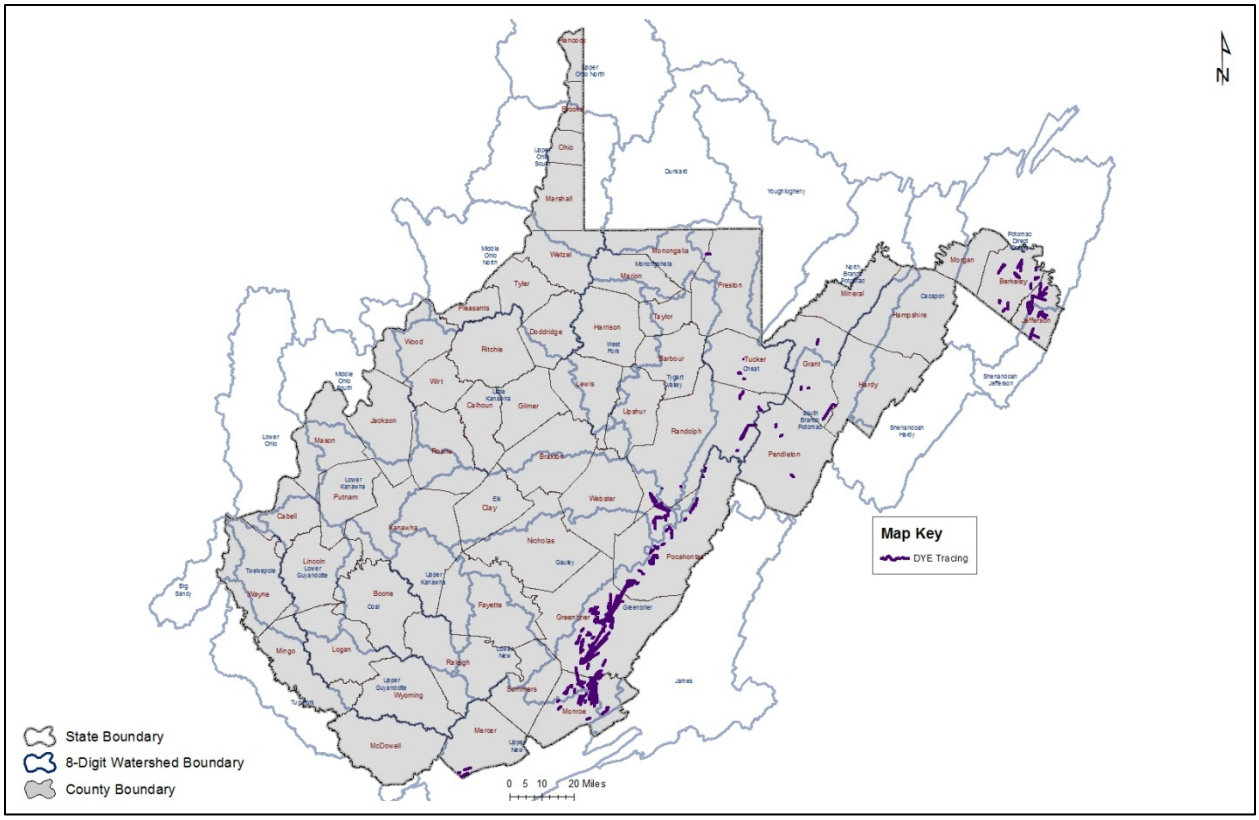


Figure 1-16 The DEP dye tracings locations in the karst regions of West Virginia

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.

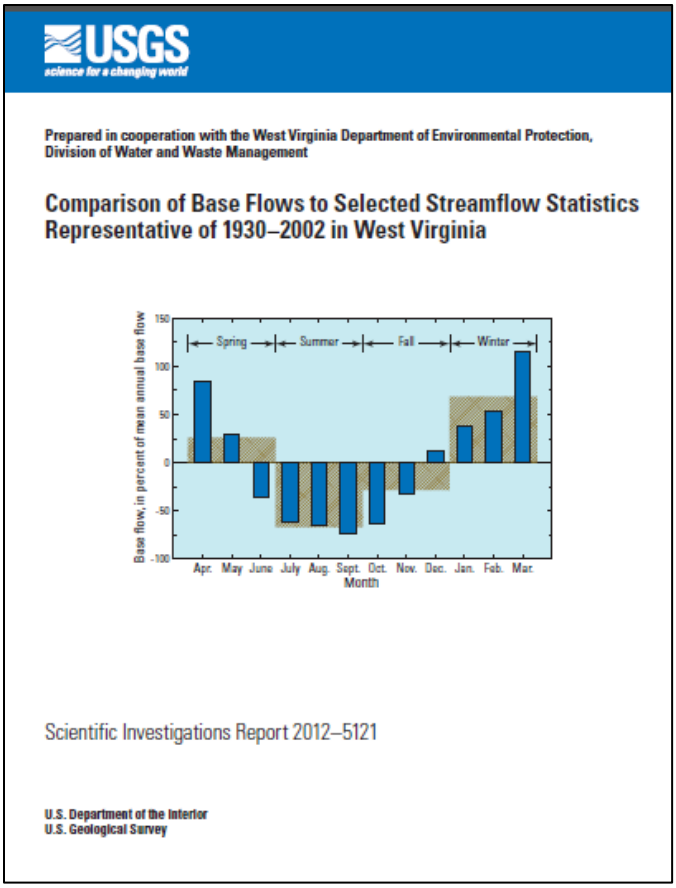
In order to identify and characterize aquifers in the state, the DEP will continue to collect and add all existing groundwater well data into a "Groundwater Database." A private water well reporting portal has been developed for ArcGIS and will soon be adapted for the DEP website. This portal will provide 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).


USGS
science for a changing world

Prepared in cooperation with the West Virginia Department of Environmental Protection, Division of Water and Waste Management

Comparison of Base Flows to Selected Streamflow Statistics Representative of 1930–2002 in West Virginia

Scientific Investigations Report 2012–5121

U.S. Department of the Interior
U.S. Geological Survey

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.

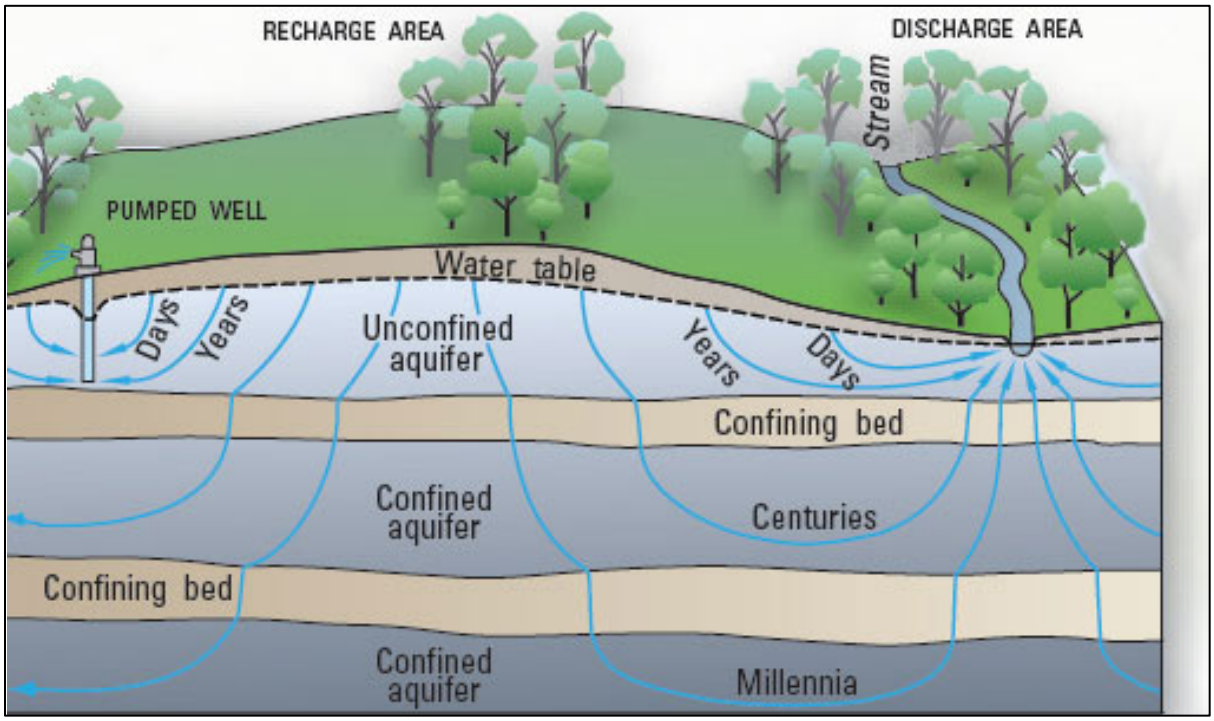
Annual and seasonal base flows representative of the period 1930–2002 at unregulated streamflow-gaging stations and ungaged locations in West Virginia can be estimated using previously published values of statistics and procedures."

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 Division of Water http://water.ky.gov	All withdrawal, transfer, and diversion >10,000gpd EXEMPT 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) http://www.mde.state.md.us	All withdrawal activities regardless of planned amounts EXEMPT 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) Division of Soil and Water Resources 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) 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 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. Major: >90,000,000gpm of if filling, flooding, or alteration of stream flow occurs. 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 http://www.srbc.net/	Consumptive users who use an avg. >20,000gpd in 30 days EXEMPT Public Supply and Agriculture (conditionally) Withdrawals from basin that avg. >100,000gpd in 30 days EXEMPT Hydroelectric (conditionally) Diversions out of the basin that avg. >20,000gpd in 30 days EXEMPT 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.

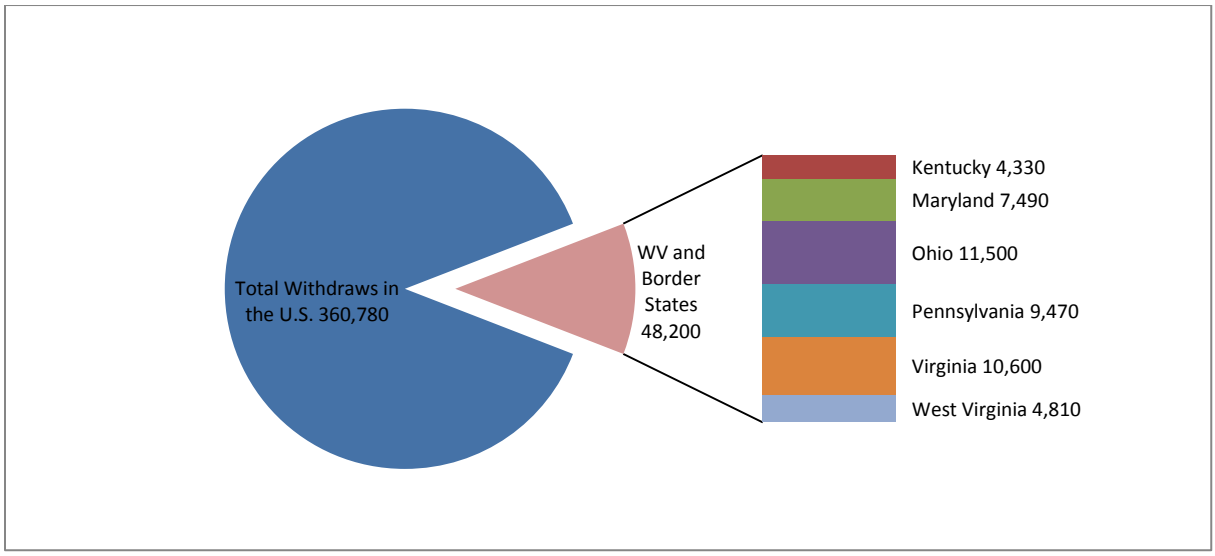


Figure 2-1 West Virginia and border states' contribution to the USGS estimates of total water withdrawals in the United States in 2005 in Mgal/day

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).

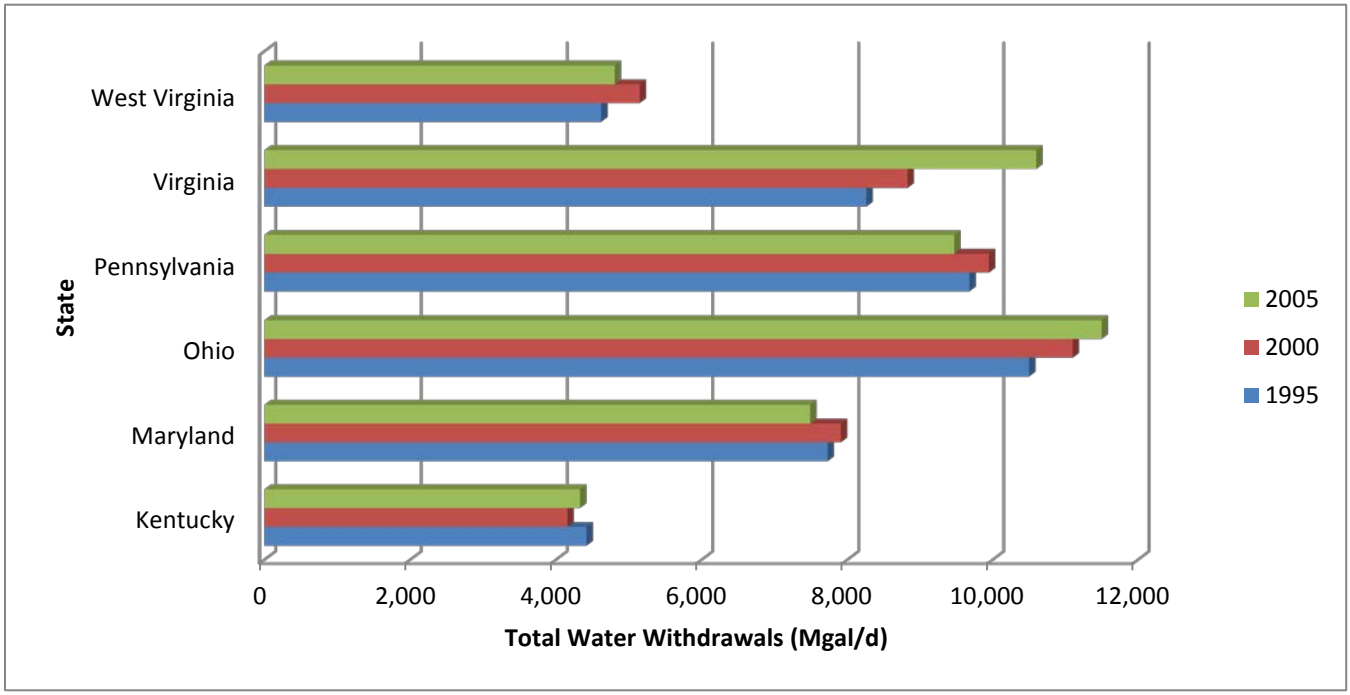
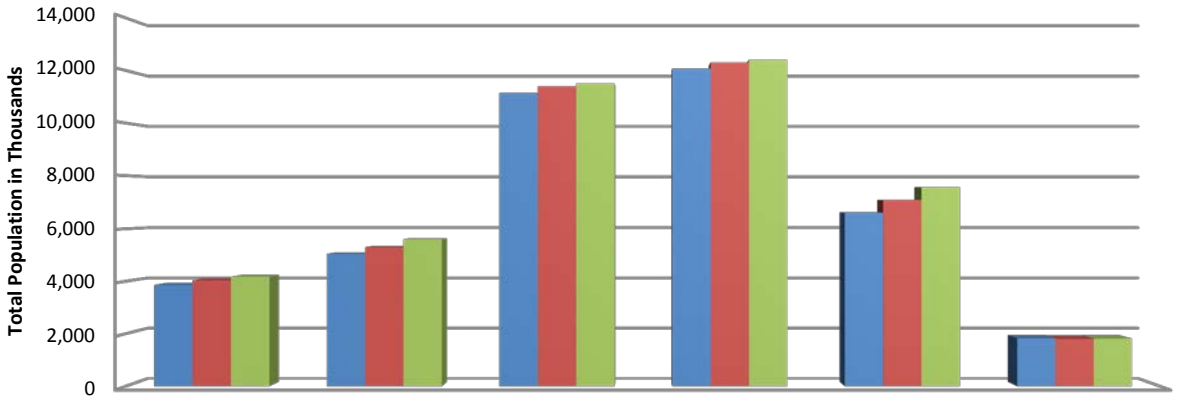


Figure 2-2 USGS estimates of total water withdrawals by state for five-year Intervals in Mgal/day.



	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).

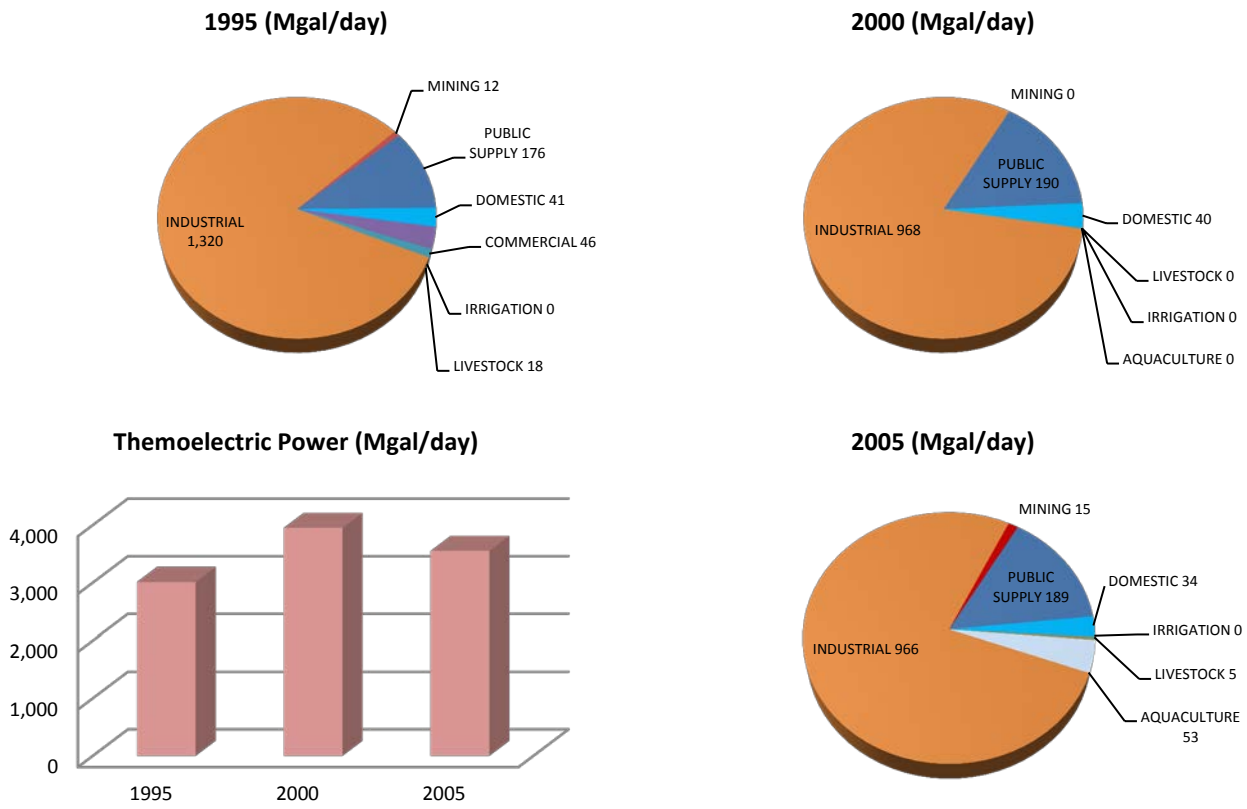


Figure 2-4 USGS estimate of West Virginia's water withdrawals (Mgal/day) by category of use and year

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.

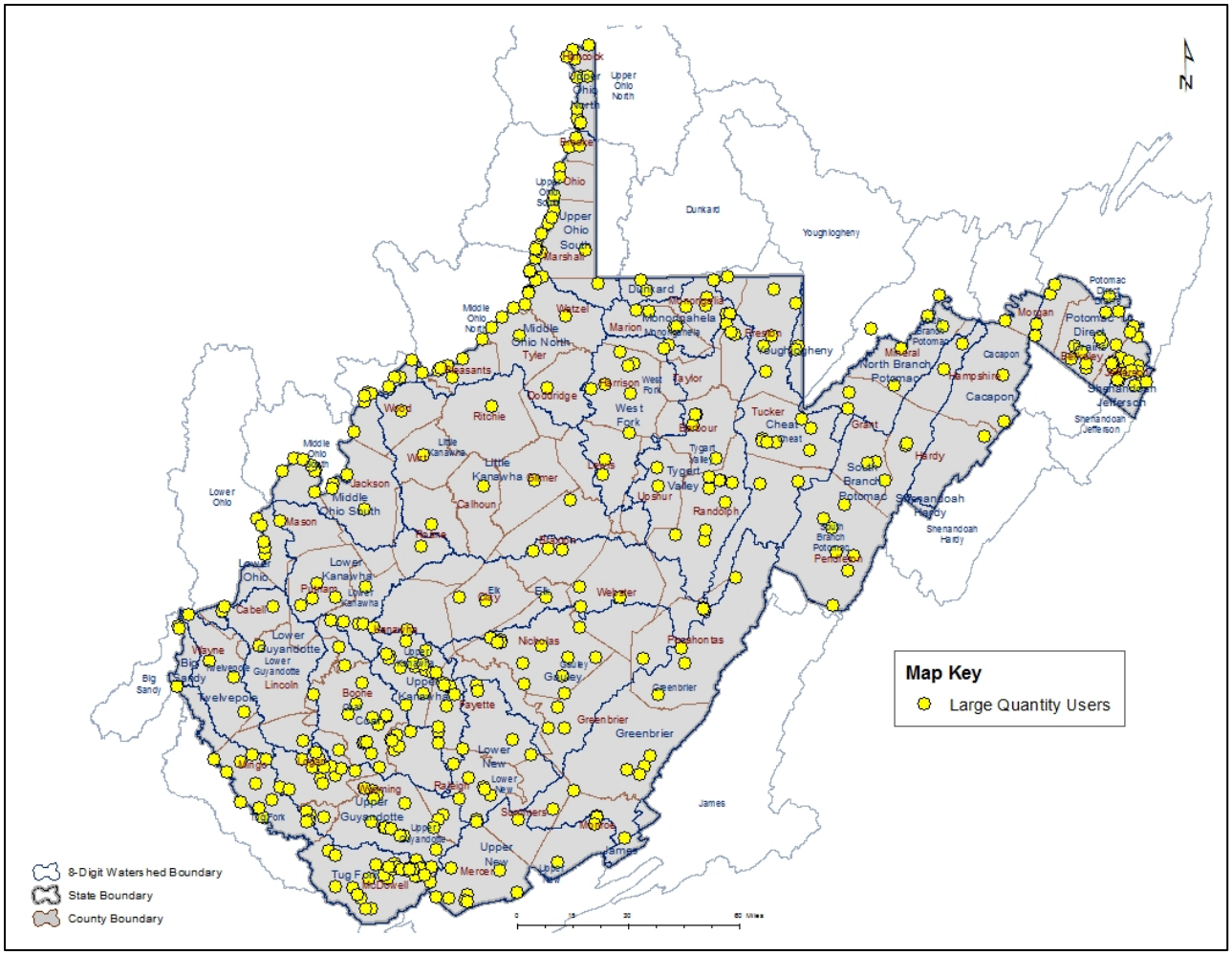


Figure 2-5 Large Quantity Users registered with DEP after 2011 reporting year.

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.

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.

> 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.

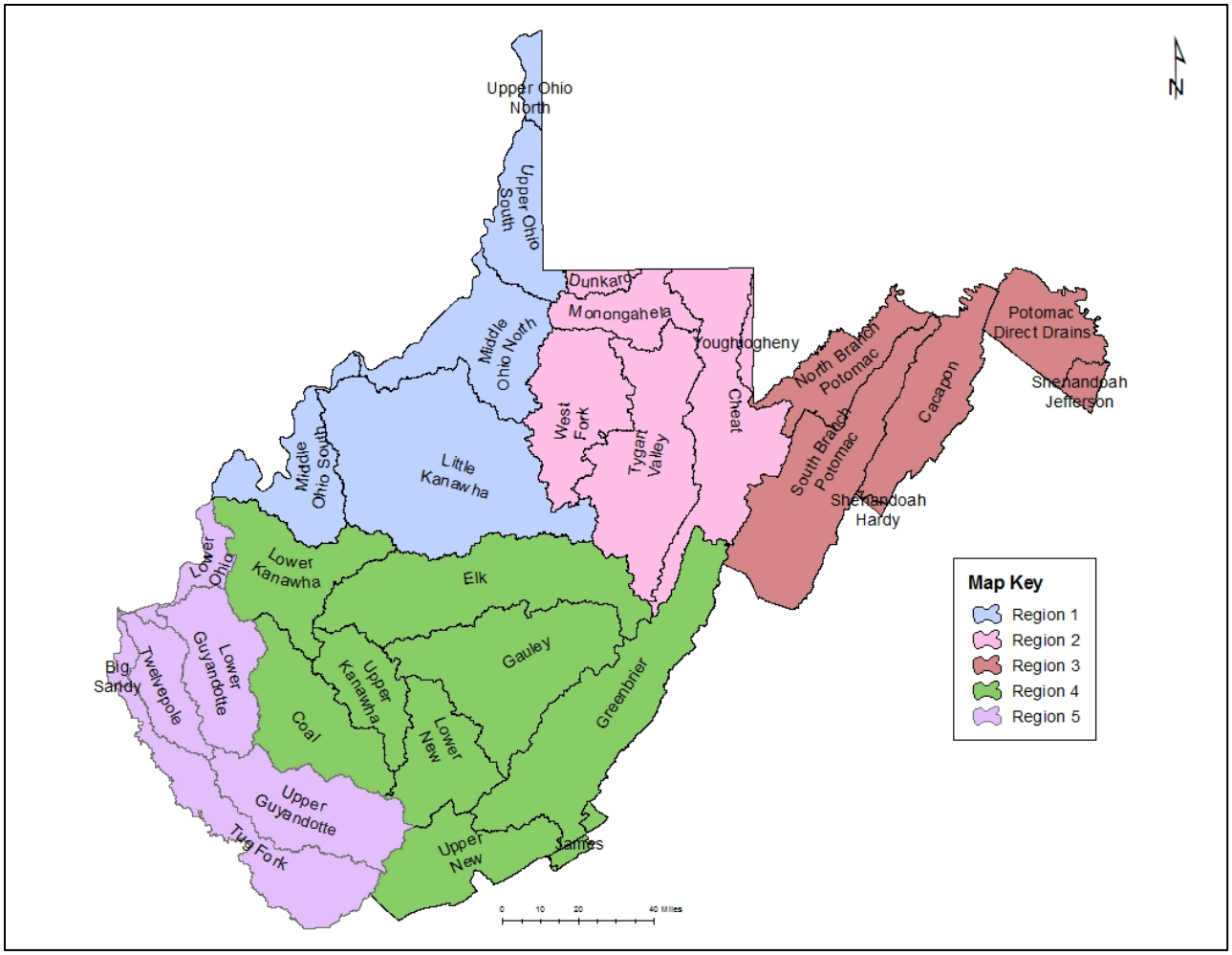


Figure 2-6 West Virginia has 32 HUC-8 watersheds and are shown divided into five regions.

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.

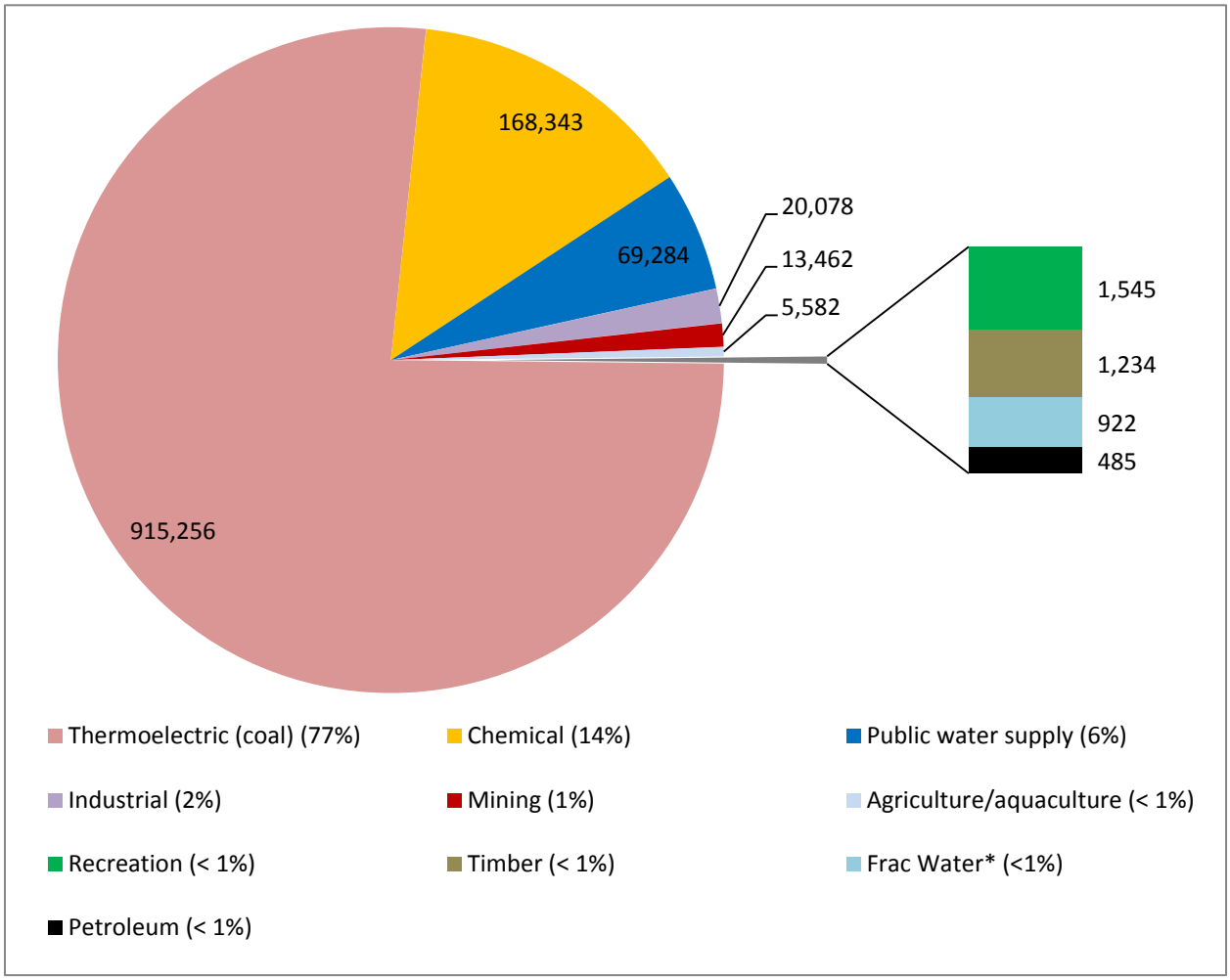


Figure 2-7 Statewide average annual water withdrawal (in millions of gallons) totals by SIC category. *Frac Water was collected from the Frac Water Reporting Tool and is only for withdrawals occurring in 2011 (hydroelectric is excluded).

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.

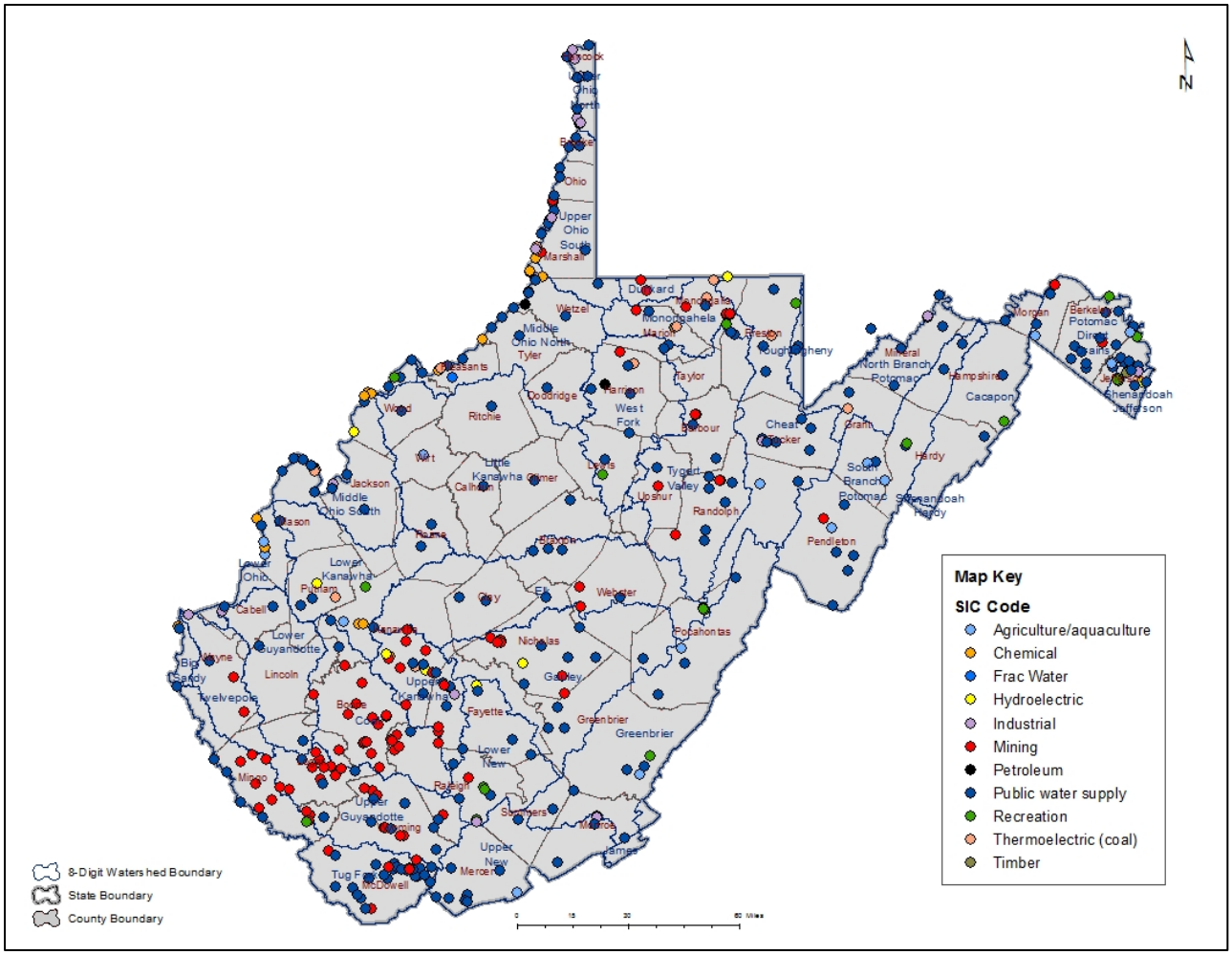


Figure 2-8 Distribution of Large Quantity Users as of 2011, identified by SIC code.

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.

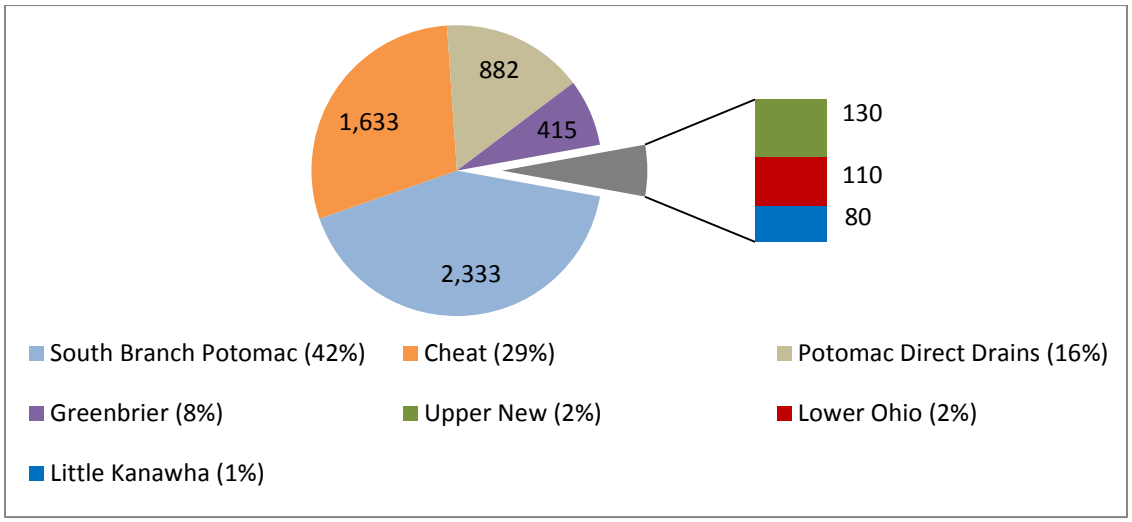


Figure 2-9 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Agriculture/aquaculture SIC category of use, estimated to be 5,581,517,720 gallons per year.

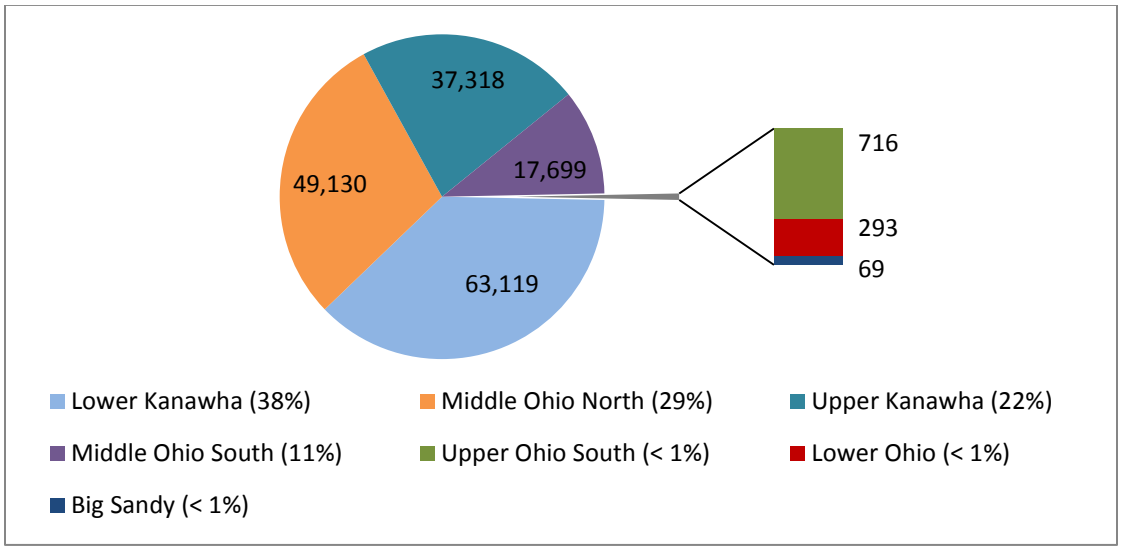


Figure 2-10 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Chemical SIC category of use, estimated to be 168,342,927,475 gallons per year.

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.

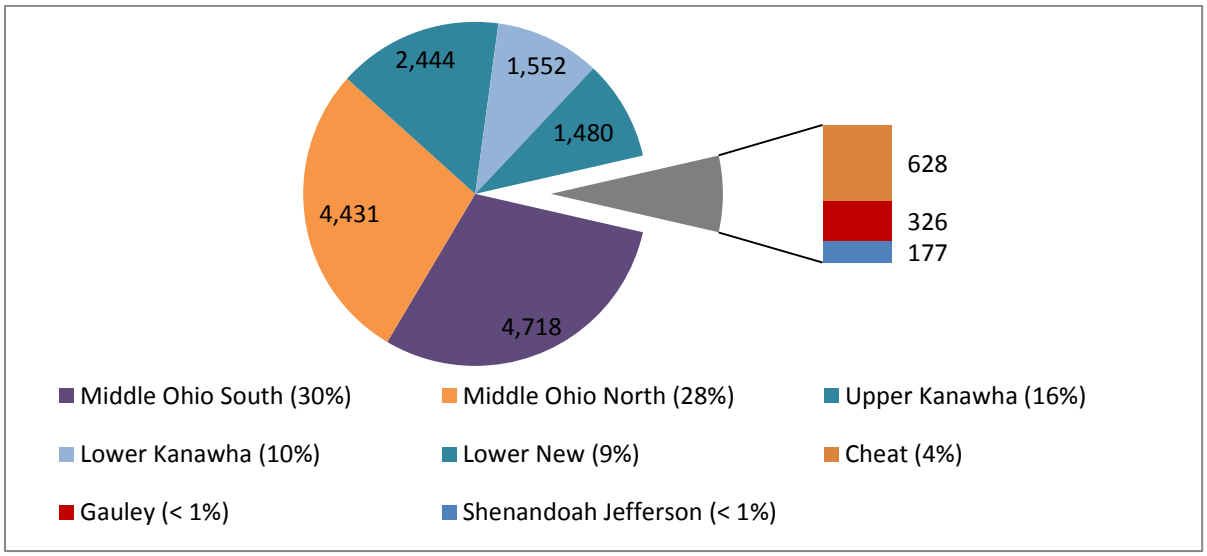


Figure 2-11 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in billions of gallons for the Hydroelectric SIC category of water use, estimated to be 15,756,375,655,427 gallons per year.

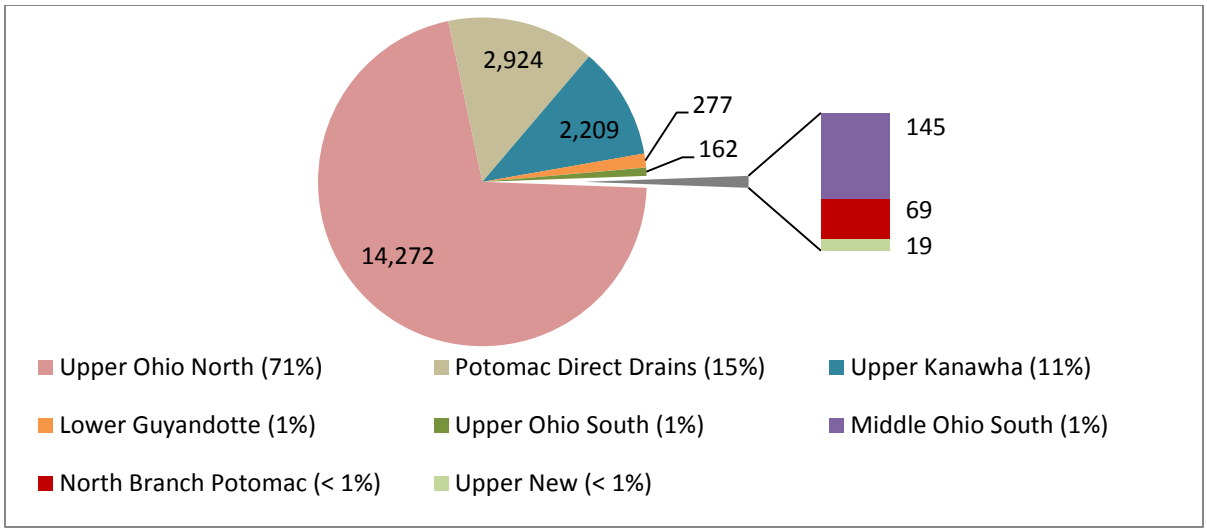


Figure 2-12 Average annual contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Industrial SIC category of use, estimated to be 20,077,779,753 gallons per year.

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%.

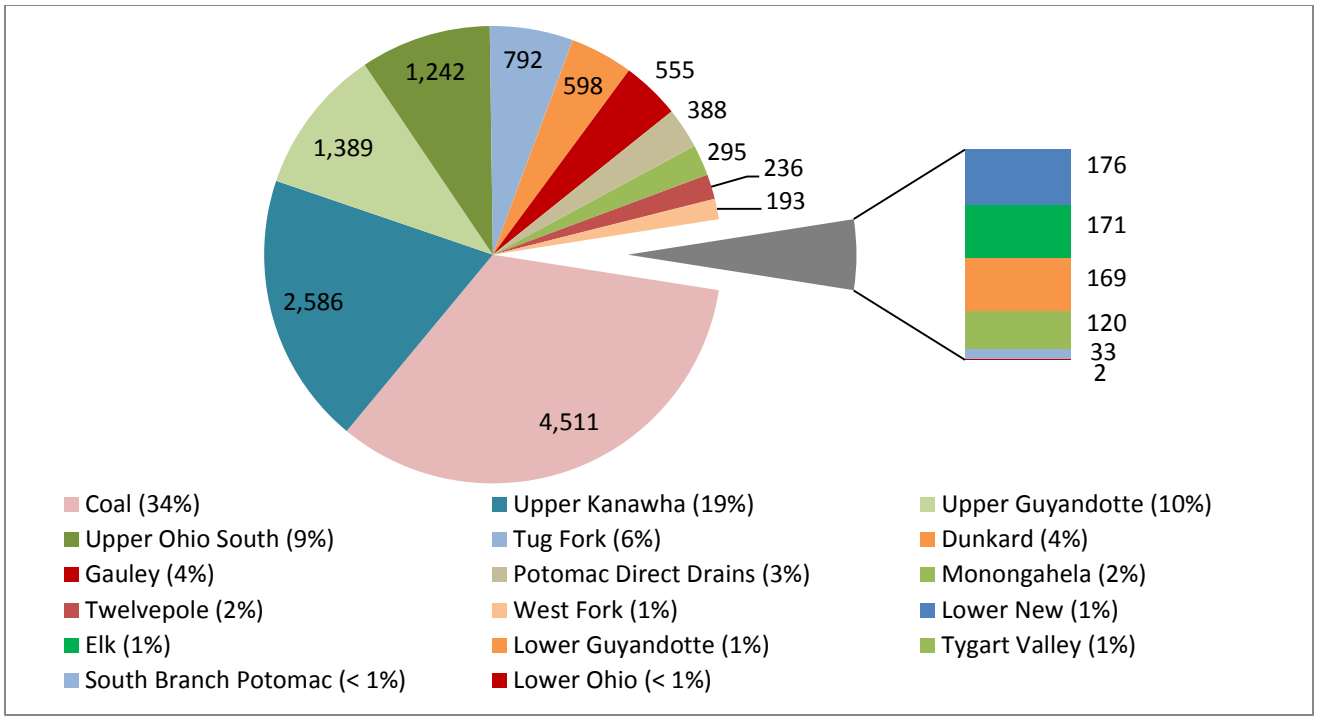


Figure 2-13 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Mining SIC category of use, estimated to be 13,462,053,653 gallons per year.

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.

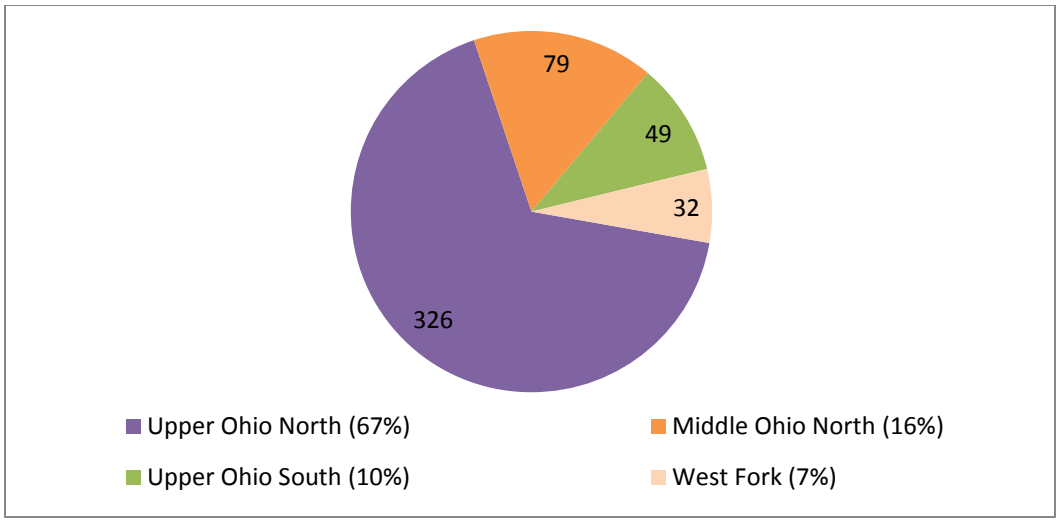


Figure 2-14 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Petroleum SIC category of use, estimated to be 484,937,415 gallons per year.

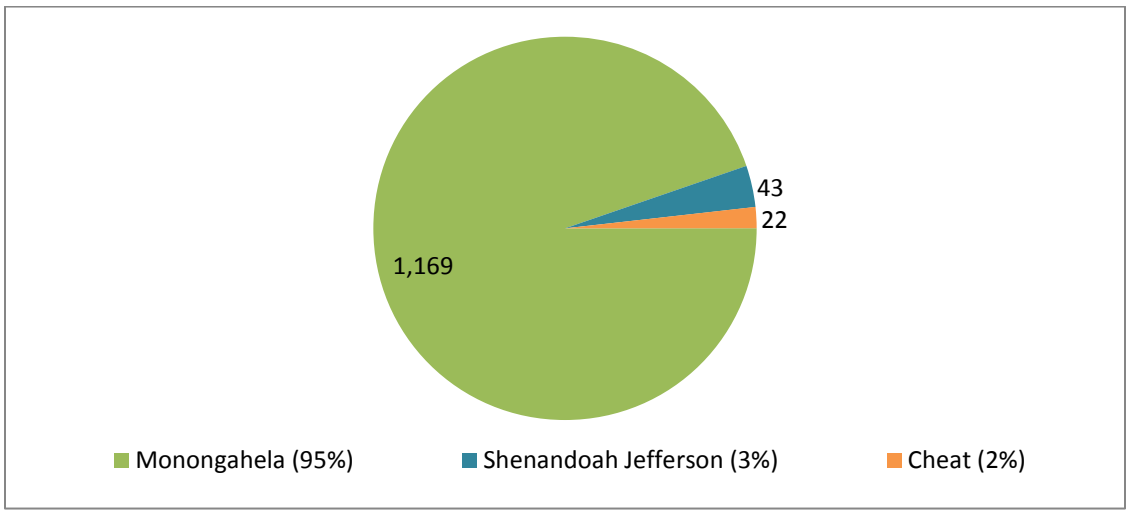


Figure 2-15 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Timber SIC category of use, estimated to be 1,233,943,576 gallons per year.

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.

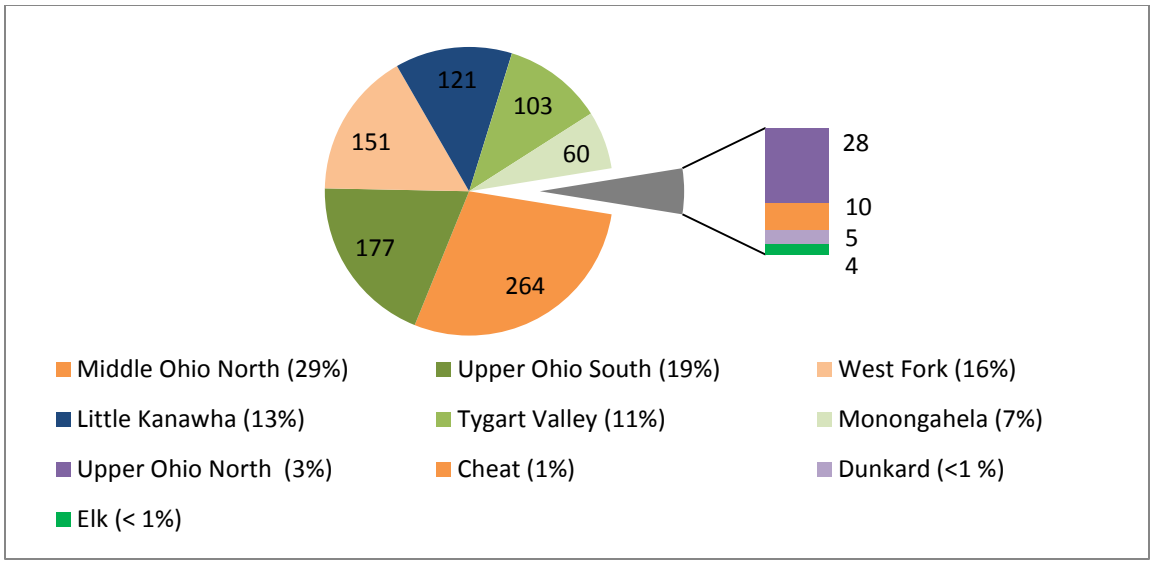


Figure 2-16 Percent contributions of watersheds to statewide withdrawals and the amount of water withdrawn for the Frac Water SIC category of use from horizontal well drilling in 2011 (from Frac Water Reporting Tool), estimated to be 922,783,143 gallons.

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.

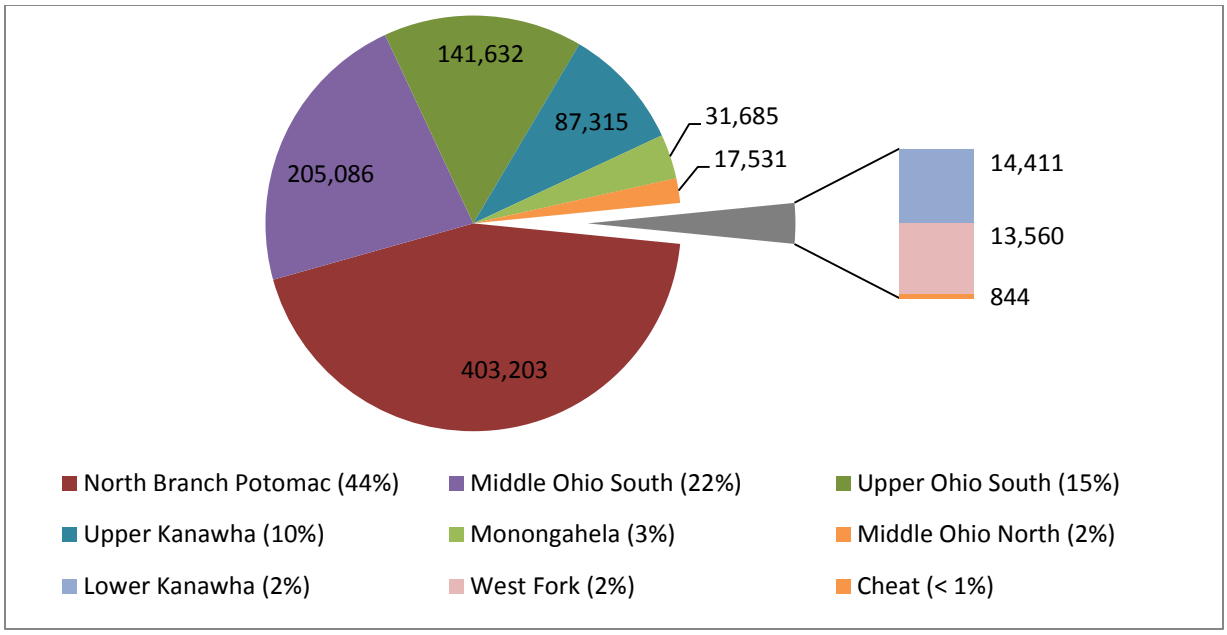


Figure 2-17 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Thermoelectric (coal) SIC category of use, estimated to be 915,256,218,694 gallons per year.

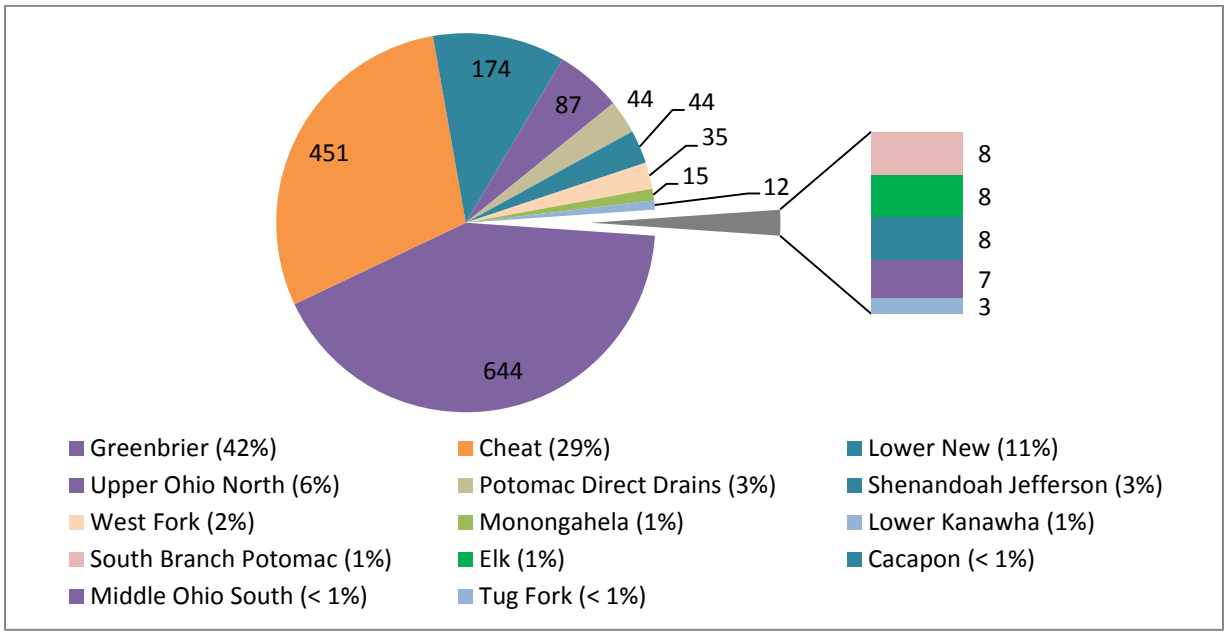


Figure 2-18 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for the Recreation SIC category of use, estimated to be 1,544,771,703 gallons per year.

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.

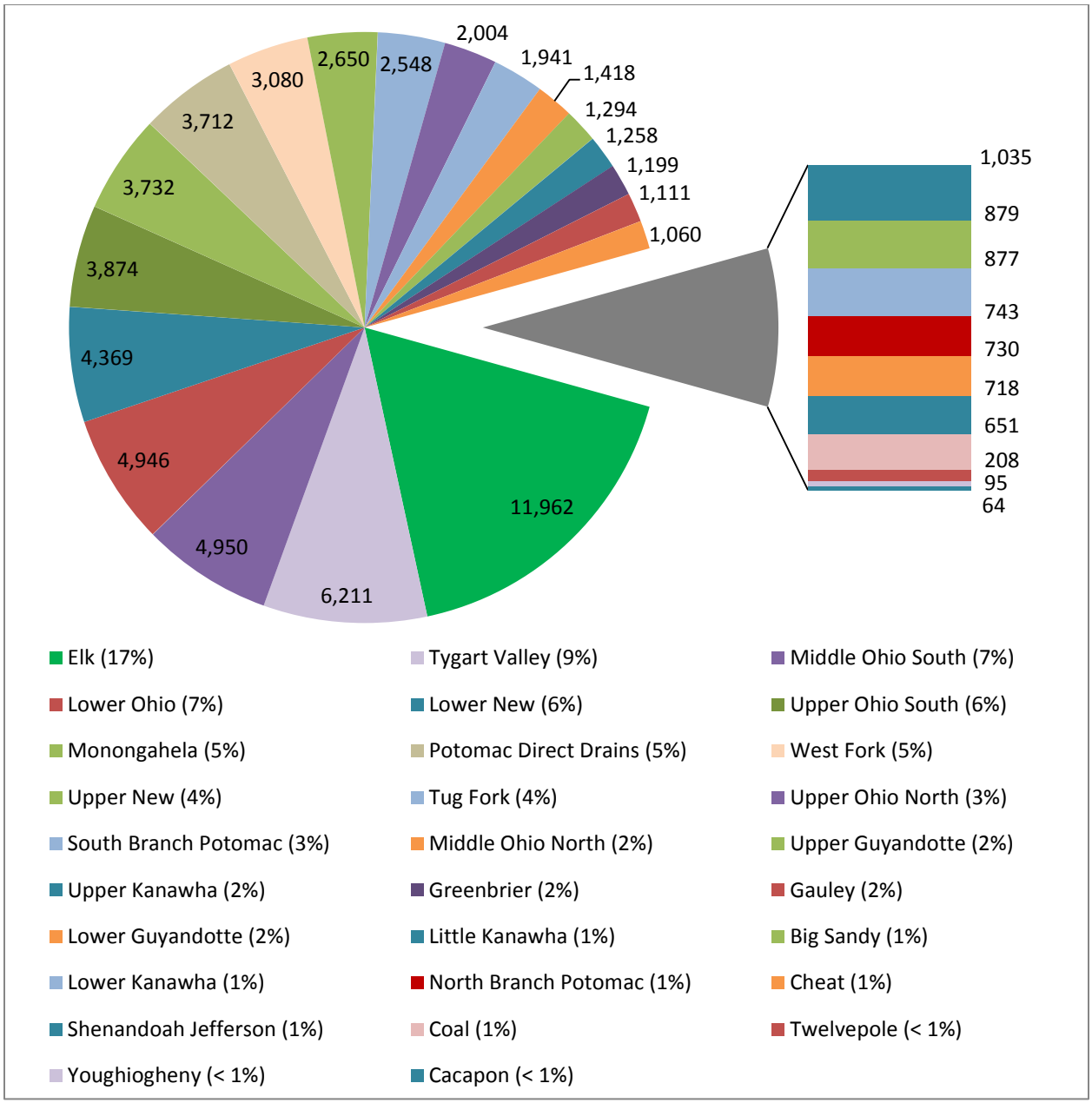
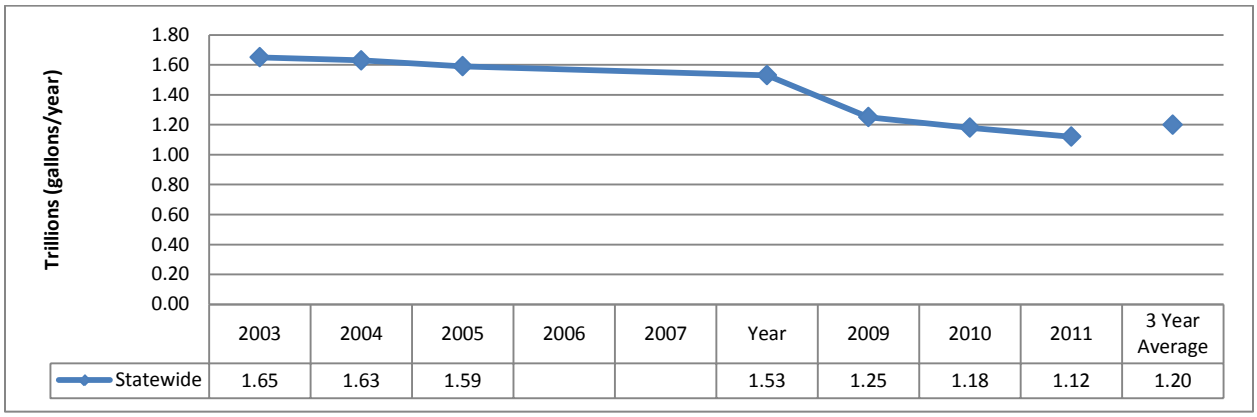


Figure 2-19 Average annual percent contributions of watersheds to statewide withdrawals and average water withdrawn annually in millions of gallons for Public Water Supply use estimated to be 69,283,527,985 gallons.

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

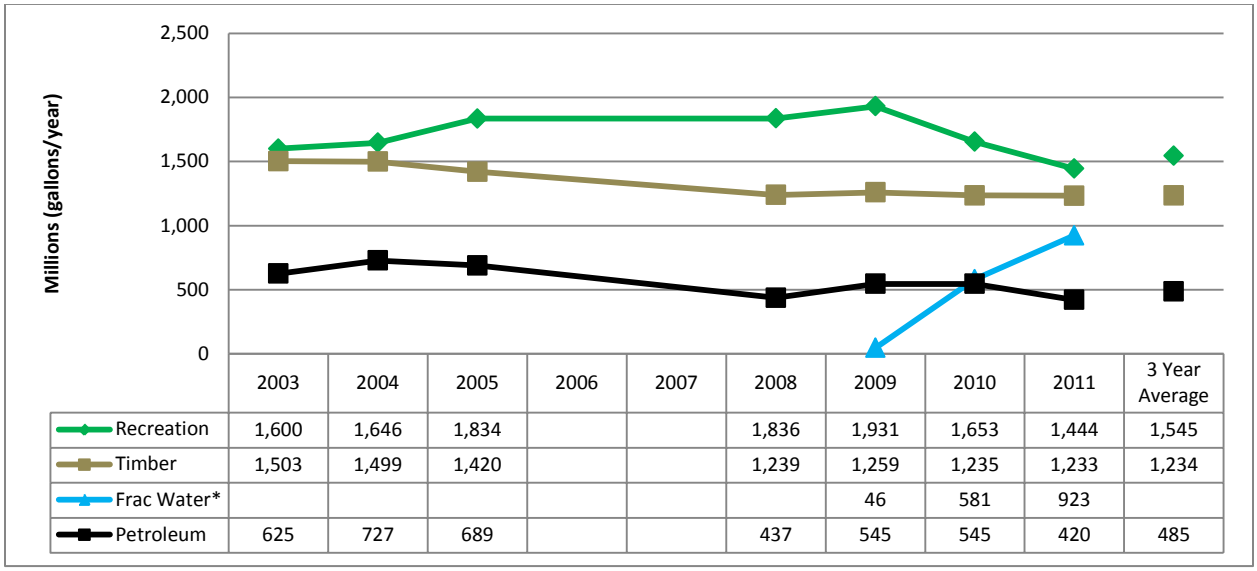
Figure 2-20 Statewide water withdraw trends over time (excluding hydroelectric).

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

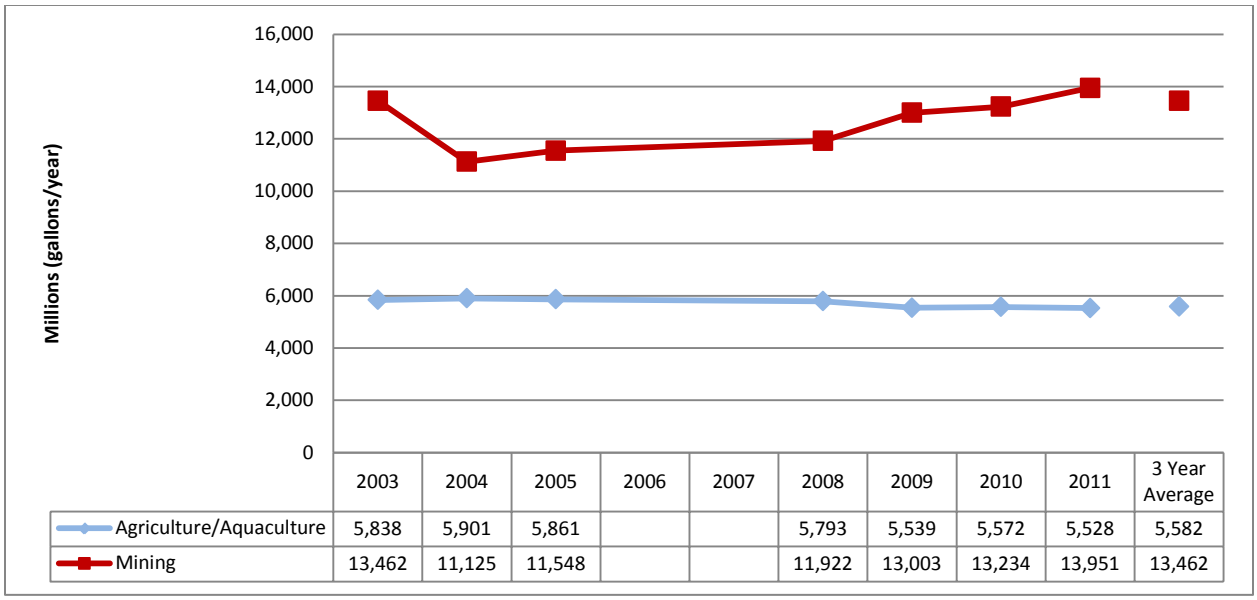
threshold, effectively removing open industries from the reporting data, or moving from withdrawal operations to purchasing the water needed for operations.

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.



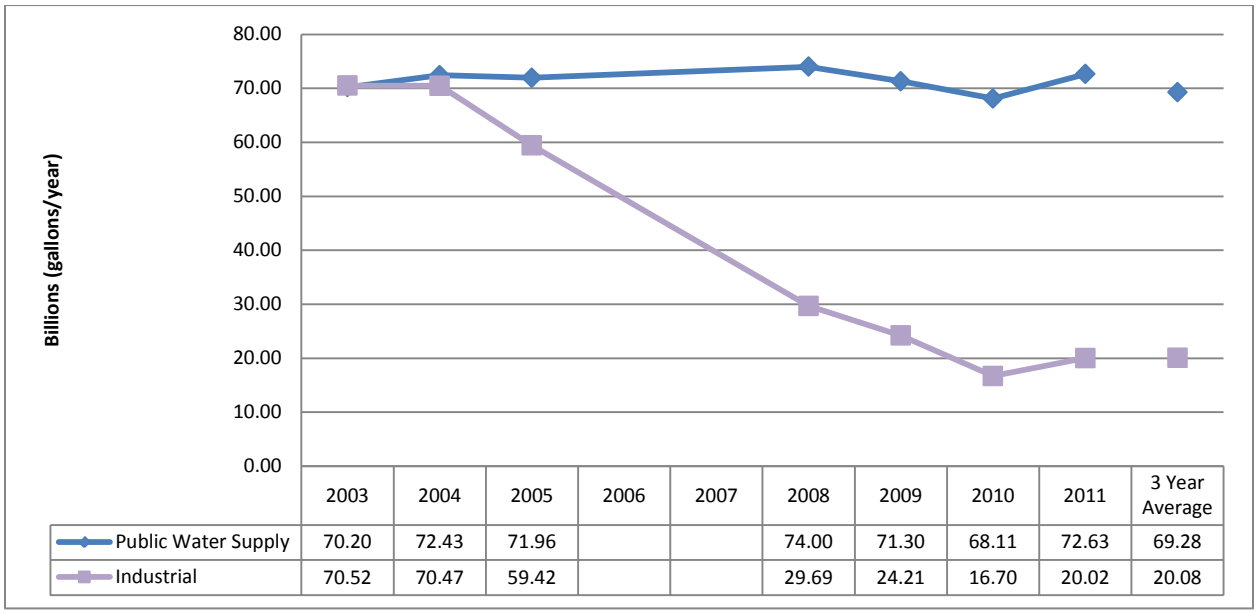
	2003	2004	2005	2006	2007	2008	2009	2010	2011	3 Year Average
Agriculture/Aquaculture	5,838	5,901	5,861			5,793	5,539	5,572	5,528	5,582
Mining	13,462	11,125	11,548			11,922	13,003	13,234	13,951	13,462

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.

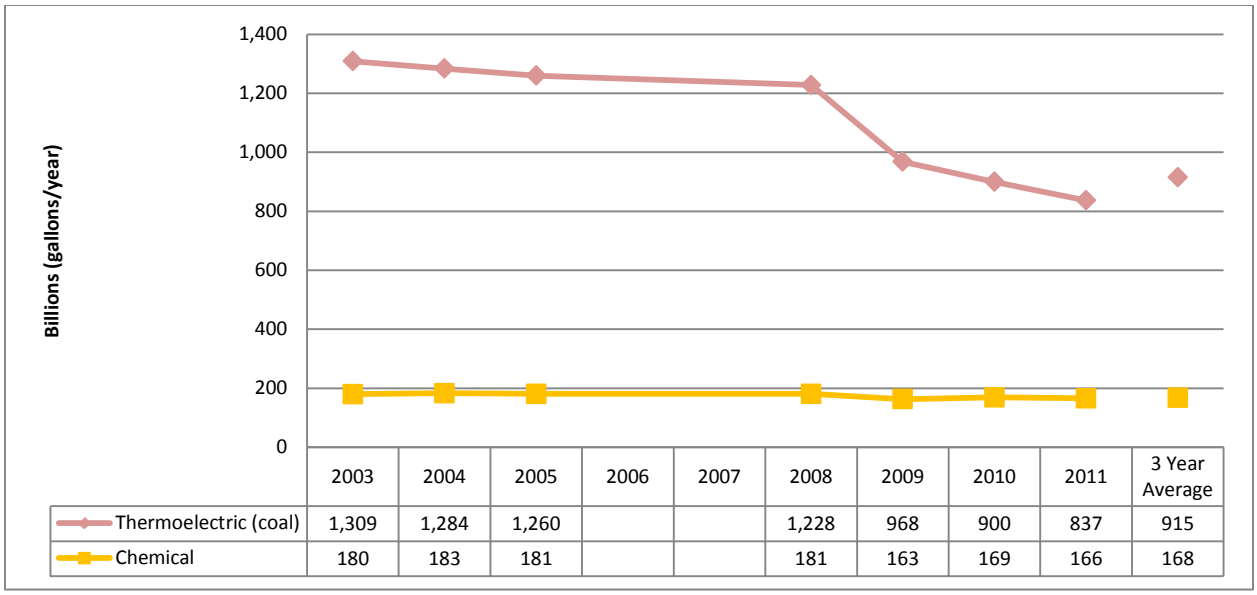


Figure 2-24 Statewide LQU water withdrawal trends for the Thermoelectric and Chemical SIC categories, measured in billions of gallons per year.

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.

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.

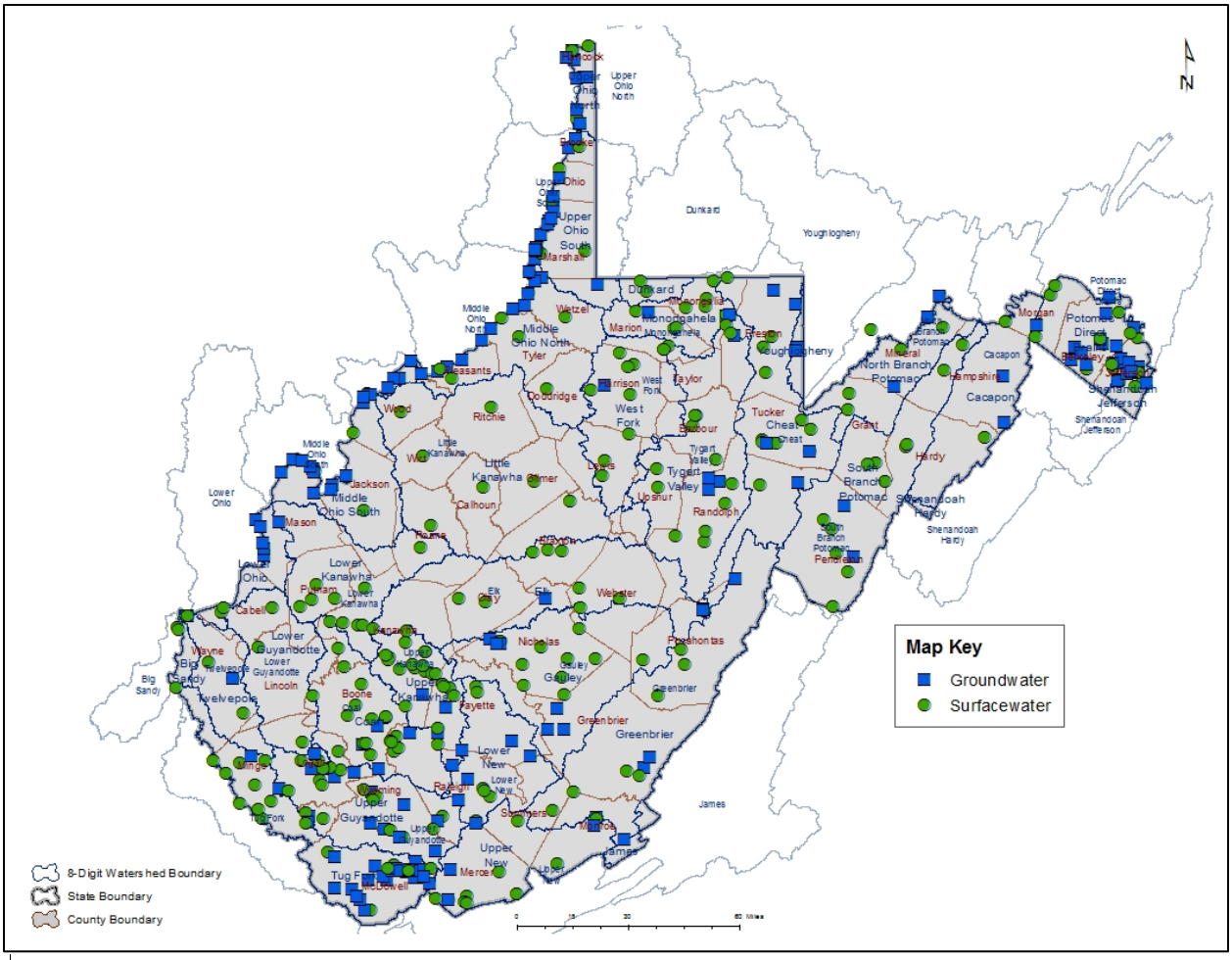


Figure 2-26 Distribution of Large Quantity User groundwater and surface water withdrawals.

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
Frac Water*	922,783,143	0.12	99.88
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	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.

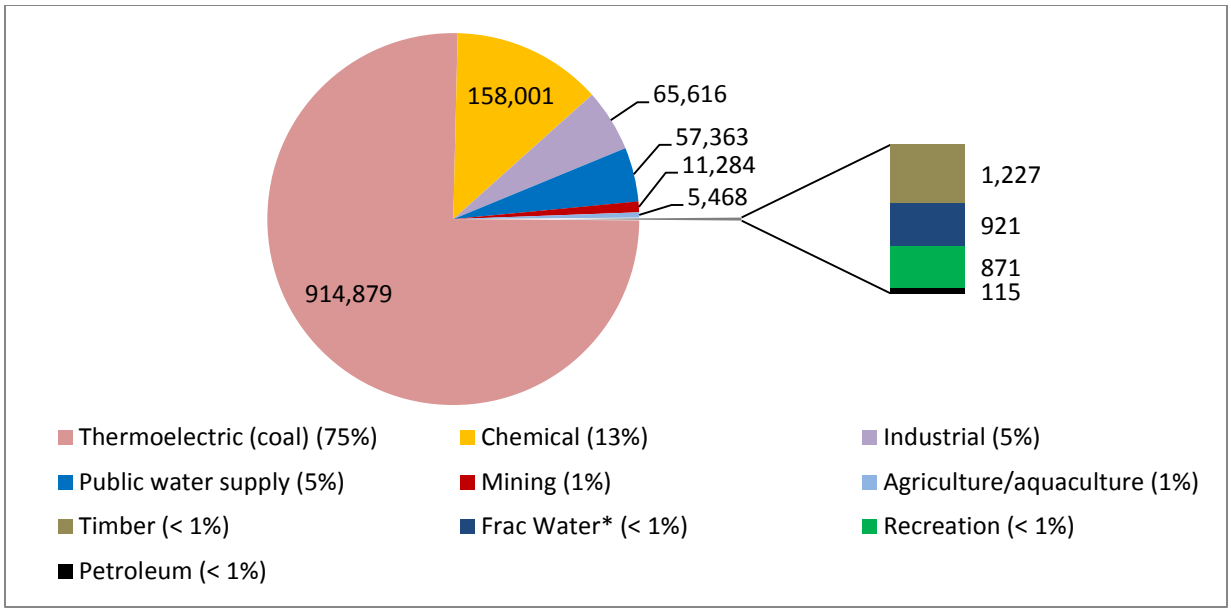


Figure 2-27 Statewide distribution of average annual amount of water withdrawn by LQUs from surface water sources (excluding Hydroelectric). * Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool.

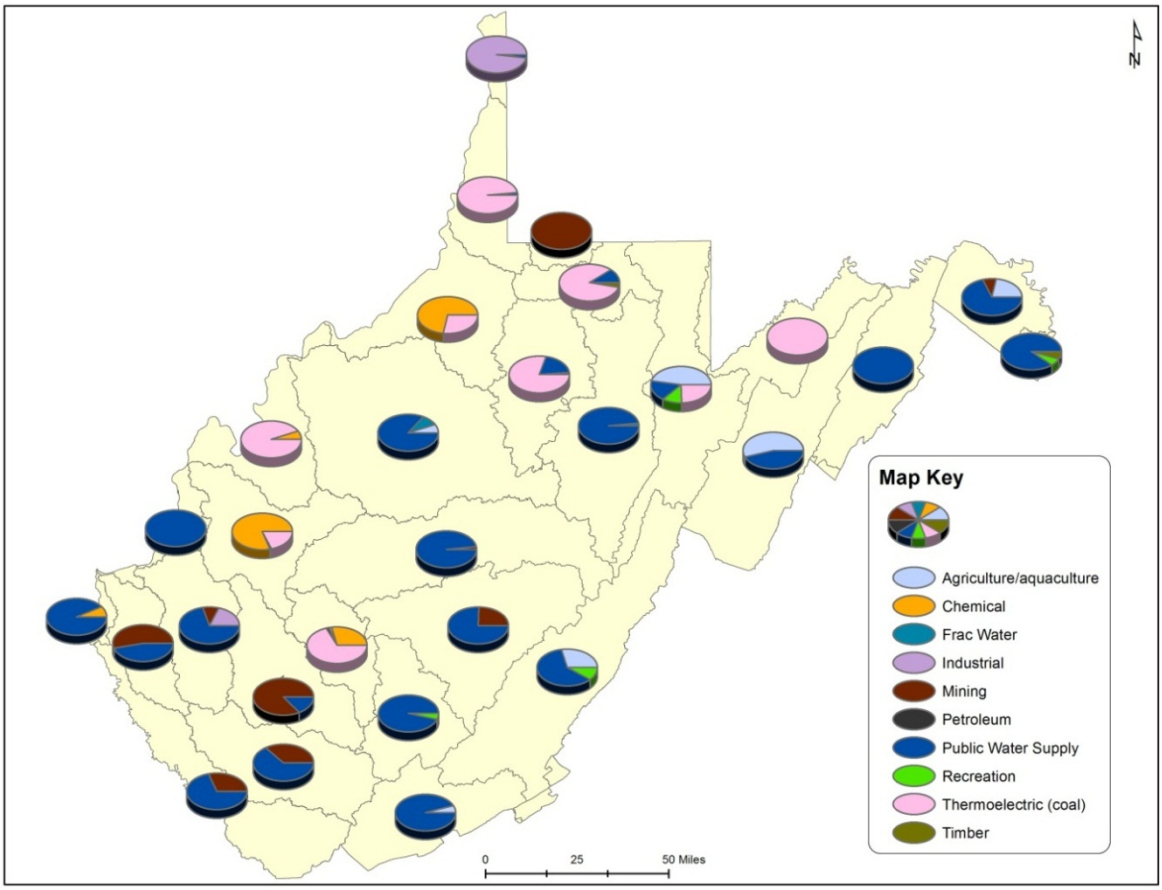


Figure 2-28 Distribution of average annual amount of water withdrawn by LQUs from surface water sources (excluding Hydroelectric) in each watershed. Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool.

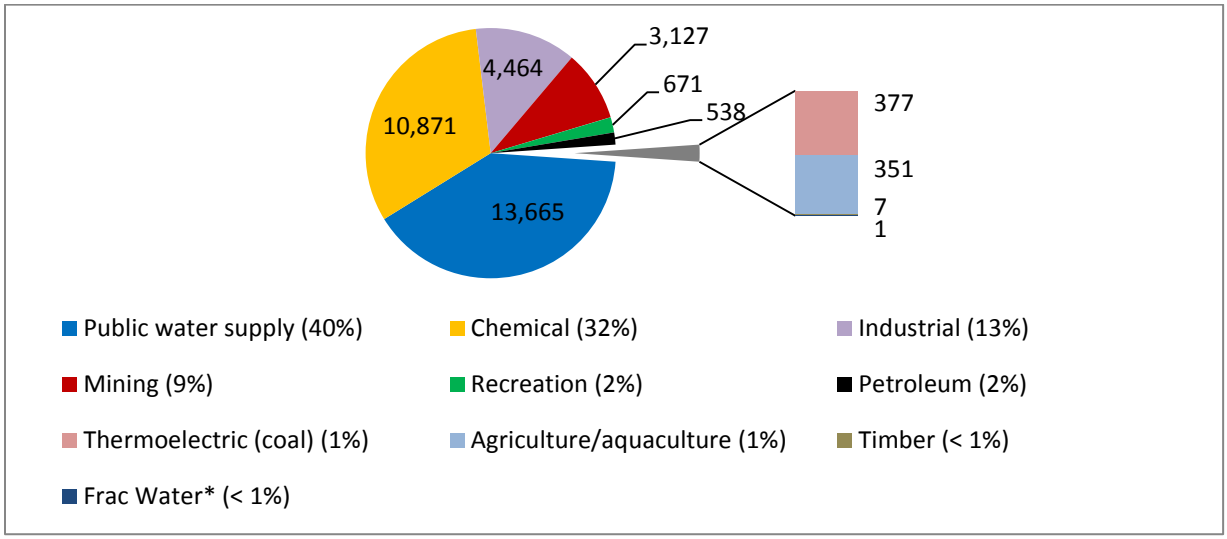


Figure 2-29 Statewide distribution of average annual amount of water withdrawn by LQUs from groundwater sources (excluding Hydroelectric). * Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool.

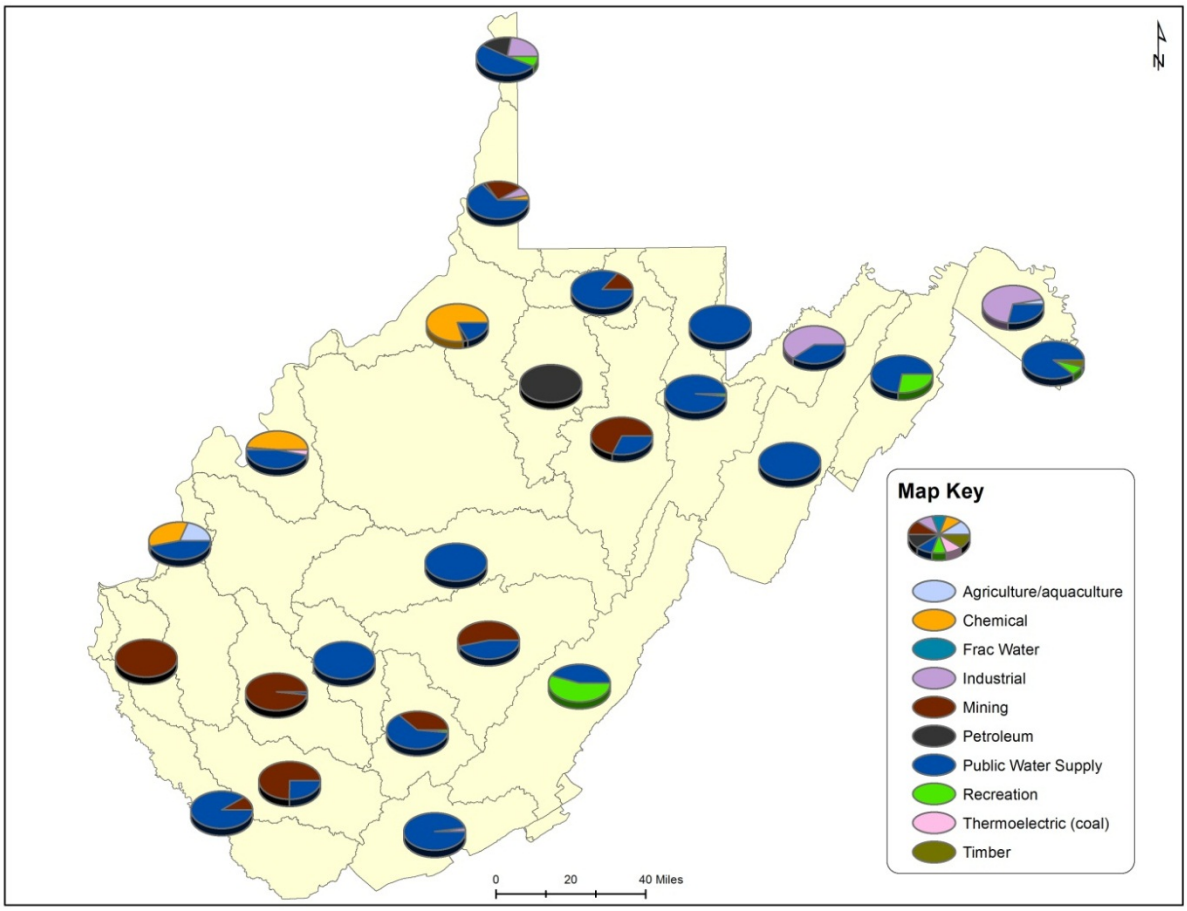


Figure 2-30 Distribution of average annual amount of water withdrawn by LQUs from groundwater sources (excluding Hydroelectric) in each watershed. Frac Water includes only the 2011 data collected from the Frac Water Reporting Tool.

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.

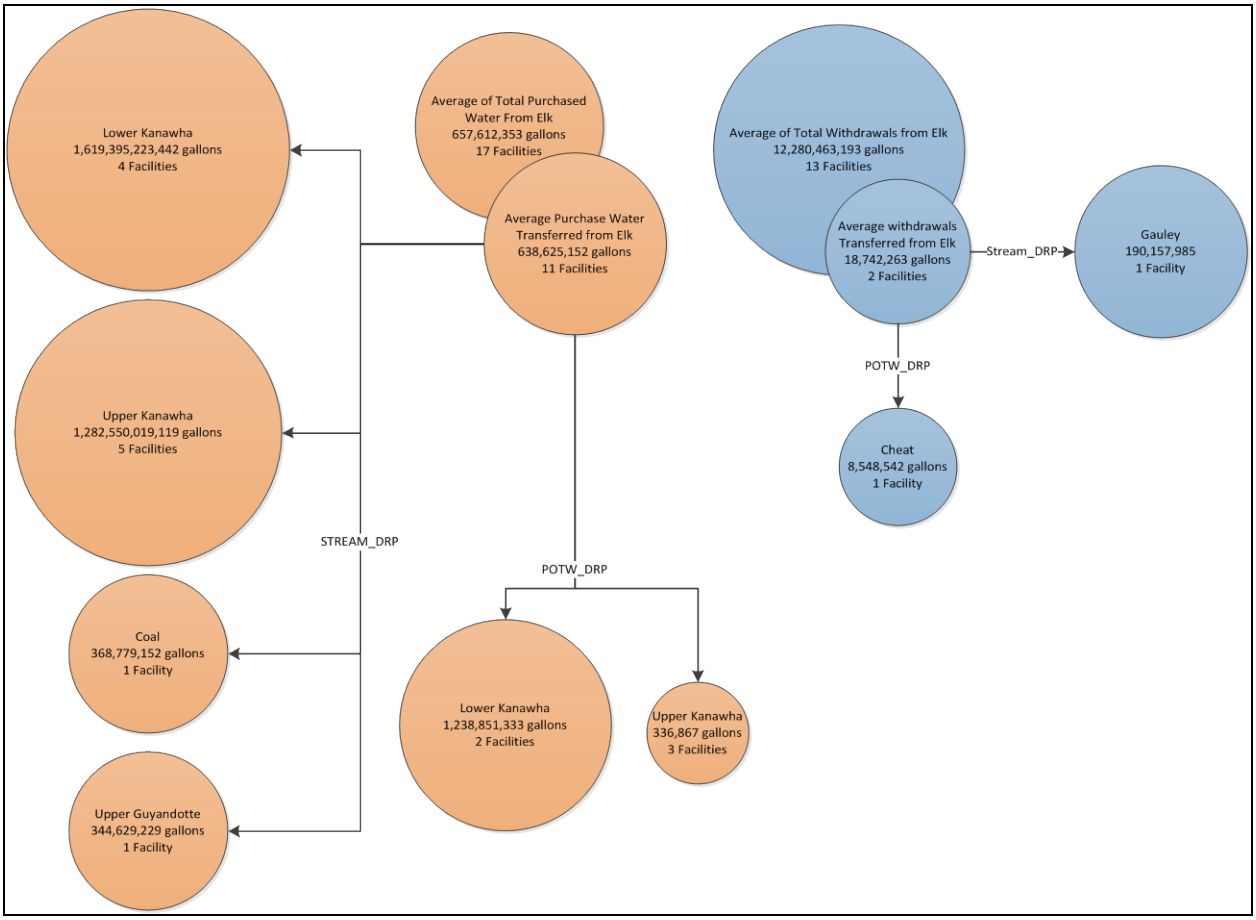


Figure 2-31 Activity in the Elk River Watershed resulting in water transfers to other watersheds (interbasin transfers). The sizes of the balloons represent the proportions of water and serve to illustrate the difficulty in understanding the actual occurrence and resulting impact of interbasin transfers.

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).

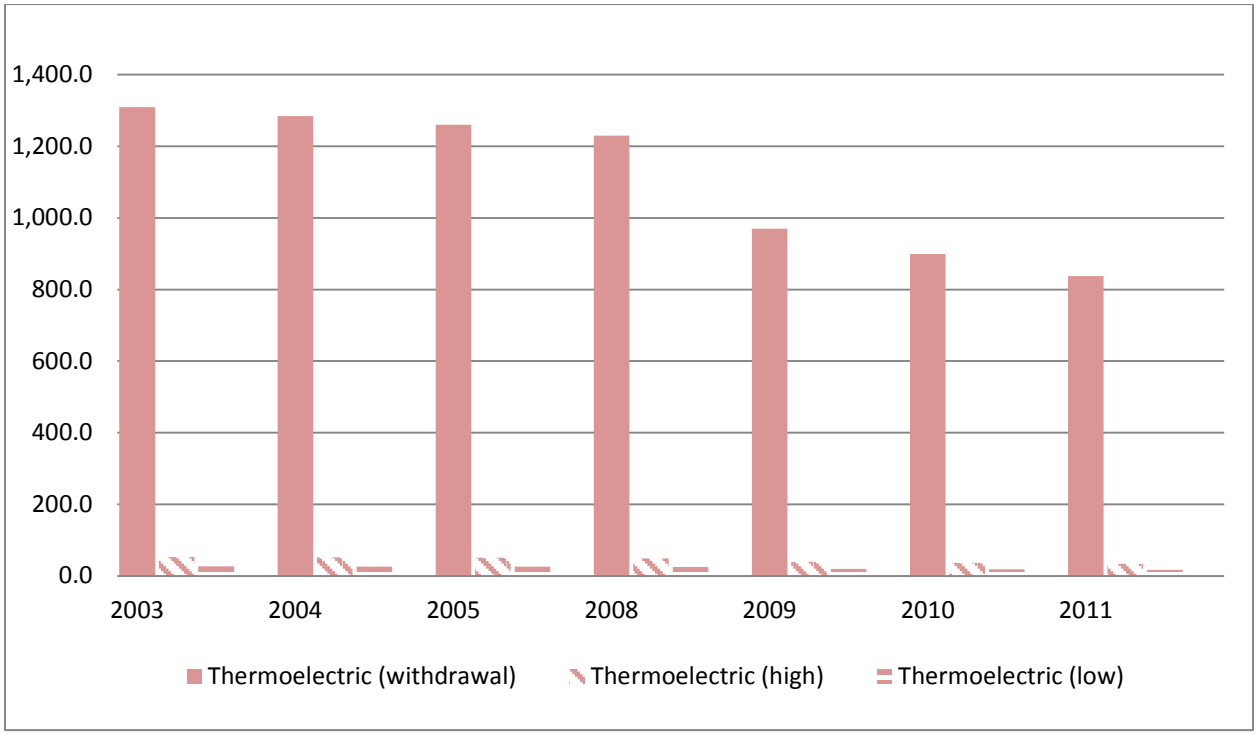


Figure 2-32 Annual withdrawals from the LQU database for the (amended) Thermoelectric* group as well as the high and low consumptive use estimates for those years (based on the Shaffer and Runkle consumptive use coefficients) in billions of gallons. *Shown separate due to scale.

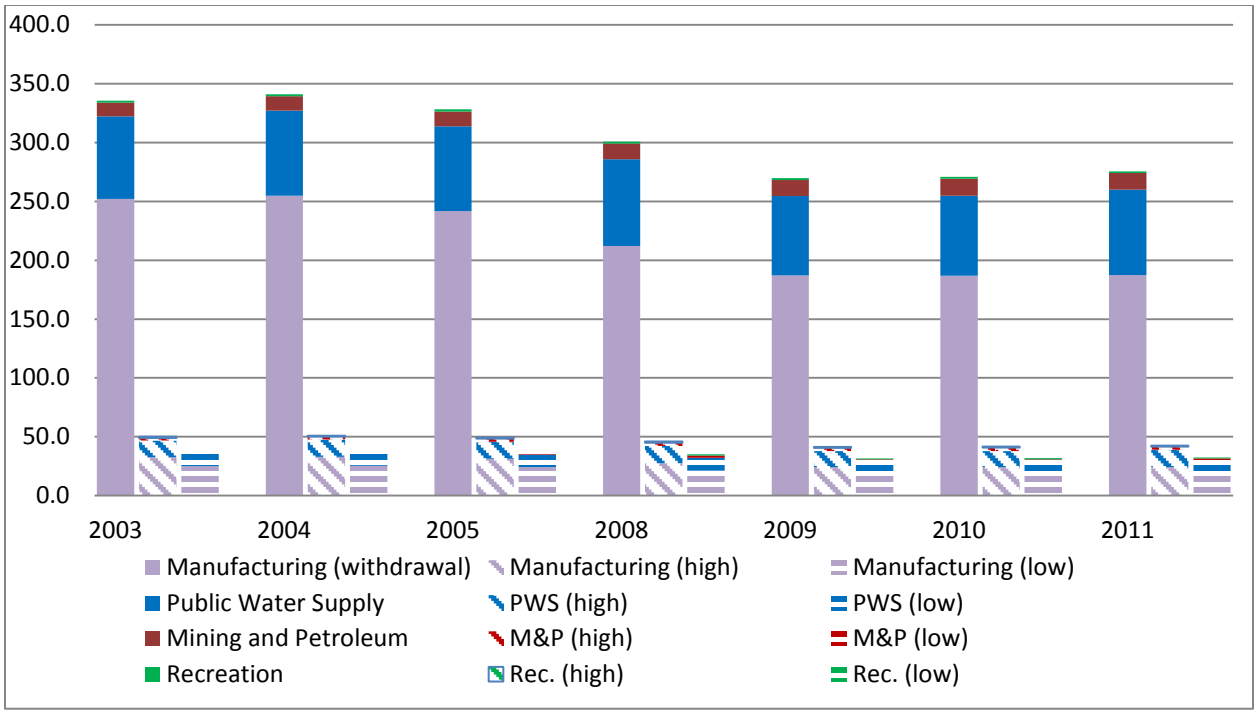


Figure 2-33 Annual withdrawals from the LQU database for (amended) groups as well as the high and low consumptive use scenario calculations (based on the Shaffer and Runkle consumptive use coefficients) in billions of gallons.

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.

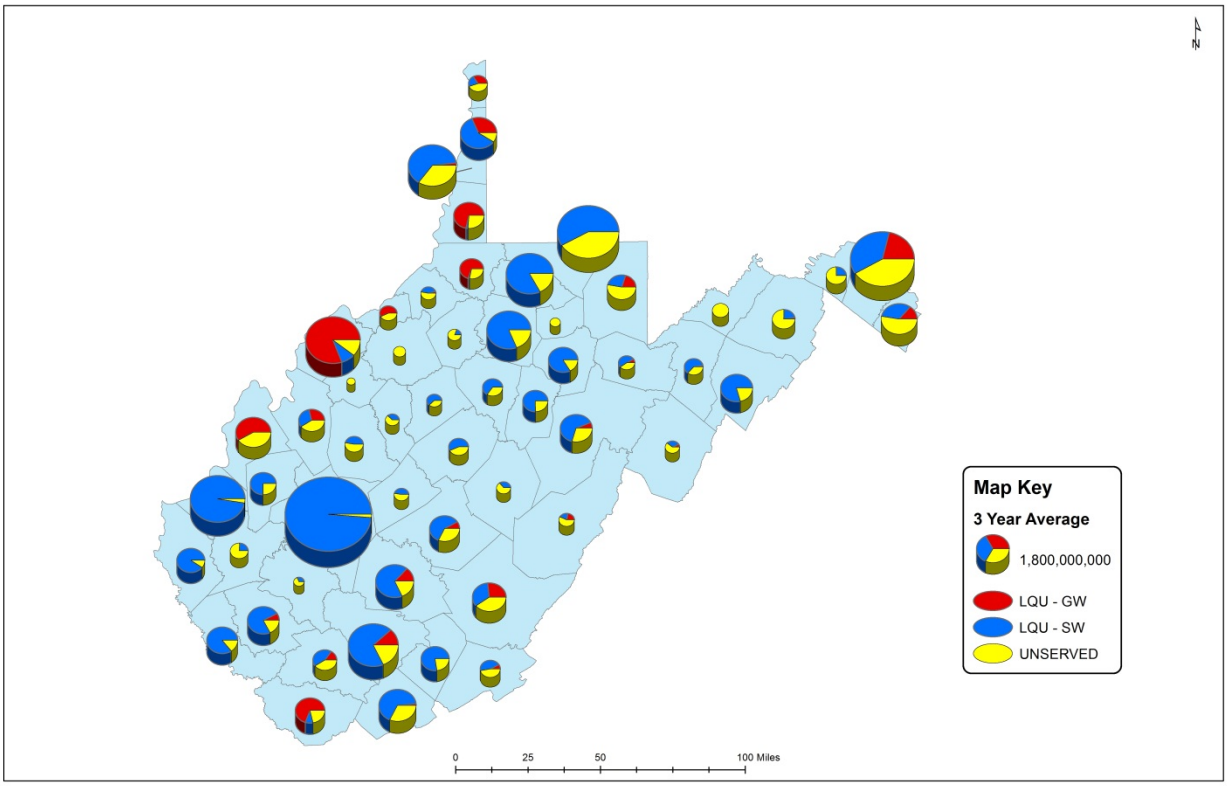


Figure 2-34 Distribution of average annual gallons of water withdrawn by LQUs in each county from groundwater and surface water sources for public supply and the estimated amount withdrawn by the unserved population for domestic use.

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.

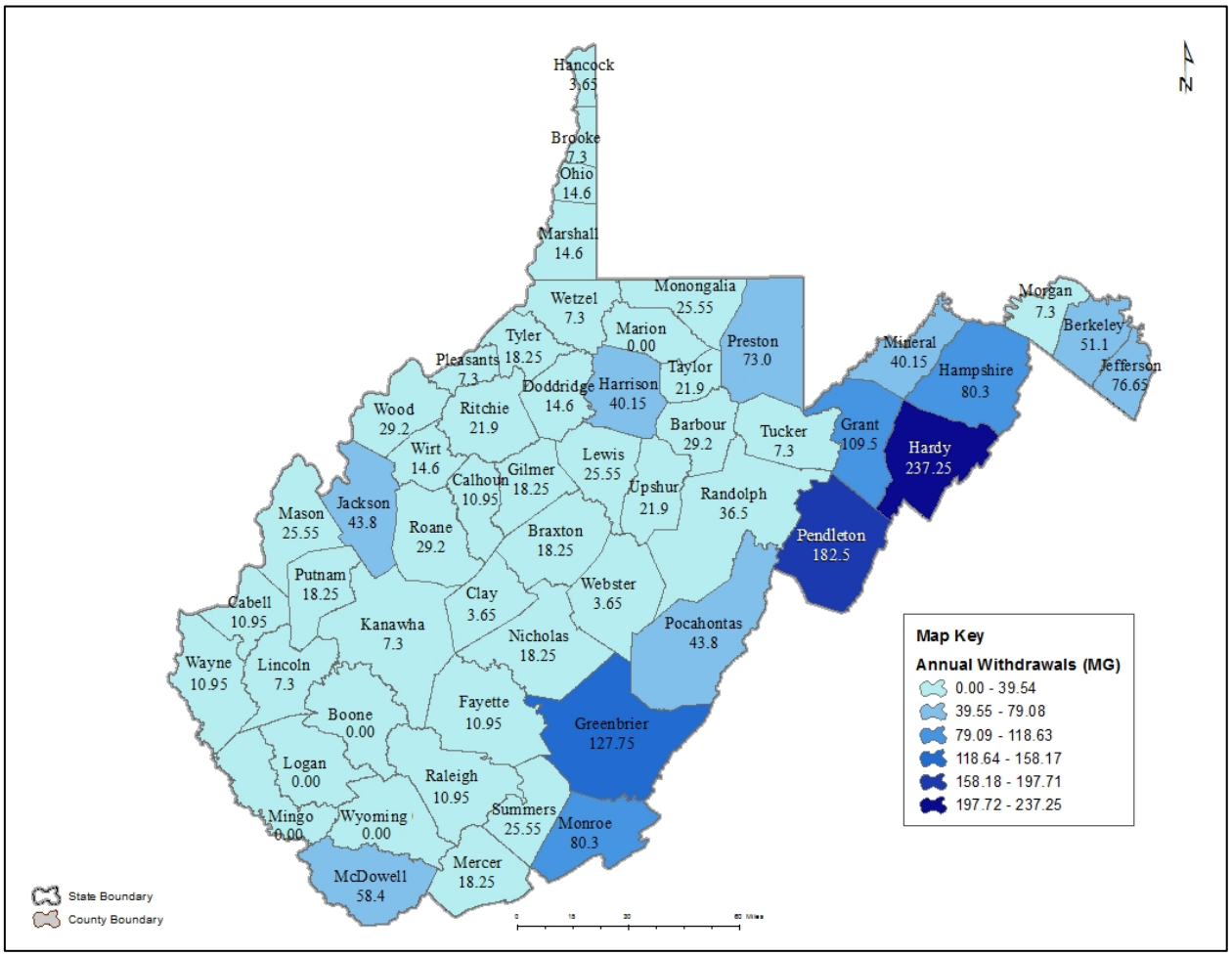


Figure 2-35 USGS Estimates of 2005 agriculture withdrawals for livestock and poultry.

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.

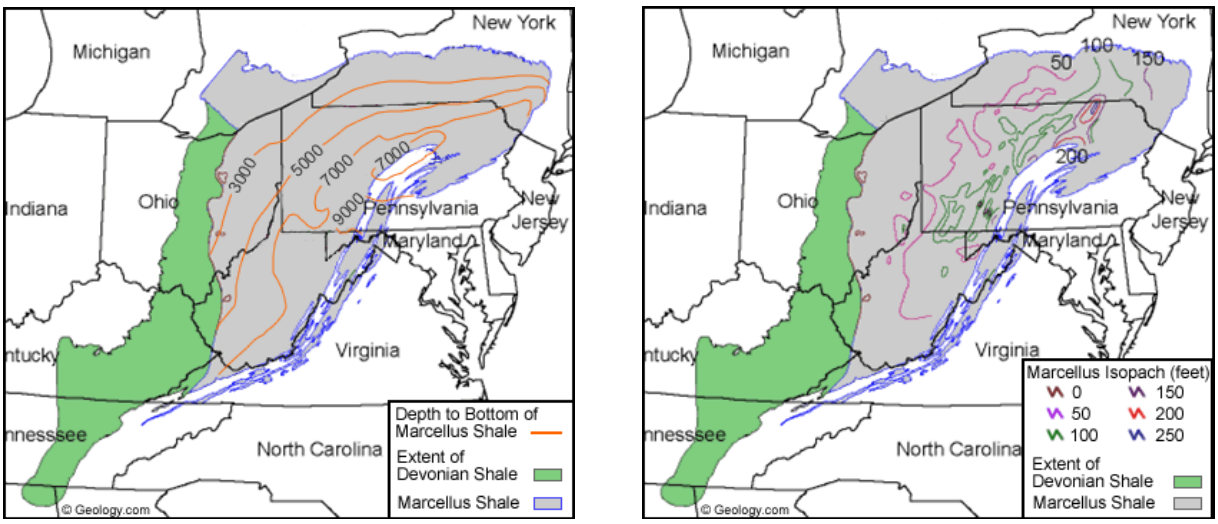


Figure 2-36 Extent, depth and thickness of Marcellus Shale in West Virginia

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.

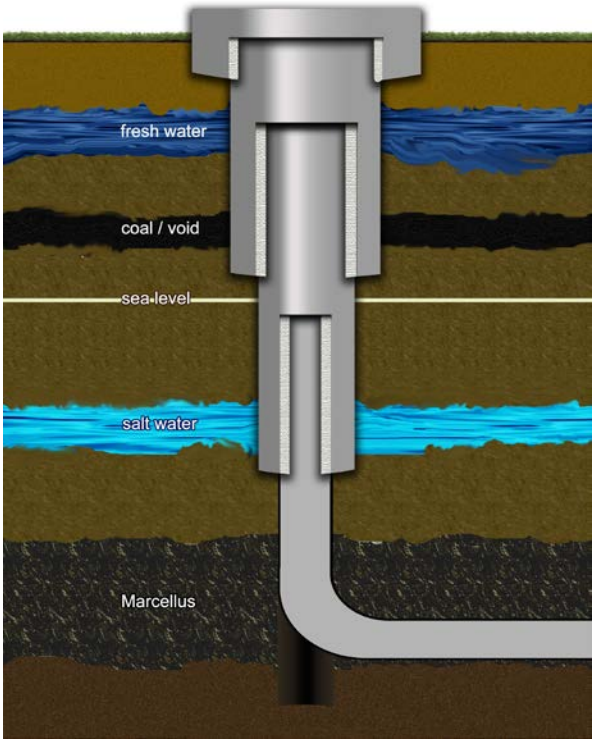


Figure 2-37 Generalized horizontal drilling

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

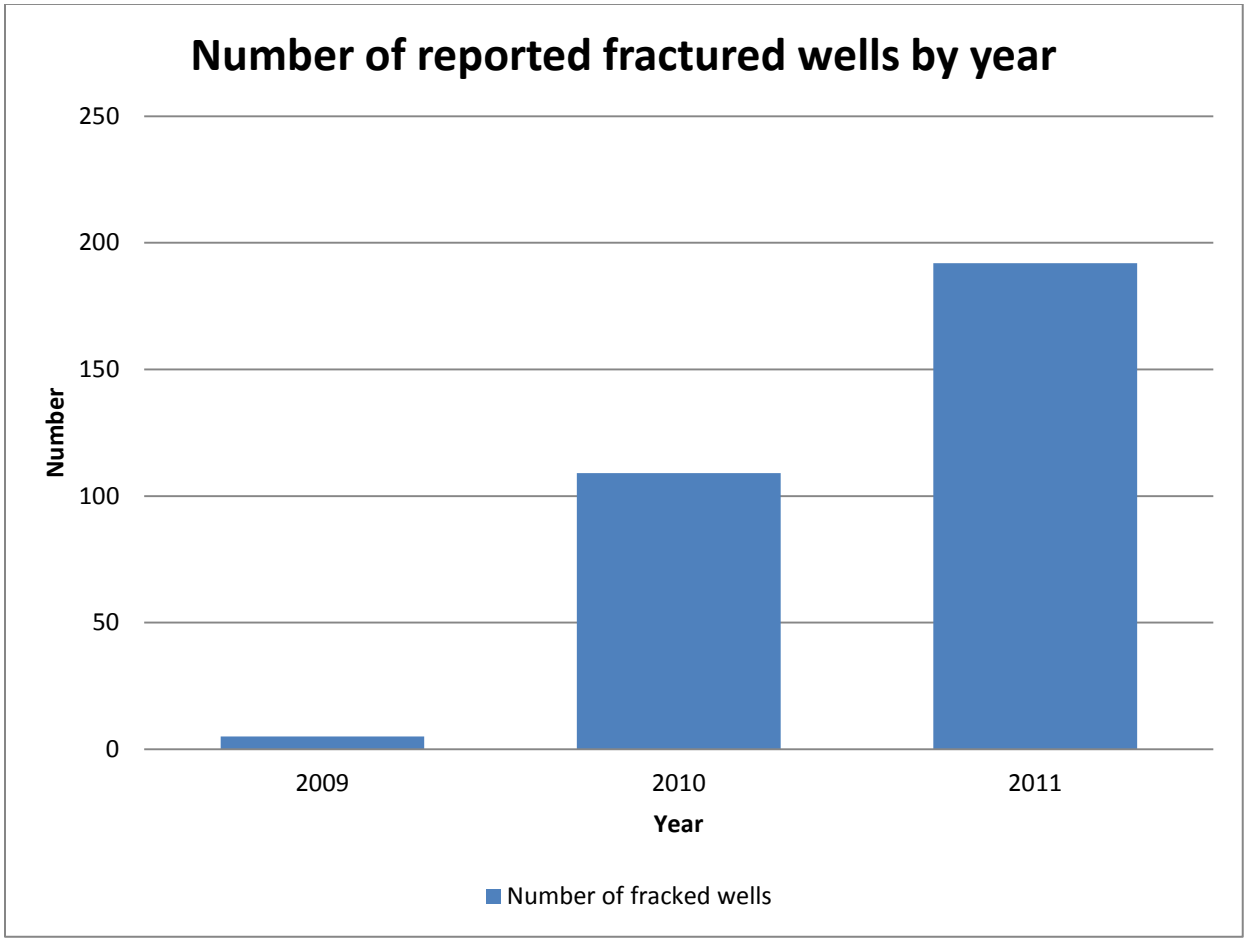
construction companies, hydro-seeders, and hydrostatic pipeline testers withdraw waters from streams without oversight or training. To improve protection of the resource the DEP, in cooperation with the Division of Natural Resources and other appropriate agencies, intends to develop a guidance document 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.

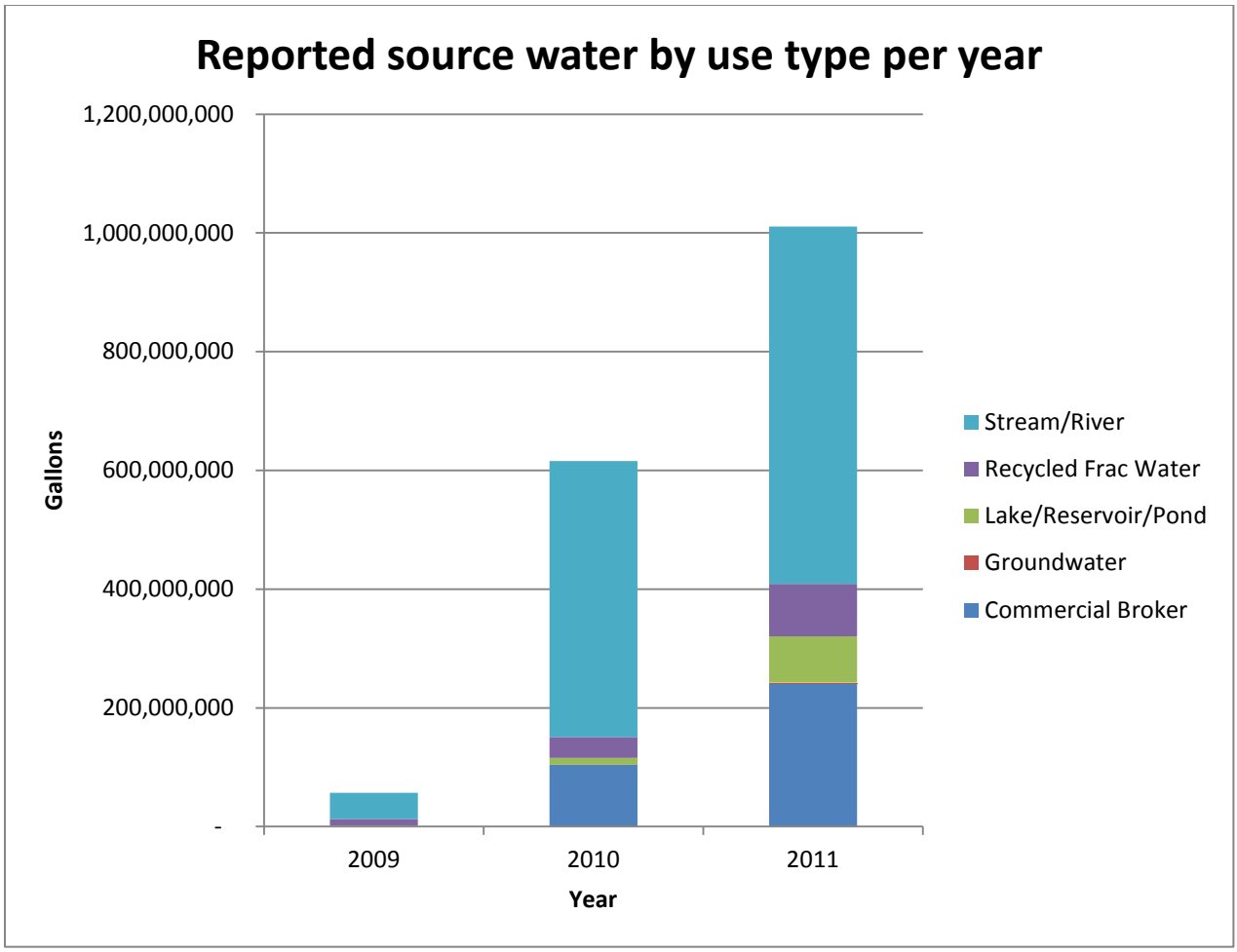


Figure 2-38 Reported horizontal drilling source water by type per year in gallons

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.

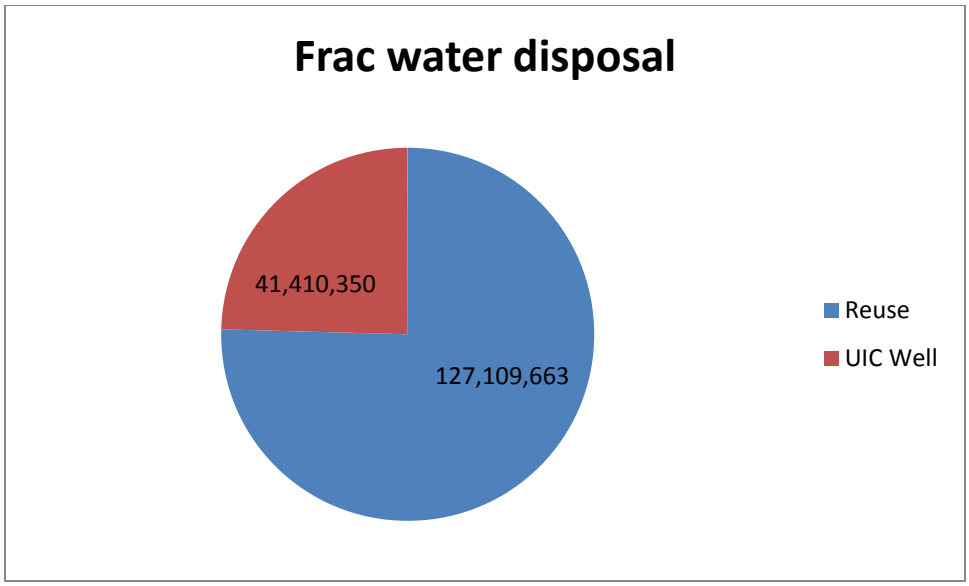


Figure 2-39 Frac water disposal data.

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.

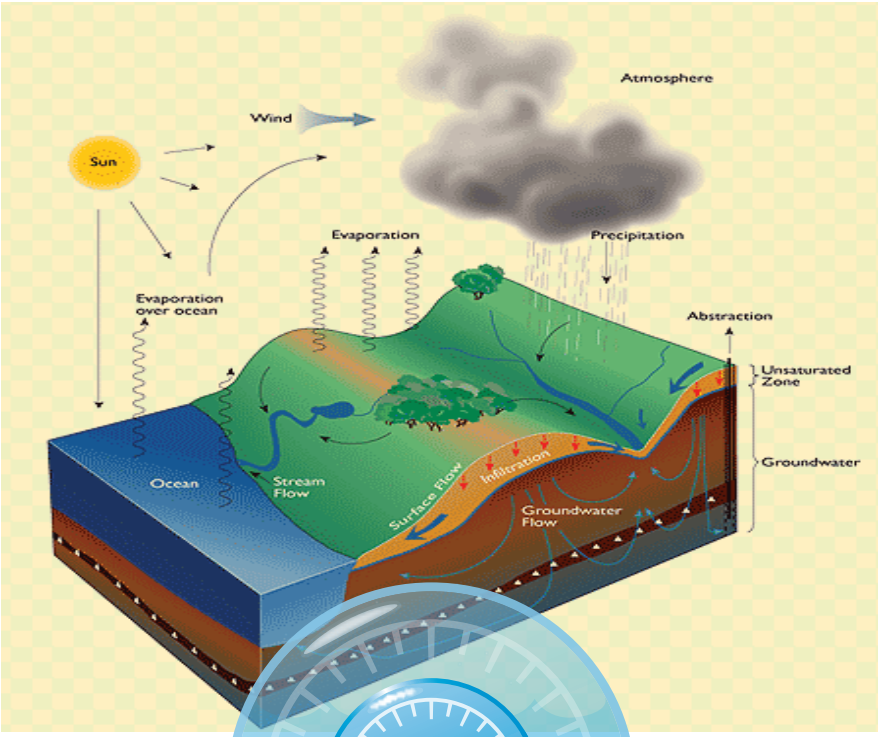
In addition to identifying all potential water sources, the operator must demonstrate that adequate in-stream flow shall be available immediately downstream of the intake while it is in use. The DEP's preferred method of ensuring adequate downstream flow is adherence to the following minimum flow criteria:

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 75th percentile flow duration statistic. Based on this project, DEP has incorporated the 75th 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 HUC8	Avg (in)	Max (in)	Min (in)	No. in HUC8	SPRING 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.

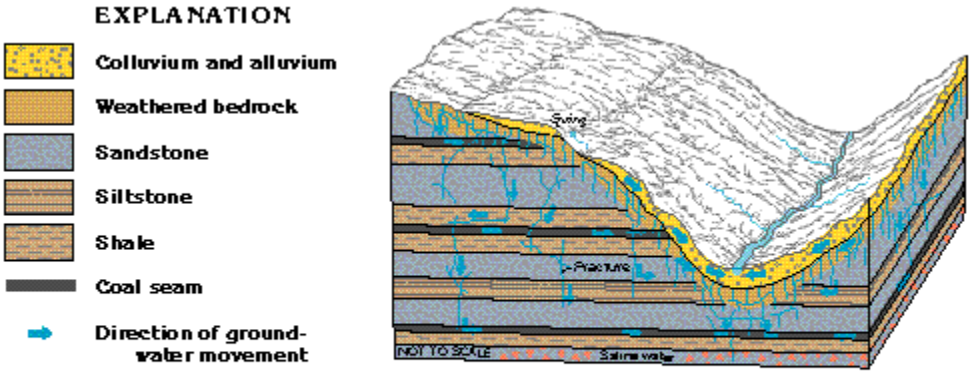
A major drawback of the water budget method is that the available water is estimated as the residual term in an equation where the other budget terms are estimated with some degree of error. The amount of water that flows into a watershed, as well as the water that must be allowed to flow out of the 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

$\mathbf{Q_{in}}$ 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

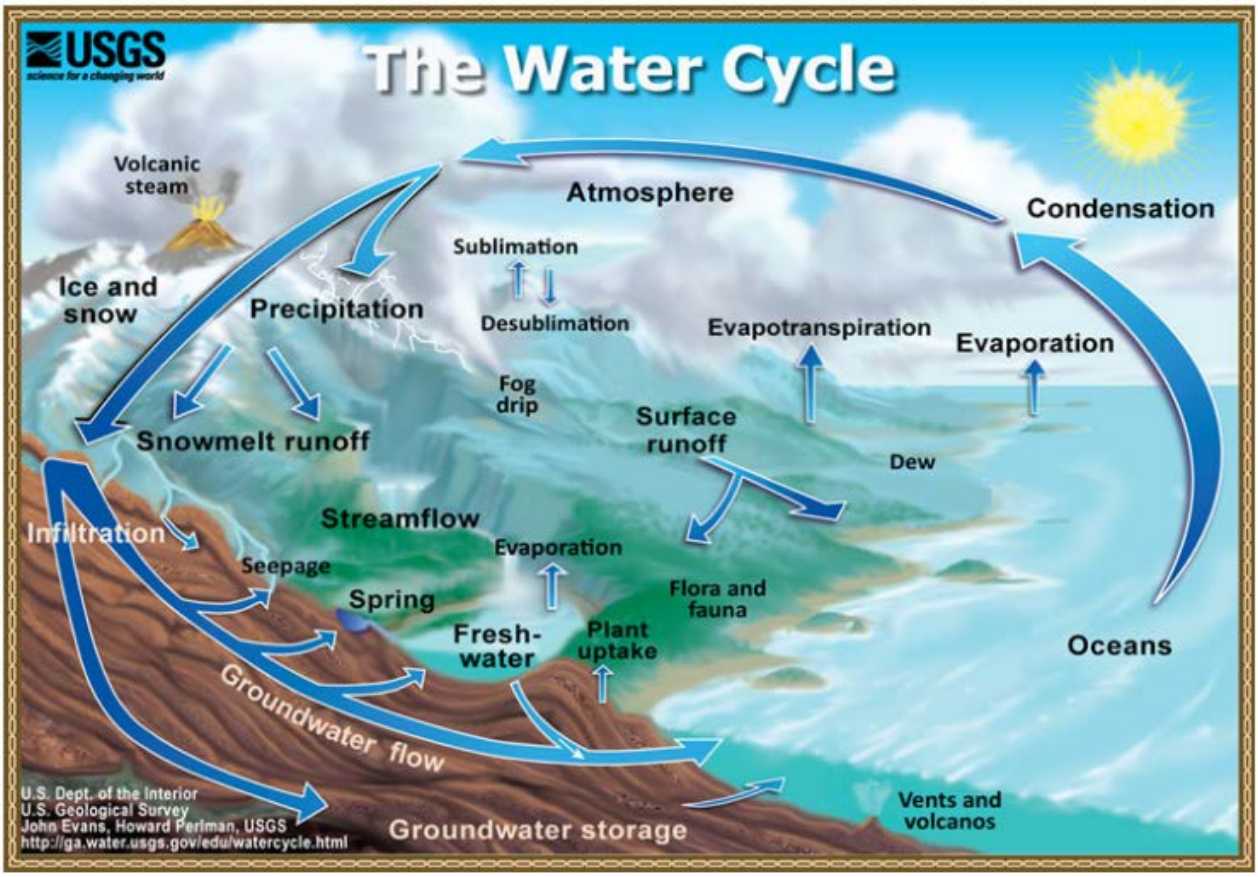
The equation has been simplified to:

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

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.

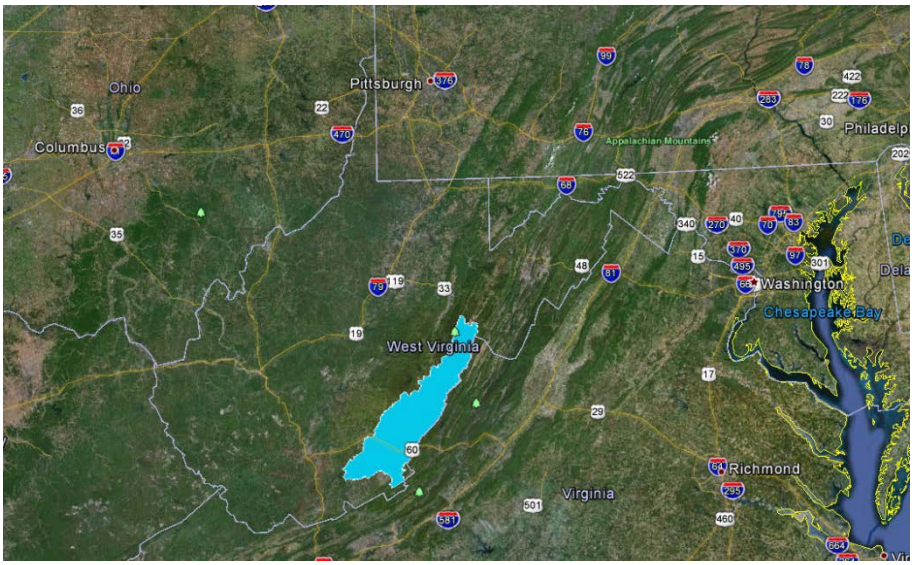


Figure 3-2 Greenbrier Watershed

Table 3-6 Summary of Greenbrier Watershed characteristics

Parameter	**Value**
Location	Lat:38.1° N 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 4.6×10^{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)
α = Priestly-Taylor calibration factor (unitless)
Δ = Slope of the saturation vapor pressure – temperature curve (kPa/K)
γ = Psychrometric constant (kPa/K)
ρ_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)
λ = 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 (+/-)
ΔS = 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.

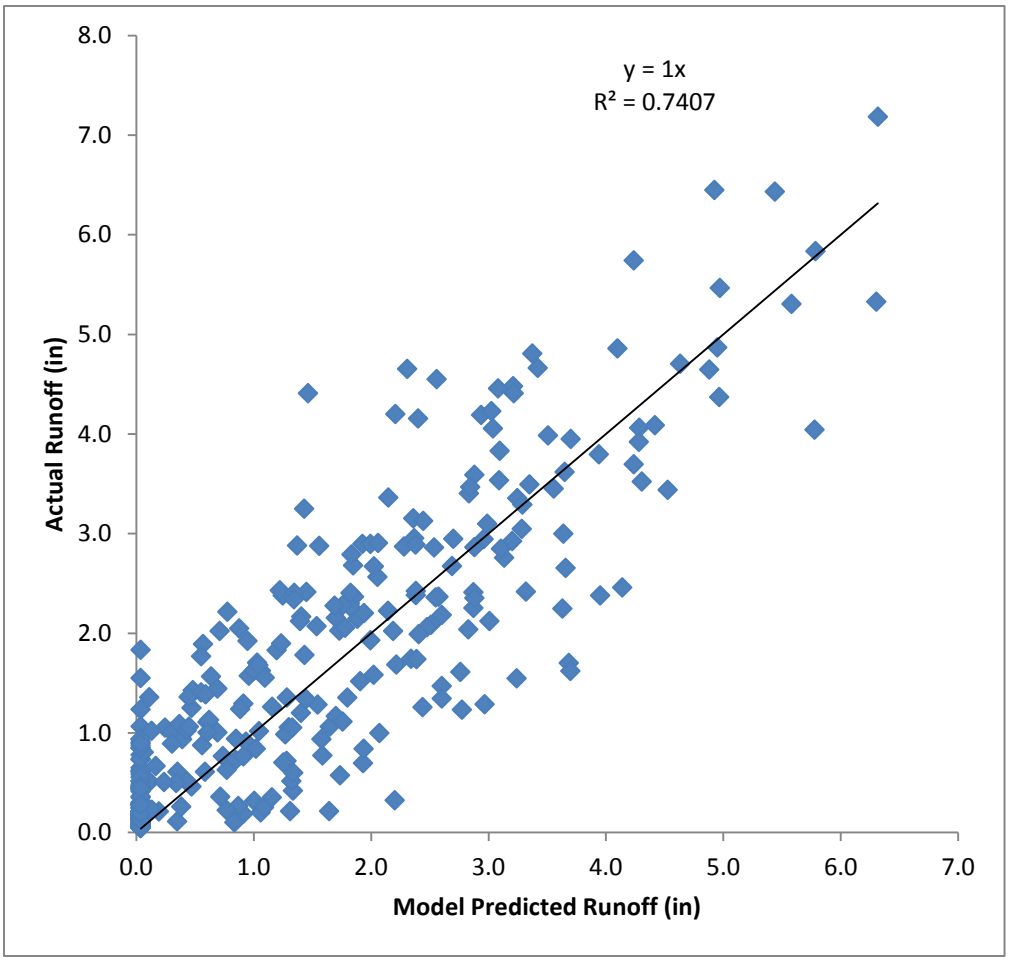


Figure 3-3 Comparison of Model Predicted Runoff and Actual Runoff during the study period (January 1986 – April 2013)

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.

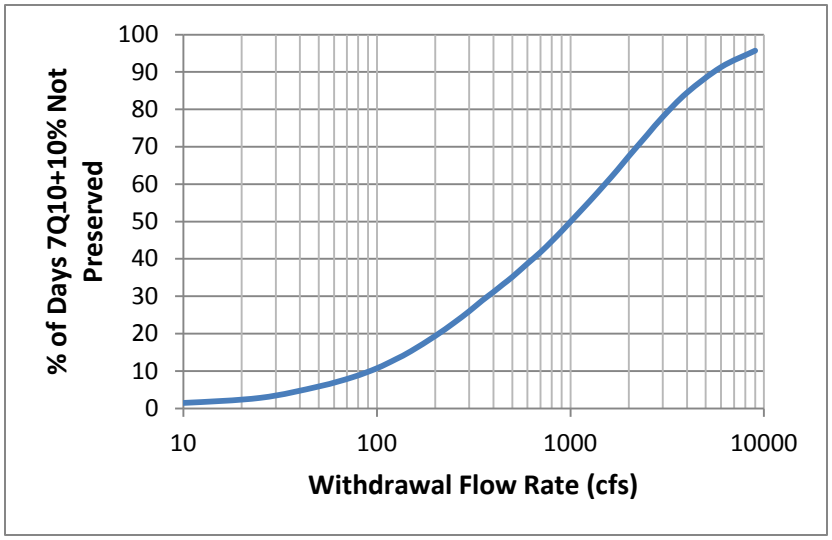


Figure 3-4 Withdrawal flow rate vs. percent of days where the 7Q10+10% flow rate would not be preserved in the stream

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.

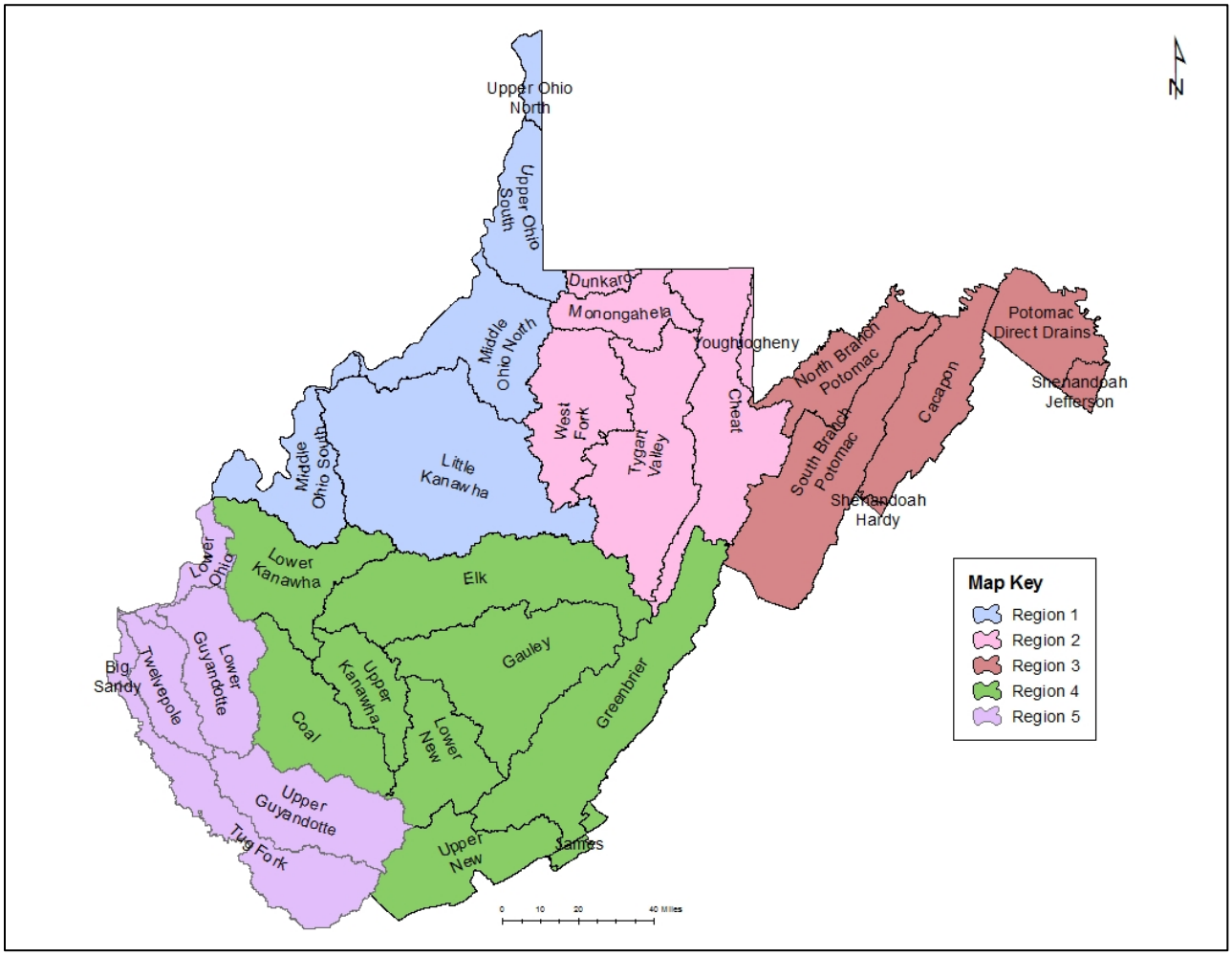


Figure 4-1 West Virginia has 32 HUC-8 watersheds and are shown divided into five regions.

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.

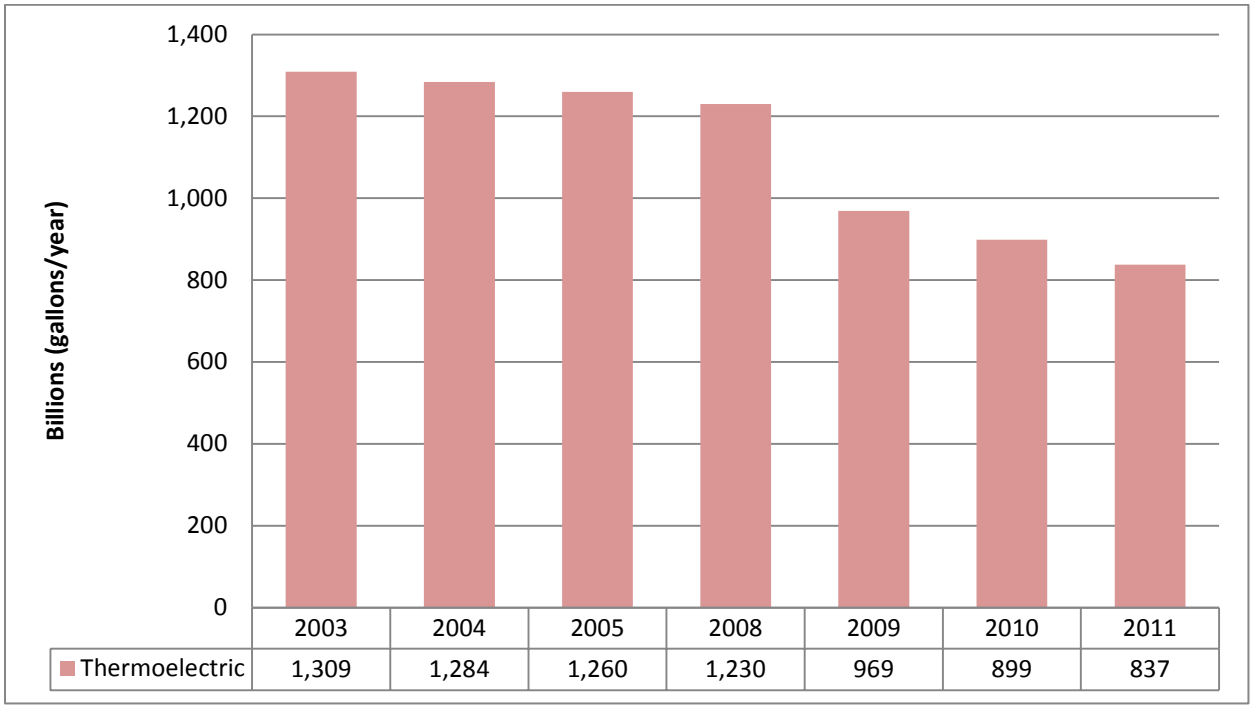
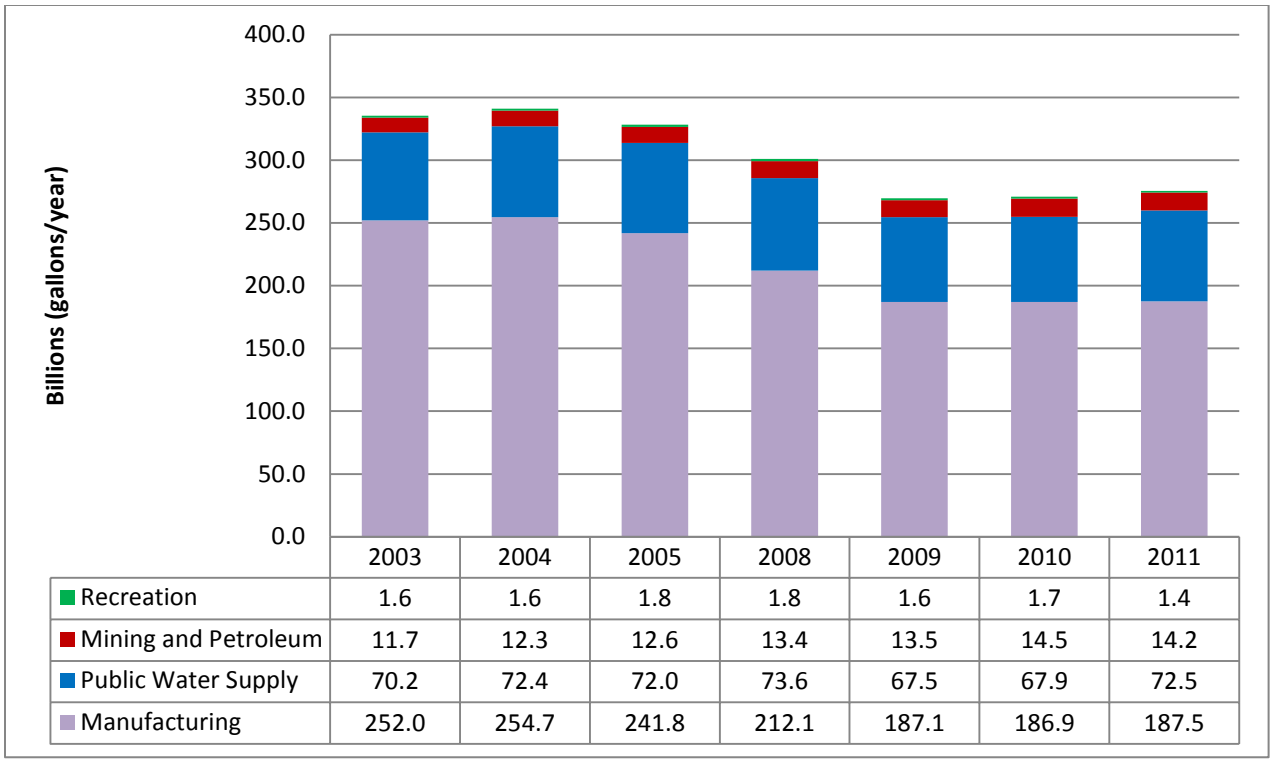


Figure 4-2 Annual withdrawals from the LQU database for the (amended) Thermoelectric* group in billions of gallons. *Shown separately due to scale.



	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.

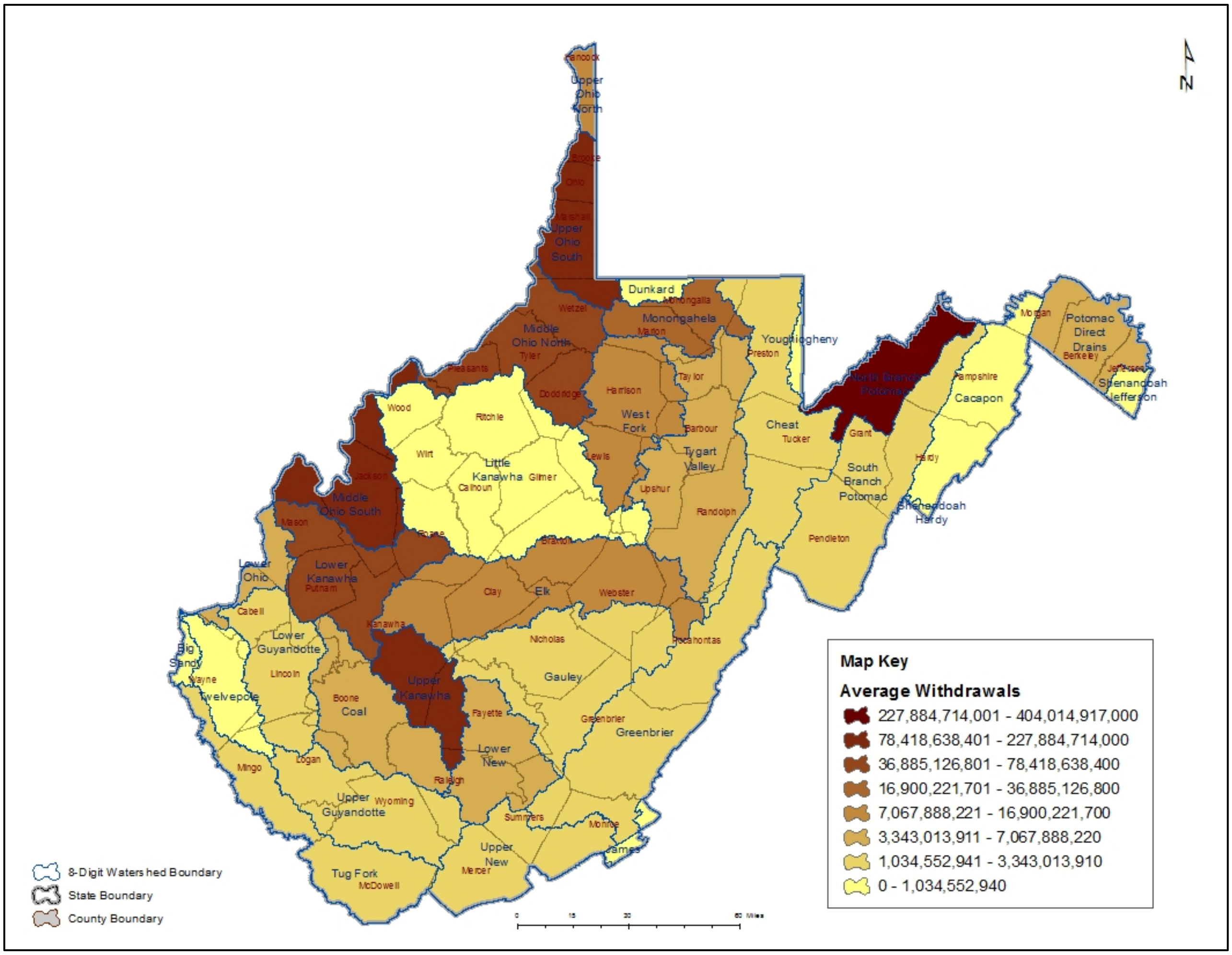


Figure 4-4 Average annual withdrawals occurring due to the activity of the recombined SIC groups, measured in gallons.

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 75th 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 75th 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	25th Percentile	Median Value	75th 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

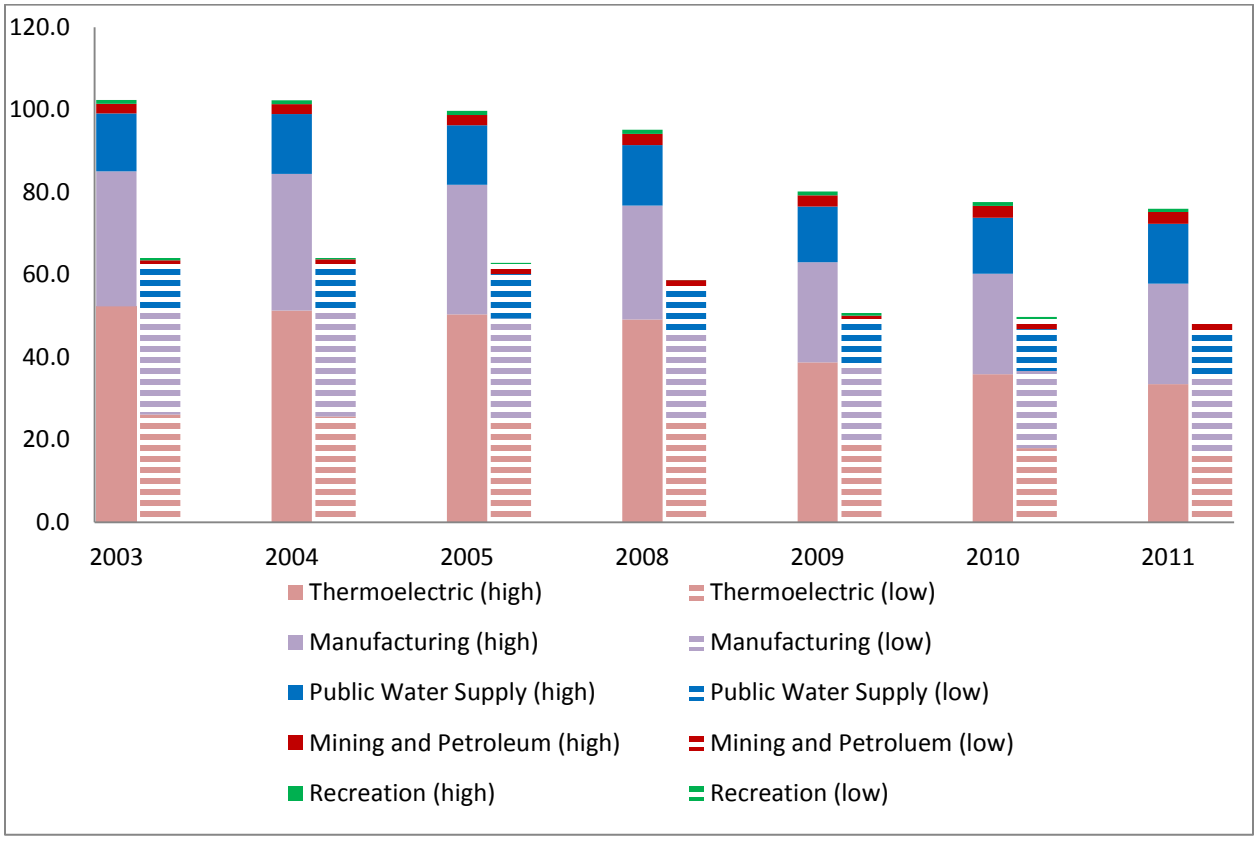


Figure 4-5 Annual high and low consumptive use scenario calculations (based on Shaffer and Runkle consumptive use coefficients) in billions of gallons.

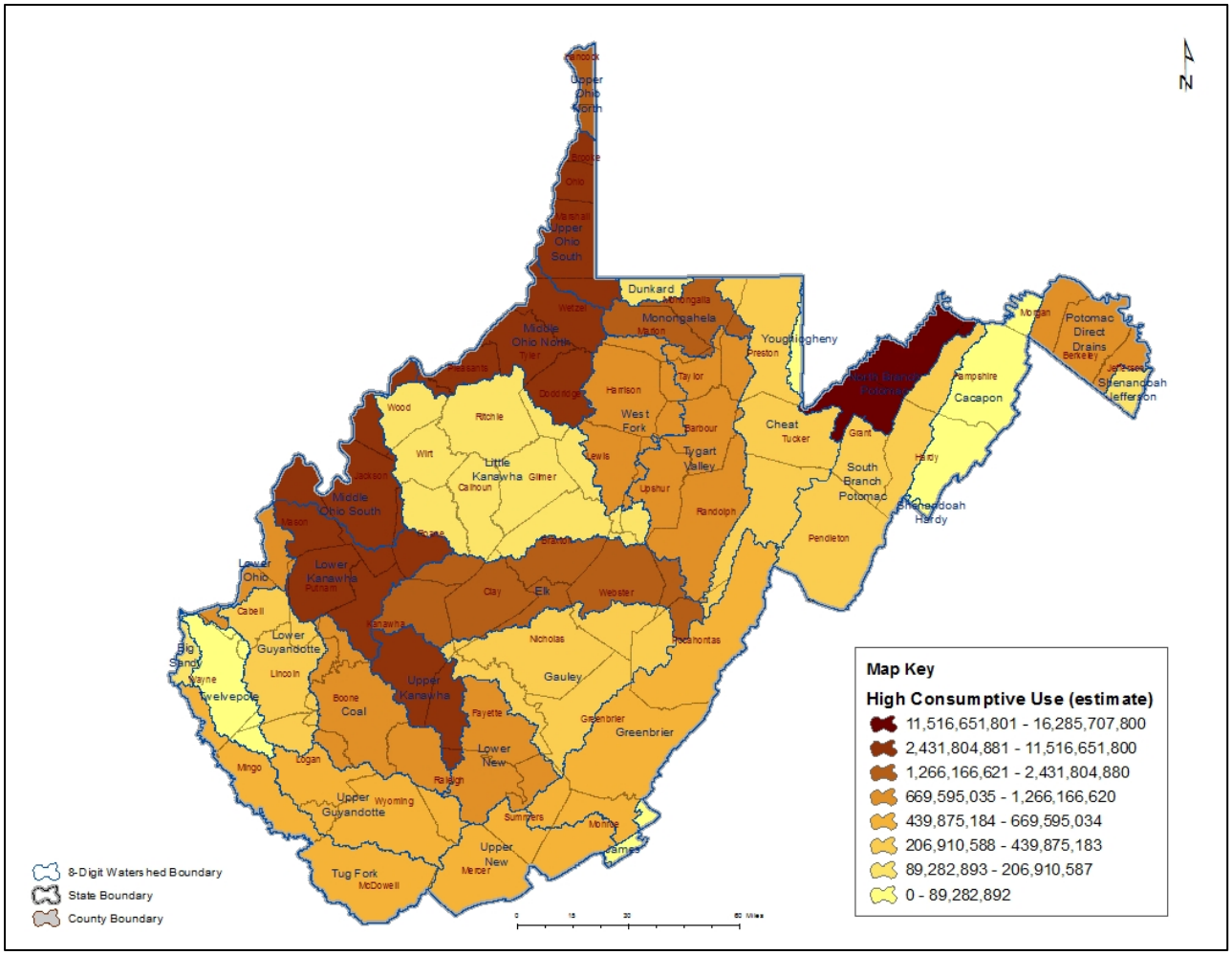


Figure 4-6 Estimate of average annual consumptive use (based on a high consumptive use scenario) occurring due to the activity of the recombined SIC groups, measured in gallons.

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.

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.

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

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.
   Example: 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.
   Example: 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).
   Example: 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_α 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.

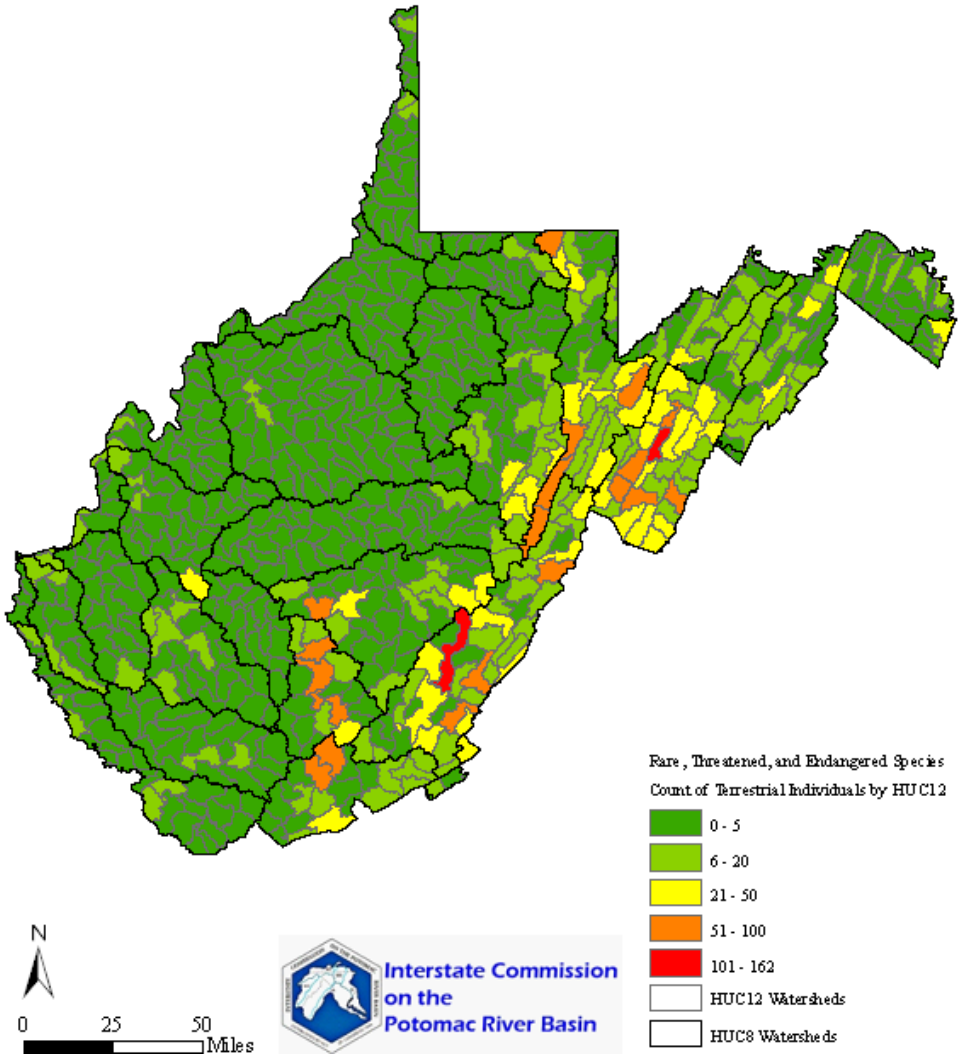


Figure 4-9 Count of rare, threatened, and endangered terrestrial individuals by HUC12. Data source: DNR

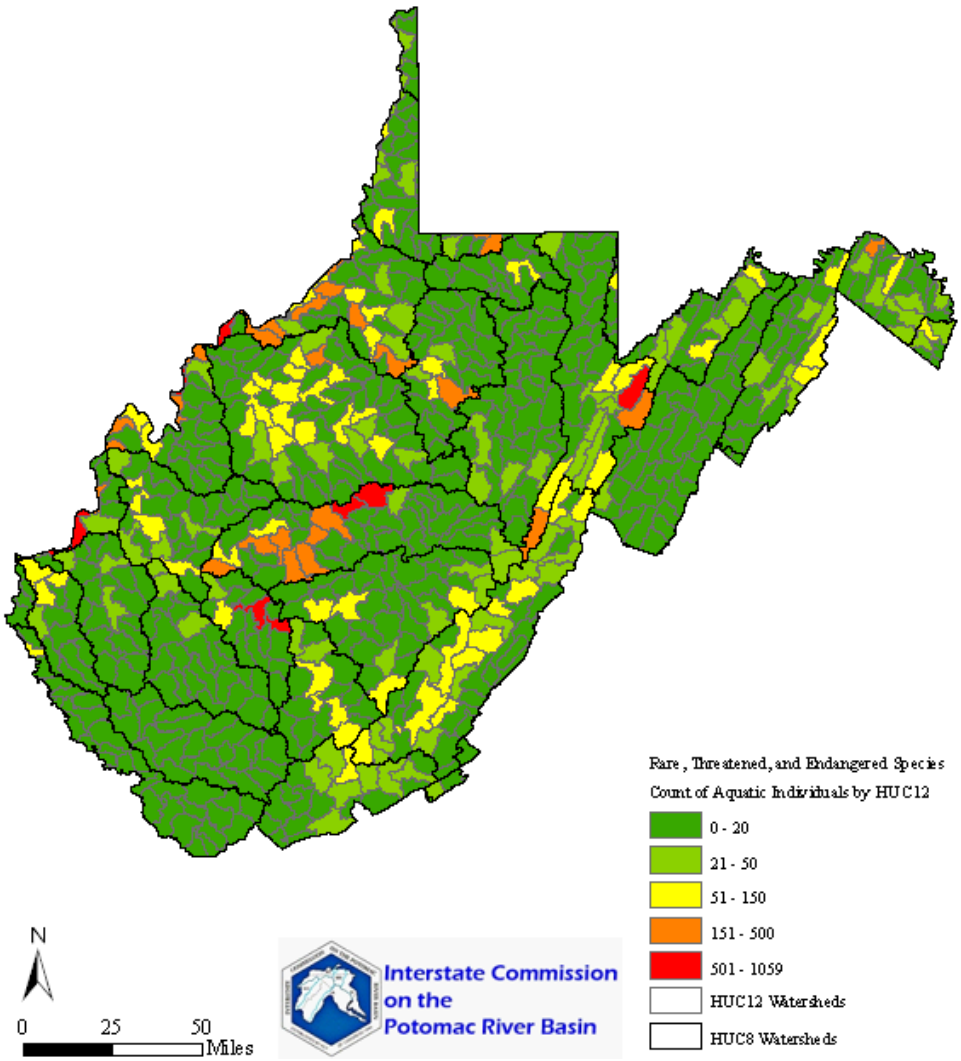


Figure 4-10 Count of rare, threatened, and endangered aquatic individuals by HUC12. Data source: DNR

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.

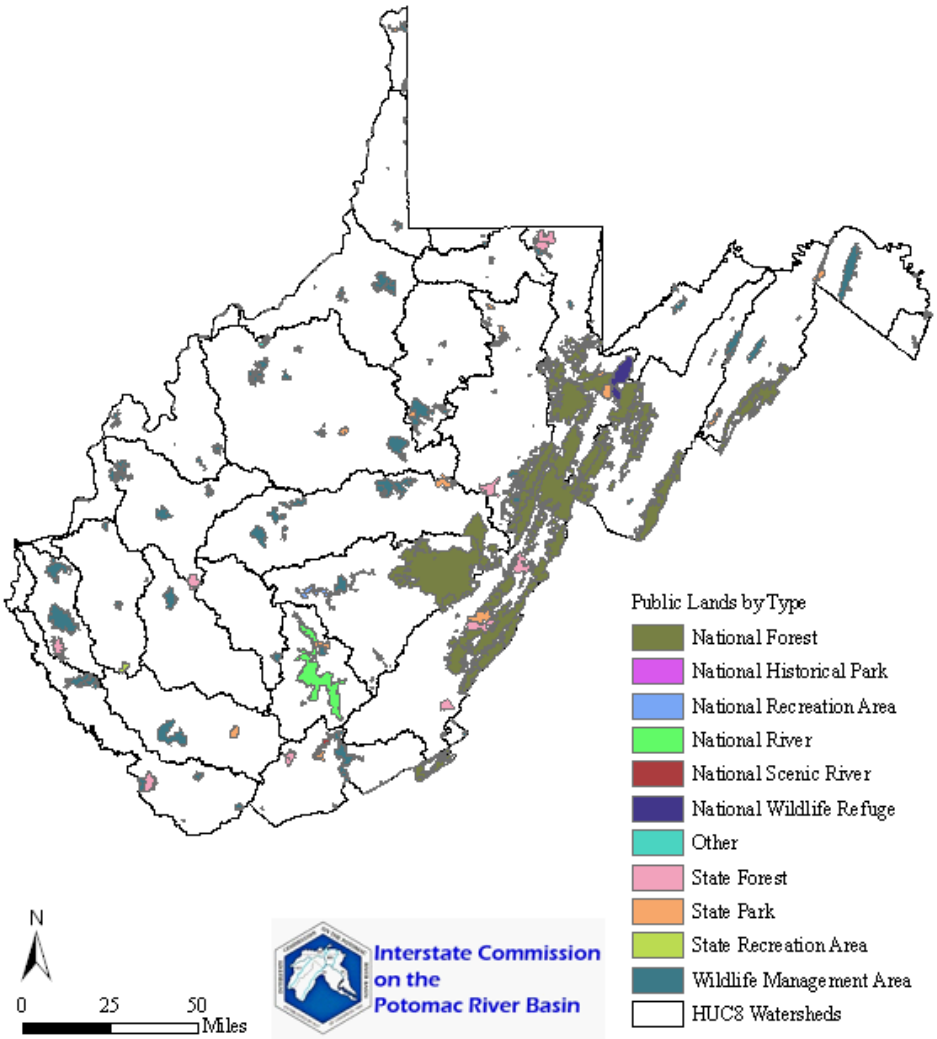


Figure 4-11 Location of public lands in West Virginia by type

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.

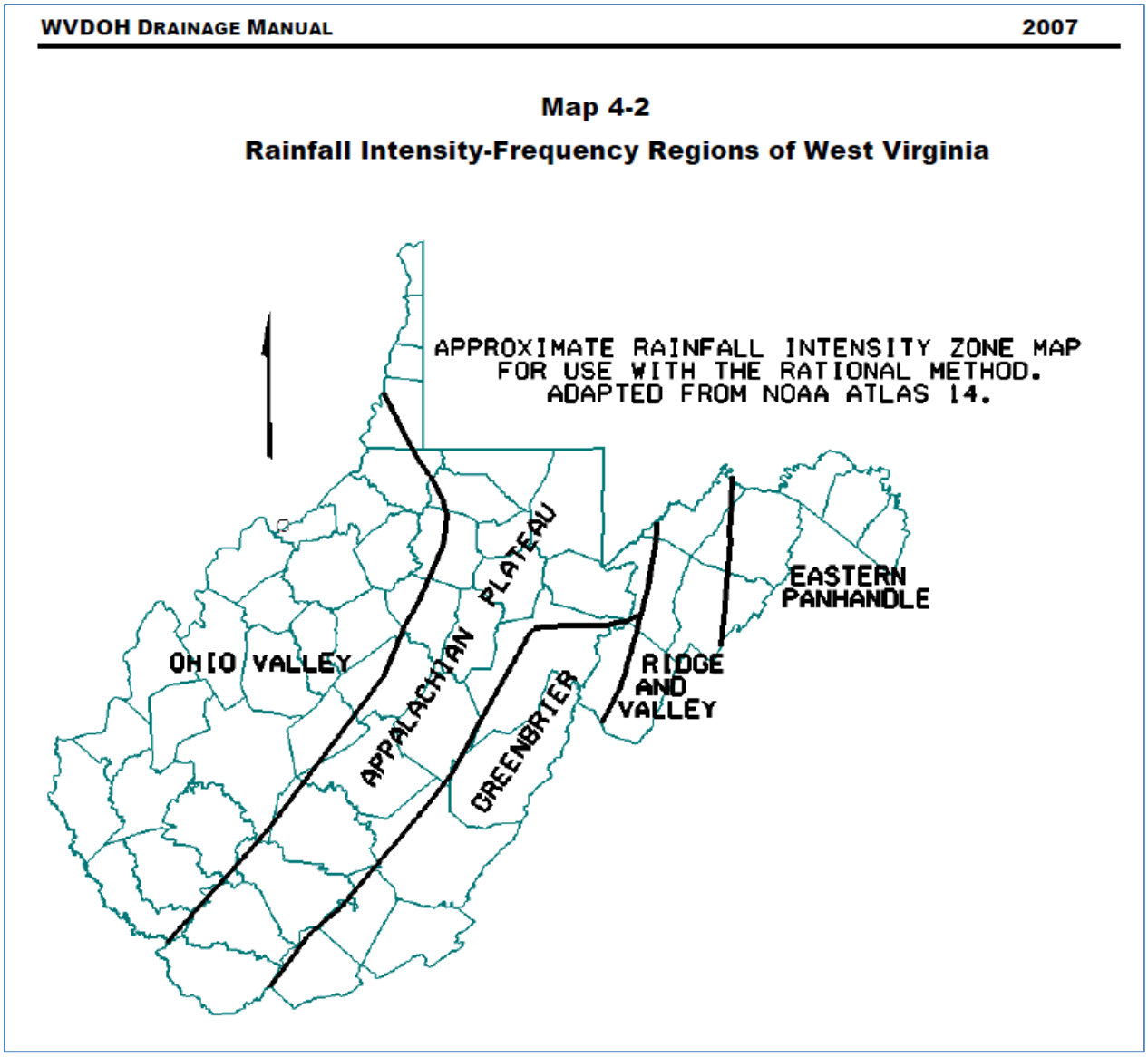


Figure 5-1 WVDOH Drainage Manual

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 (yellow)	-1.0 to -1.9 (yellow)	-1.00 to -1.49 (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 (tan) Severe Drought	-2.0 to -2.9 (tan) Excessively Dry	-1.50 to -1.99 (brown) 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 (brown) Extreme Drought	-3.0 or less (brown) Severely Dry	-2.00 and less (red) 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

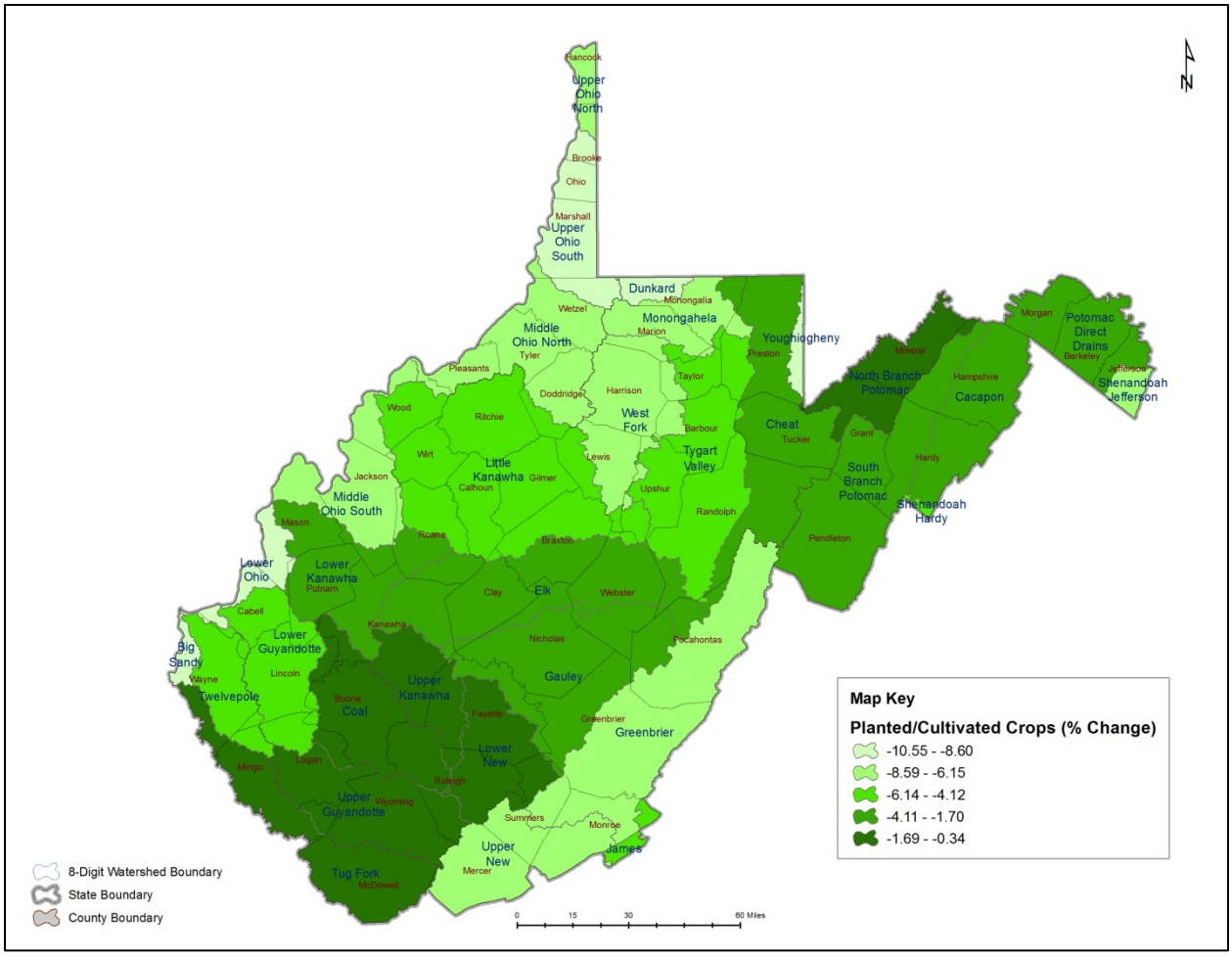


Figure 5-2 Percent change in Planted/Cultivated Crops (NLCD land cover database 1992 – 2006) by HUC-8 watershed.

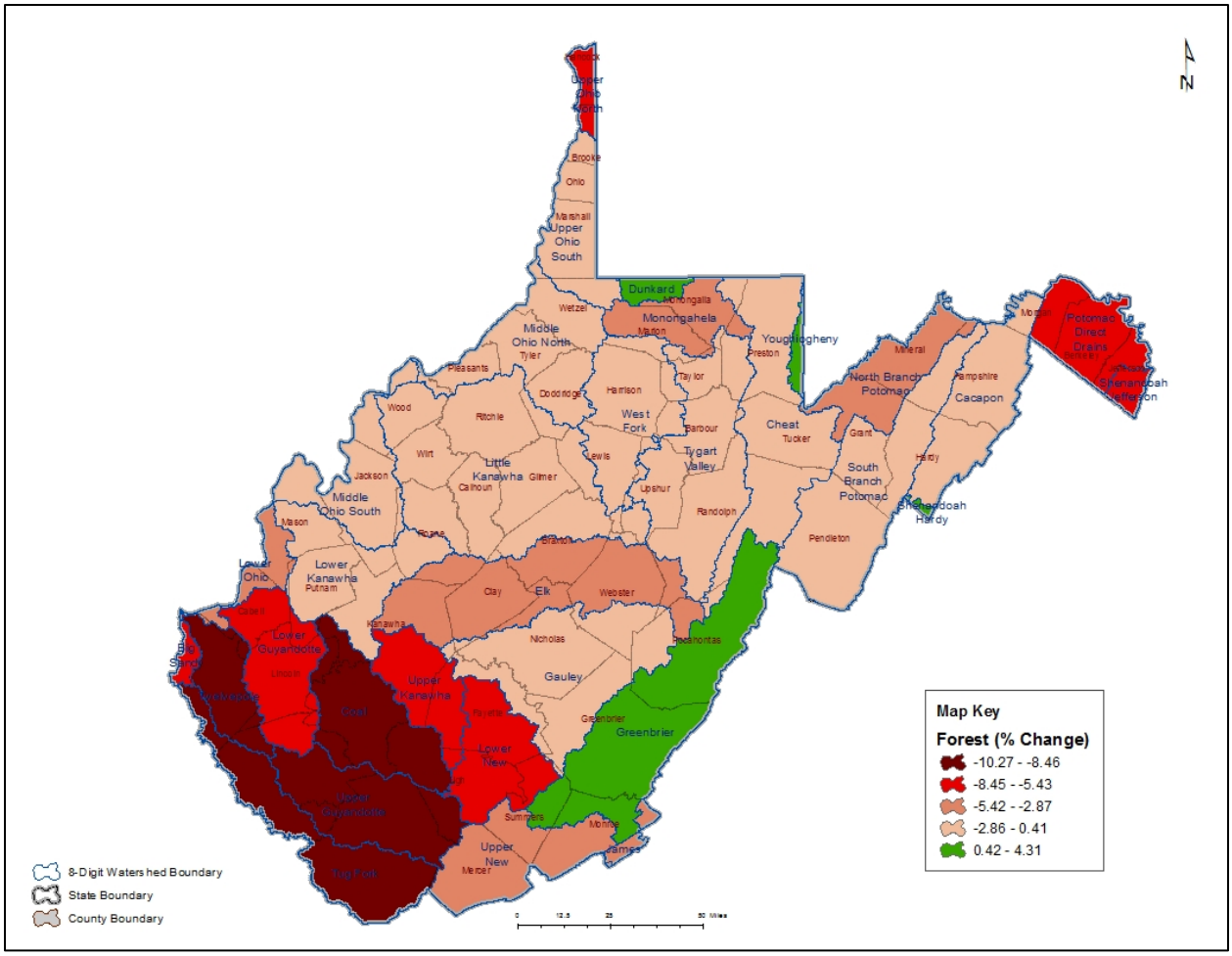


Figure 5-3 Percent Change in Forest NLCD land cover database 1992 – 2006 by HUC-8 watershed.

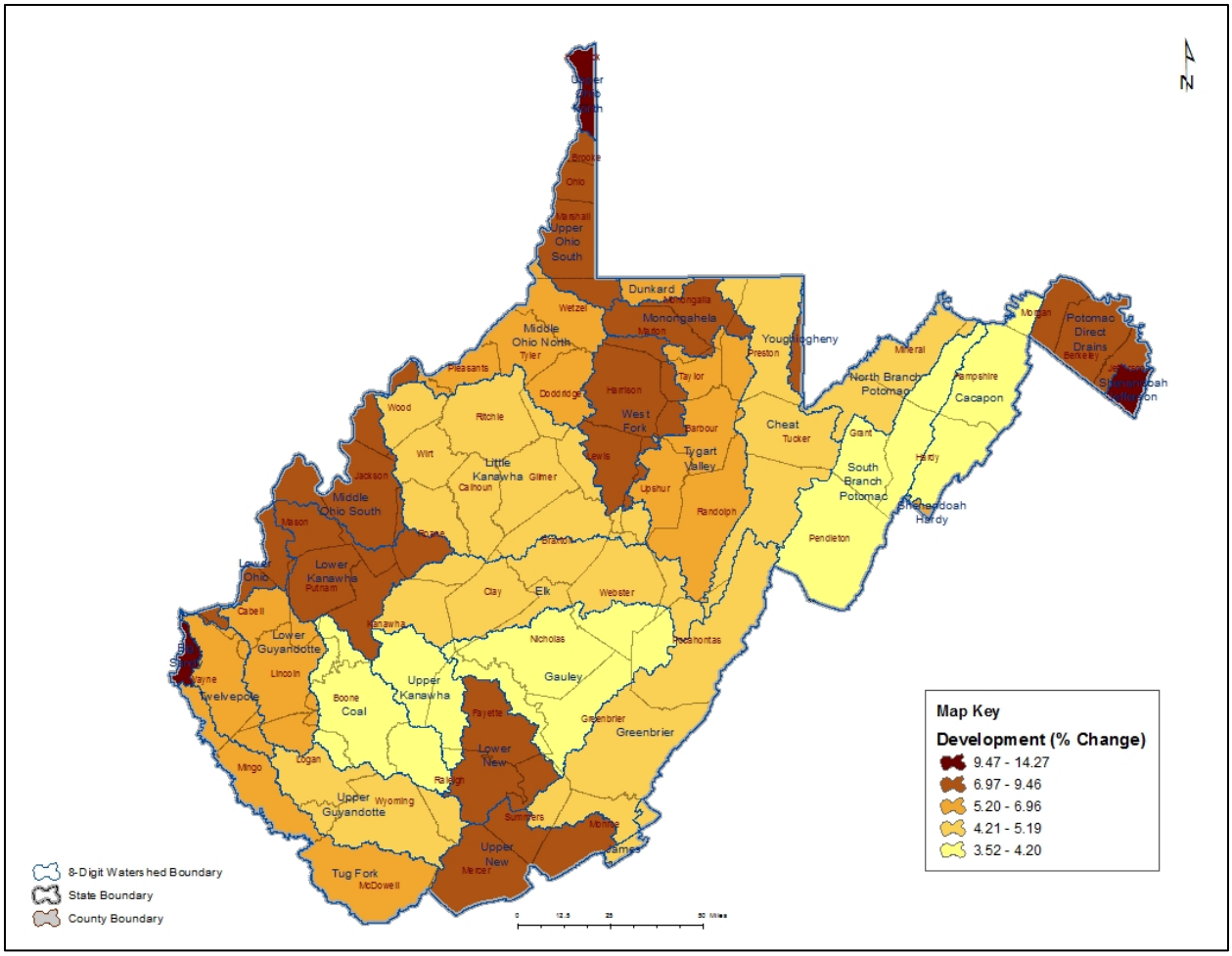


Figure 5-4 Percent Change in Development NLCD land cover database 1992 – 2006 by HUC-8 watershed.

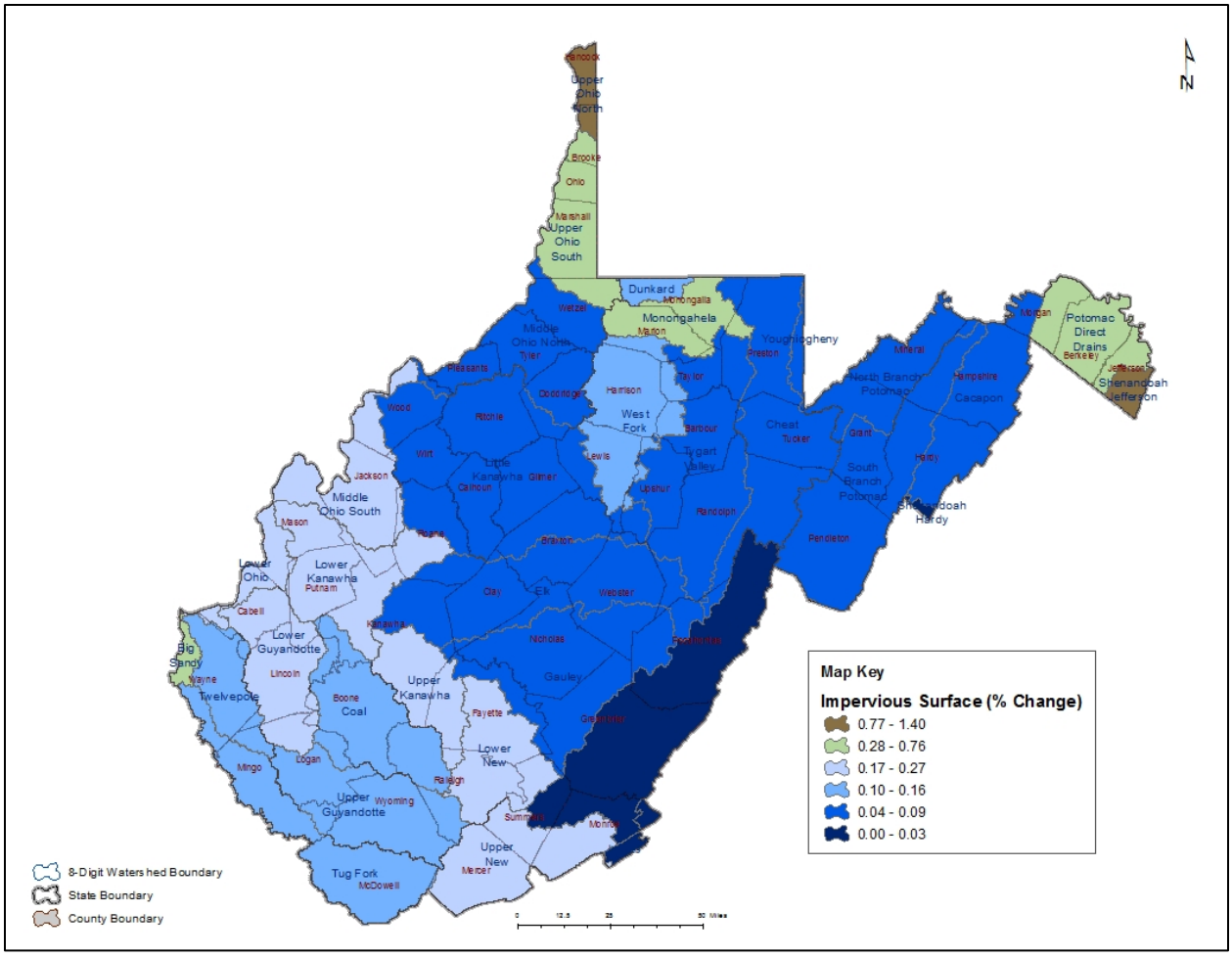


Figure 5-5 Percent change in Impervious NLCD land cover database 2001 – 2006 by HUC-8 watershed.

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.

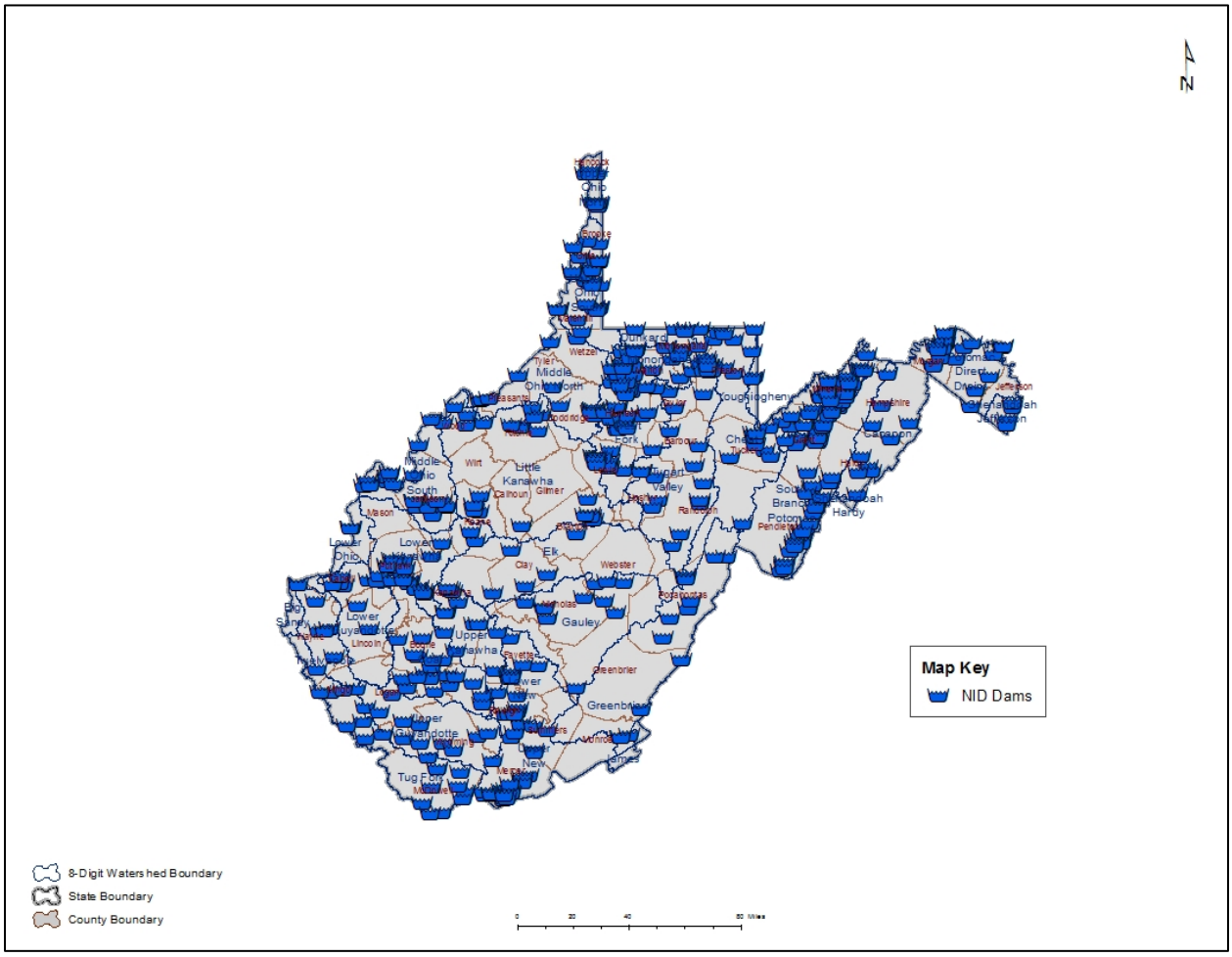


Figure 5-6 Location of NID dams within the state.

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) Zela Elementary School (NTNC)	Ravencliff, McGraws, Salusville (C) Summersville Municipal Water (C) Town of Alderson (C) Raleigh Co. PSD - Slab Fork (C) Zela Elementary School (NTNC)
2	St. Albans	Buffalo Creek PSD (C) Town of Hurricane (C) Pt. Pleasant Water Works (C) Coal River Energy (NTNC)	City of Ravenswood Water (C) Town of Wayne Water (C) Coal River Energy (NTNC)
3	Fairmont	NONE*	NONE*
4	Kearneysville	Valley Water & Sewer Services (C) Cavaland Subdivision (C) Glen Haven Utilities (C)	Berkeley Co. PSWD (C) City of Romney Water (C) Jefferson Util. – Burr Industrial (NTNC)
5	Wheeling	City of Cameron Water (C) City of Saint Marys (C)	NONE*
6	Philippi	Century Volga PSD (C) Chestnut Ridge PSD (C) Preston Co. PSD #4 (C)	Cheat Mountain Water (C) Town of Tunnelton (C) Aurora School (NTNC) 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%

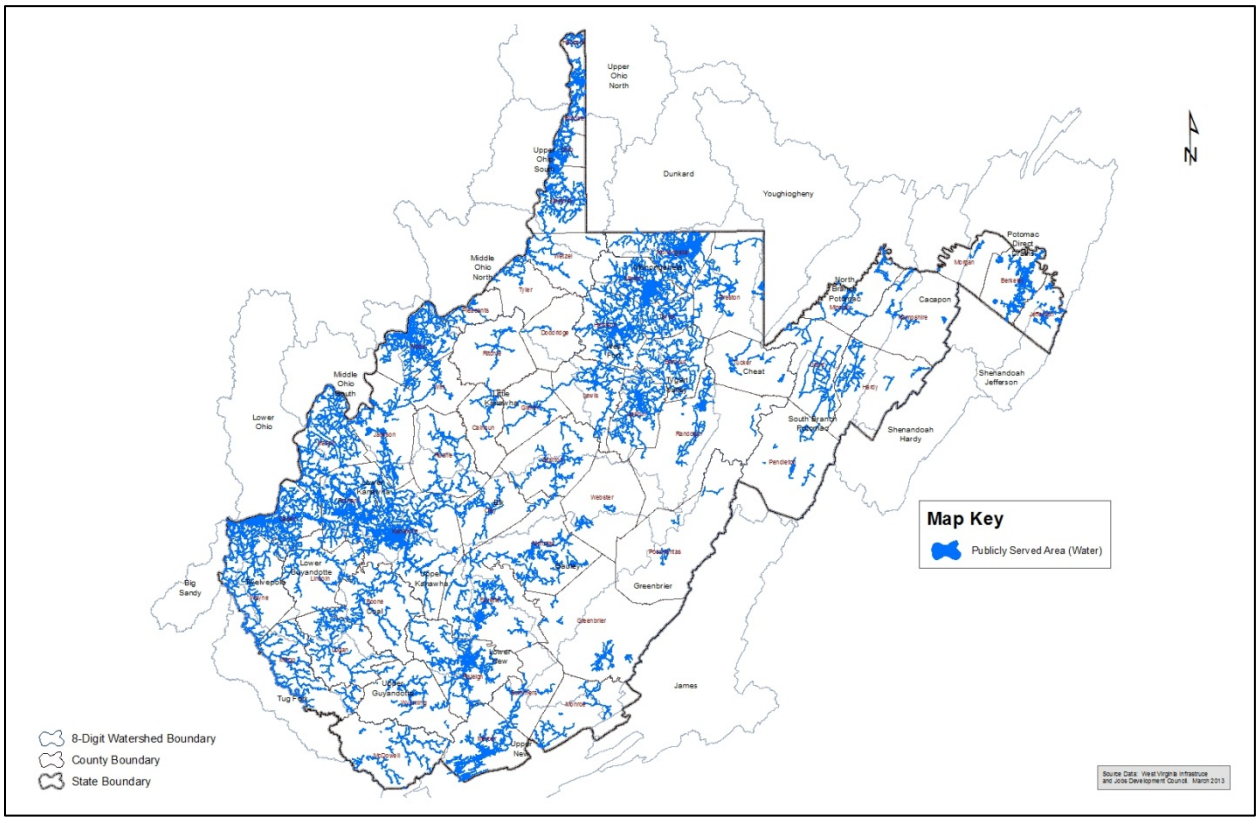


Figure 5-7 IJDC identified areas of public water supply serviced areas.

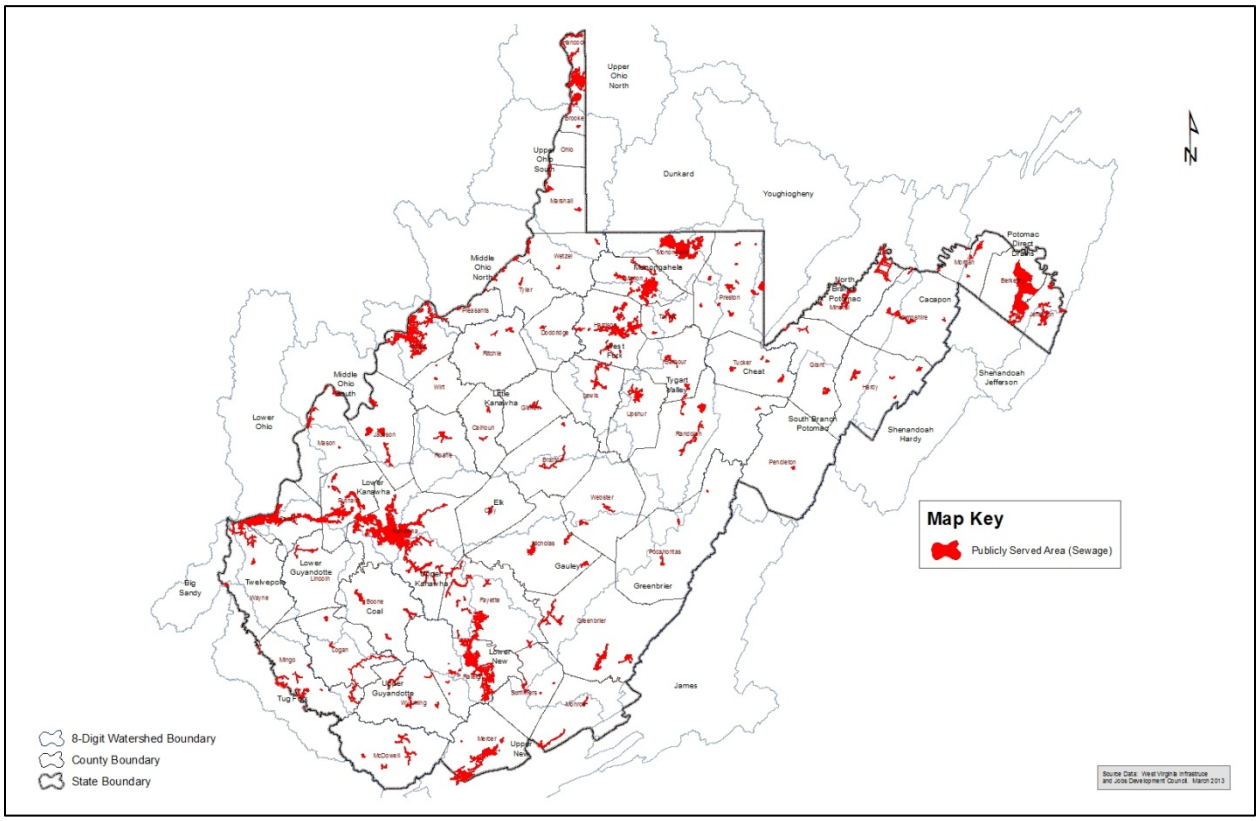


Figure 5-8 IJDC identified areas of public sewage serviced areas.

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

[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

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.

BIBLIOGRAPHY
APPENDICES

WATER USE SECTION west virginia department of environmental protection

Bibliography

TornadoHistoryProject.com. (2013). Retrieved February 7, 2013, from TornadoHistoryProject.com: http://www.tornadohistoryproject.com/

AEP Ohio. (2013). *Impact of New EPA Rulez.* Retrieved 01 30, 2013, from https://www.aepohio.com/info/news/NewEPARules/

Ahmed, S. A., Schultz, C. L., & Bencala, K. R. (2013). *2010 Washington Metropolitan Area Water Supply Reliability Study, Part 2: Potential Impacts of Climate Change. ICPRB report No. 13-01.*

Ahmed, S. N., Bencala, K. R., & Schultz, C. L. (2010). *2010 Washington Metropolitan Area Water Supply Reliability Study, Part 1: Potential Impacts of Climate Change.* ICPRB.

Ahmed, S. N., Bencala, K. R., & Schultz, C. L. (2011). *2010 Watshington Metropolitan Area Drought Operations Summary and Lessons Learned.* ICPRB.

Ahmed, S. N., Schultz, C. L., & Bencala, K. R. (2010). *2010 Washington Metropolitan Area Water Supply Reliability Study, Part 2: Demand and Resource Availability Forecast for the Year 2040.* ICPRB.

Allegheny Energy Supply prepared by URS Corporation. (2003). *Thermal, Water Quality, and Biological Study for West Fork River Clean Water Act, Section 316(a) Demonstration.*

Alley, W. M., Reilly, T. E., & Franke, O. L. (1999). Sustainability of Ground-Water Resources. *USGS Circular 1186*, p. 79.

American Society of Civil Engineers, Task Committee on Sustainability Criteria, & Unesco/IHP-IV. (1998). *Sustainability Criteria for Water Resource Systems.* Reston.

Archfield, S. A., Vogel, R. M., Steeves, P. A., Brandt, S. L., Weiskel, P. K., & Garabedian, S. P. (2010). The Massachusetts Sustainable-Yield Estimator: A Decision-Support Tool to Assess Water Availability at Ungaged Stream Locations in Massachusetts. In USGS, *Scientific Investigations Report 2009-5227* (p. 41).

Archfield, S. A., Vogel, R. M., Steeves, P. A., Brandt, S. L., Weiskel, P. K., & Garabedian, S. P. (2010). The Massachusetts Sustainable-Yield Estimator: A Decision-Support Tool to Assess Water Availability at Ungaged Stream Locations in Massachusetts. In USGS, *Scientific Investigations Report 2009-5227* (p. 41).

Australian Department of Sustainability, Environment, Water, Population, and Communities. (2004). *Definition and Approach to Sustainable Groundwater Yield, Annex A.* Retrieved 02 15, 2013, from http://www.environment.gov.au/water/publications/environmental/groundwater/pubs/annex-a.pdf

AWWA. (2009). *Water Audits and Loss Control Programs* (3rd ed.). American Waterworks Association.

Bailes, J. D., Costa, J. E., Holtschlag, D. J., Lanfear, K. J., Lipscomb, S., Milly, P. D., . . . Wolock, D. M. (2004). Design of a National Streamflow Information Program -- Report with recommendations of a committee. *U.S. Geological Survey, Open File Report 2004-1263*, p. 42.

Ballaron, P. B., Gavin, A., Pody, R. D., & Ladd, D. S. (2005). *Groundwater Management Plan For The Susquehanna River Basin, SRBC Report No. 236.*

Baniecki, J. F., & Dabaan, M. E. (1999). Crop Profile for Dairy in West Virginia. USDA. Retrieved 02 27, 2013, from http://www.ipmcenters.org/cropprofiles/docs/wvdairy.pdf

Barksdale, H. C., O'Bryan, D., & Schneider, W. J. (1966). Effect of drought on water resources in the Northeast. *U.S. Geological Survey Hydrologic Investigations Atlas HA-243*.

Barnes, Jr., H. H. (1964). Floods of March 1963, Alabama to West Virginia. *U.S. Geological Survey Open-File Report, 63*(8), p. 44.

Black and Veatch. (2008). Central Water Supply Plan Final Report. Prepared for Loudon Water, Black and Veatch Project No. 161194.

Brown, S. (2003). *This land is your land: West Virginia's public lands and waters.* Retrieved 02 19, 2013, from http://www.wvdnr.gov/wildlife/magazine/archive/03Fall/This_Land_is_Your_Land.shtm

Bureau of Labor Statistics. (2012). *Employment Projections - Employment by Major Industry Sector.* Retrieved 01 29, 2013, from http://www.bls.gov/emp/ep_table_201.htm

Bureau of Labor Statistics. (2013). *Industries at a Glance - Industries in Alphabetical Order.* Retrieved 01 25, 2013, from http://stats.bls.gov/iag/tgs/iag_index_alpha.htm

Carrow, R. N., Duncan, R. R., & Waltz, C. (2007). Best Management Practices (BMPs) Water-Use Efficiency/Conservation Plan for Golf Courses. University of Georgia, Crop and Soil Science Dept.,

Griffin, GA. Retrieved 02 25, 2013, from http://www.gcsaa.org/environment/resources/water-conservation/Course- Environment-WaterConservation-TemplateGuidelines-3.pdf

Chester County Water Resources Authority. (2002). *Watersheds: An Integrated Water Resources Plan for Chester County, Pennsylvania, and its Watersheds.*

Conger, R. W. (1996). Borehole geophysical logging for water-resources investigation in Pennsylvania. *U.S. Geological Survey Fact Sheet 218-95*, p. 4.

Connecticut Department of Environmental Protection. (2006). Best Mangament Practices for Golf Courses. 76. Retrieved 02 25, 2013, from http://www.gcsaa.org/environment/resources/water-conservation/Course- Environment-WaterConservation-Connecticut-BMPs.pdf

Considine, T. J. (2010). *The Economic Impacts of the Marcellus Shale: Implications for New York, Pennsylvania, and West Virginia - A Report to the American Petroleum Institute.* Natural Resource Economics Inc., Laramie. Retrieved 01 31, 2013, from http://www.api.org/news-and-media/news/newsitems/2010/jul-2010/~/media/Files/News/2010/API%20Economic%20Impacts%20Marcellus%20Shale.ashx

Cristiadi. (2011). *Population Projection for West Virginia Counties.* West Virginia University, Bureau of Business & Economic Research, College of Business and Economics. Retrieved 01 04, 2013, from http://www.be.wvu.edu/demographics/documents/WVPopProjectionbyCounty2011_001.pdf

Cummins, J., Buchanan, C., Moltz, H., Griggs, A., Jones, C., Kraus, R., . . . Bumgardner, R. (2010). Potomac Large River Ecologically Sustainable Water Management Report. In ICPRB.

Cutright, A. E., & Giglio, K. (2012). Coal Mine Drainage for Marcellus Shale Natural Gas Extraction. *Roundtable on Feasibility and Challenges* (p. 67). Santa Monica: RAND Corporation.

Davies, W. F., Bailey, J. F., & Kelly, D. B. (1972). West Virginia's Buffalo Creek flood - A study of the hydrology and engineering geology. *U.S. Geological Survey Circular*, p. 32.

DEP. (2006). *Implementation of the Water Resources Protection Act, WV Code, Article 22-26, Final Report.*

DNR. (2012). *Federally Threatened and Endangered Species in West Virginia.* Retrieved 02 22, 2013, from http://www.wvdnr.gov/Wildlife/PDFFiles/TElist.pdf

Doll, W. C., Meyer, G., & Archer, R. J. (1963). *Water resources of West Virginia.* West Virginia Department of Natural Resources, Division of Water Resources, Charleston, WV.

Donovan, J. J., Duffy, B., Leavitt, B. R., Stiles, J., Vandivort, T., & Ziemkiewicz, P. (2004). *Strategies for Cooling Electric Generating Facilities Utilizing Mine Water: Technical and Economic Feasibility Project, Final Report to the U.S. Department of Energy under Cooperative Agreement No. DE-PS26-03NT41719.* West Virginia University, West Virginia Water Research Institute.

DRBC. (1999). *Delaware River Basin Commission Groundwater Protected Area Regulations Southeastern Pennsylvania. Resolution No. 80-18 with amendments.*

D'Souza, G. D., Miller, D., Semmens, K., & Smith, D. (2004). Mine Water Aquaculture: Linking Coal Mining, Fish Farming, Water Conservation, and Recreation. *2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mining Drainage Task Force.* Lexington: ASMR.

EPA. (2002). Potential Environmental Impacts of Dust Suppressants: "Avoiding another Times Beach". *An Expert Panel Summary*, (p. 97). Las Vegas. Retrieved 02 27, 2013, from www.epa.gov/esd/cmb/pdf/dust.pdf

EPA. (2004). *Environmental Best Management Practices for Small Business.* Hotel. Retrieved 02 27, 2013, from www.smallbiz-enviroweb.org/Industry/bmpfiles/BMP_Hotel-5-4.pdf

EPA. (2009). *Review Draft: Control and Mitigation of Drinking Water Losses in Distribution Systems: EPA 816-D-09-001.* Retrieved 02 27, 2013, from www.epa.gov/ogwdw/pws/pdfs/analysis_wa-03_water_loss_doc_final_draft_v62.pdf

EPA. (2011). *The Lean and Water Toolkit.* Lean Manufacturing, Office of Strategic Management, Washington, D.C. Retrieved 02 25, 2013, from www.epa.gov/lean/environment/toolkits/water/resources/lean-water-toolkit.pdf

Feeley, T., Green, L., Murphy, J., Hoffman, J., Duda, J., Kleinmann, R., & Ackman, T. (2005). *Addressing the Critical Link Between Fossil Energy and Water.* Department of Energy, Office of Fossil Energy's Water Related Research, Development, and Demonstration Programs, Washington, D.C.

First Energy Corp. (2012). *First Energy, Citing Impact of Environmental Regulations, will retire six coal-fired power plants.* Retrieved 01 30, 2013, from https://www.firstenergycorp.com/content/fecorp/newsroom/featured_stories/Coal_Plant_Retirements0.html

Florida Department of Environmental Protection. (2009). *Green Lodging.* Water Conservation. Retrieved 02 25, 2013, from www.dep.state.fl.us/greenlodging/bmp_water.htm

Folkedahl, B. C., Weber, G. F., Collings, M. E., Copen, J., Sullivan, T., & Deen, P. (2006). *Water Extraction From Coal-Fired Power Plant Flue Gas: Final Report to National Energy Tech Laboratory contract No. DE-FC26-03NT41907.*

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang , L., . . . Wickham, J. (2011). Completion of the 2006 National Land Cover Database for the Conterminous United States. *PE&RS, 77*(9), pp. 858-864.

GE Water and Process Technologies. (2007). *Solutions for Sustainable Water Savings: A Guide to Water Efficency,.* Trevose.

GEMI. (2007). *Collecting the Drops: A Water Sustainability Planner.* Washington, D.C. Retrieved 02 26, 2013, from www.gemi.org/waterplanner/category-documents/asp?MapCat=50

Gerdes, K., & Nichols, C. (2008). *Water Requirements for Existing and Emerging Thermoelectric Plan Technologies.* Departent of Energy, National Energy Laboratory.

Gerhart, J. M., & Lazorchick, G. J. (1988). Evaluation of the Ground-Water Resources of the Lowe Susquehanna River Basin, Pennsylvania and Maryland. In USGS, *Water-Supply Paper 2284* (p. 128).

Hagen, E., Dalpra, C., & Steiner, R. C. (1999). *Washington Area 1999 Drought Operations.* ICPRB.

Harlow, Jr., G. E., Yager, R. M., Nelms, D. L., Kozar, M. D., Sanford, W. E., & Moberg, R. M. (2008). Estimating Recharge to Heterogenous Fractured-Rock and Karst Aquifer Systems in the Shenandoah Valley of Virginia and West Virginia. In USGS, *Survey Scientific Investigations Report 2008-5023* (p. 50). Bowling Green.

IPCC. (2007). Climate Change 2007: The Physical Science Basis. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, . . . H. L. Miller, *Contribution of Working Group 1 to the Fourth*

Assessment Report of the Intergovernmental Panel on Climate Change. New York: Cambridge University Press.

Jarrett, A. R., & Roudsari, S. S. (2007). *Animal and Irrigation Water Use in Pennsylvania in 2002, 2010, 2020, and 2030.* Pennsylvania Department of Environmental Protection, Bureau of Watershed Management, Harrisburg.

Jarrett, A. R., & Roudsari, S. S. (2007). *Animal and Irrigation Water Use in Pennsylvania in 2002, 2010, 2020, and 2030.* Pennsylvania Department of Environmental Protection, Bureau of Watershed Management.

Johnston, H. E., & Baer, M. J. (1987). Rhode Island water supply and use. *U.S. Geological Survey Water-Supply Paper*, pp. 447-452.

Keaton, J. N., Messinger, T., & Doheny, E. J. (2005). Development and analysis of regional curves for streams in the non-urban Valley and Ridge Physiographic Province, Maryland, Virginia, and West Virginia. *U.S. Geological Survey Scientific Investigations Report 2005-5076*, p. 116.

Kenny, J. F., Barber, N. L., Hutson, S. S., Linsey, K. S., Lovelace, J. K., & Maupin, M. A. (2009). Estimated use of water in the United States in 2005. *U.S. Geological Survey Circular*, p. 52.

Keys, W. S. (1988). Borehole geophysics applied to ground-water investigations. *U.S. Geological Survey Open-File Report 87-539*, p. 305.

Kiang, J. E., & Hagen, E. R. (2003). *2002 Drought Operations and Lesson Learned Washington Metropolitan Area.* ICPRB.

Kozar, M. D., & Mathes, M. V. (2001). Aquifer-Characteristics Data for West Virginia. In USGS, *Water Resources Investigation 2001-4036* (p. 74). Reston.

Loomis, J. B. (2002). *Integrated Public Lands Management: Principle and Applications to National Forests, Parks, Wildlife Refuges, and BLM Lands.* New York: Columbia University Press.

Lumb, A. M., Kittle, Jr., J. L., & Flynn, K. M. (1998). User's Manual for ANNIE, a computer program for interactive hydrologic analyses and data management. In USGS, *Water Resources Investigations Report 89-4080* (p. 236).

Macleod, R., & Congalton, R. (1998). A Quantitative Comparison of Change-Detection Algorithms for Monitoring Eelgrass from Remotely Sensed Data. *Photogrammetric Engineering and Remote Sensing, 64*(3), 207-216.

Masry, S., Crawley, B., & Hilborn, W. (1975). Difference Detection. *Photogrammetric Engineering and Remote Sensing, 41*(9), 1145-1148.

Mavis, J. (2003). *Water Use in Industries of the Future.* U.S. Department of Energy.

Mehan, III, G. T., & Kline, I. (2012). Pricing as a Demand-Side Management Tool: Implications for Water Policy and Governance. *Journal of the American Water Works Association, 104*(2).

Messinger, T. (2003). Comparison of Storm Response of Streams in Small, Unmined and Valley-Filled Watersheds, 1999-2001, Ballard Fork, West Virginia. In USGS, *Water-Resources Investigation Report 02-4303* (p. 2).

Messinger, T. (2009). Regional curves for bankfull channel characteristics in the Appalachian Plateaus, West Virginia. *U.S. Geological Survey Scientific Investigations Report 2009-5242*, p. 43.

Messinger, T., & Paybins, K. S. (2003). Relations Between Precipitation and Daily and Montly Mean Flows in Gaged, Unmined and Valley-Filled Watersheds, Ballard Fork, WV, 1999-2001. In USGS, *Water-Resources Investigation Report 03-4113* (p. 51).

Miller, D. (2008). Using Aquaculture as a Post-Mining Land Use in West Virginia. *Mine Water Environment*(27), 122-126.

National Hydrologic Warning Council. (2006). *Benefits of USGS streamgaging program - users and uses of streamflow data.* Retrieved March 19, 2013, from http://water.usgs.gov/osw/pubs/nhwc_report.pdf

National Park Service. (2008, September 16). Letter From Dennis R. Reidenbach, Regional Director, Northeast Region, National Park Service to Joe Hoffman, Executive Director, ICPRB.

NC-DENR. (2009). *Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities.* North Carolina Department of Environment and Natural Resources Division of Water Resources, Division of Pollution Prevention and Assistance, Land-of-Sky Regional Council.

NHDES. (2010). *Water Efficiency Practices for Snowmaking.*

NRCS. (2006). *Conservation Practices That Save: Irrigation Water Management.* Retrieved 02 26, 2013, from www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/energy/?cid=nrcs143_023638

Olmstead, S. M., & Stavins, R. N. (2007). Managing Water Demand: Price vs. Non-Price Conservation Programs. A Pioneer Institute White Paper. *39*, 47. Retrieved 02 27, 2013, from www.hks.harvard.edu/fs/rstavins/Monographs_&_Reports/Pioneer_Olmstead_Stavins_Water.pdf

PA DEP. (1992). *General Policy and Procedure for the Review of Water Allocation Permit Applications.* Retrieved 02 15, 2013, from http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-48371/392-2130-001.pdf

Penn State. (2008). *Household Water Conservation.* Penn State University, Agricultural Research and Cooperative Extension. Retrieved 05 28, 2012, from http://pubs.cas.psu.edu/freepubs/pdfs/uh164.pdf

Poff, N. L., Richter, B. D., Arthington, A. H., Bunn, S. E., Naiman, R. J., Kendy, E., . . . Warner, A. (2010). The Ecological Limits of Hydrologic Alteration (ELOHA): A new framework for developing regional environmental flow standards. *Freshwater Biology, 55*(1), 147-170.

Richter, B. D., & Thomas, G. A. (2007). Restoring Environmental Flows by Modifying Dam Operations. *Ecology and Society, 12*(1), 12. Retrieved 02 28, 2013, from http://www.ecologyandsociety.org/vol12/iss1/art12/

Risser, D. W., Gburek, W. J., & Folmar, G. J. (2005). Comparison of Methods for Estimating Ground-Water Recharge and Base Flow at a Small Watershed Underlain by Fractured Bedrock in the Eastern United States. In USGS, *Scientific Investigations Report 2005-5038* (p. 37).

Rossman, L. A. (1990). *DFLOW User's Manual.* EPA, Washington, D.C.

Runner, G. S., & Chin, E. H. (1980). Flood of April 1977 in the Appalachian region of Kentucky, Tennessee, Virginia, and West Virginia. *U.S. Geological Survey Professional Paper*, p. 43.

Rutledge, A. T. (1998). Computer Programs for Describing the Recession of Ground-Water Discharge and for Estimating Mean Ground-Water Recharge and Discharge From Streamflow Records-Update. In USGS, *Water Resources Investigation Report 98-4148* (p. 43).

Semmens, K. J., & Jacobs, J. J. (2012). Sustainable Aquaculture Using Treated and Untreated Water From Coal Mines. In J. A. Jacobs, J. H. Lehr, & S. M. Testa, *Handbook of Acid Mine Drainage and Acid Sulfate Soils.* Hoboken, New Jersey: John Wiley & Sons, Inc.

Semmens, K. J., & Miller, D. (2010). Growing Fish in Treated Mine Water. *Fish Tales Newsletter, 8*(1).

Shaffer, K. H. (2009). Variations in Withdrawal, Return Flow, and Consumptive Use of Water in Ohio and Indiana, With Selected Data From Wisconsin, 1999-2004. In USGS, *USGS Scientific Investigations Report 2009-5096* (p. 93).

Shaffer, K. H., & Runkle, D. L. (2007). Consumptive Water-Use Coefficients for the Great Lakes Basin and Climatically Similar Areas. In USGS, *USGS Scientific Investigations Report 2007-5197* (p. 191). Reston.

Shiklomanov, I. A. (1993). World fresh water resources. In P. H. Gleick, *Water in crisis: a guide to the world's fresh water resources.* New York: Oxford University Press.

Singh, A. (1989). Digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing, 10*(6), 989-1003.

Smith, A., Walker, G., & Turner, J. (2010). *Aquifer Sustainability Factor: a Review of Previous Estimates. .*

Solley, W. B., Merk, C. F., & Pierce, R. R. (1988). Estimated Use of Water in the United States in 1985. In USGS, *Circular 1004* (p. 82).

Solley, W. B., Pierce, R. R., & Perlman, H. A. (1993). Estimated Use of Water in the United States in 1990. In USGS, *Circular 1081* (p. 76).

Solley, W. B., Pierce, R. R., & Perlman, H. A. (1998). Estimated Use of Water in the United States in 1995. In USGS, *Circular 1200* (p. 71).

Stuckey, M. H. (n.d.). *Development of the Water-Analysis Screening Tool Used in the Initial Screening for the Pennsylvania State Water Plan Update of 2008.* USGS, Reston.

Teets, B., & Young, S. (1985). *Killing Waters - The Great West Virginia Flood of 1985.* Parsons, West Virginia: McClain Printing Company.

Templin, W. E., Herbert, R. A., Stainaker, C. B., Horn, M., & Solley, W. B. (1980). Water Use. In *The National Handbook of Recommended Methods for Data Acquisition.* Retrieved 02 27, 2013, from http://pubs.usgs.gov/chapter11/chapter11A.html

Tennant, D. L. (1976). Instream Flow Regimes for Fish, Wildlife, Recreation, and Related Environmental Resources. *Fisheries, 1*(4), 6-10.

The Charleston Gazette. (2012). U.S. Seeks Protections for Diamond Darter Habitat. In T. A. Press. Retrieved 01 03, 2013, from http://wvgazette.com/News/201207260020

The Nature Conservancy. (2007). *Indicators of Hydrologic Alteration, Version 7 User's Manual.* Retrieved 02 21, 2013, from http://www.nature.org/initiatives/freshwater/conservationtools

U.S. Army Corps of Engineers, The Nature Conservancy, and Interstate Commission on the Potomac River Basin. (2012). *Middle Potomac River Watershed Assessment: Potomac River Sustainable Flow and Water Resources Analysis. Final Report.*

U.S. Army Corps of Engineers, The Nature Conservancy, ICPRB. (2012). Middle Potomac River Watershed Assessment: Potomac River Sustainable Flow and Water Resources Analysis. In *Appendix B - Water Withdrawals and Consumptive Use in the Potomac River Basin* (p. 120).

U.S. Energy Information Administration. (2012). *Annual Energy Outlook 2012 Early Release Overview.* Washington, D.C. Retrieved 01 28, 2013, from http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2013).pdf

U.S. EPA. (2011). *The Effects of Mountaintop Mines and Valley Fills on Aquatic Ecosystems of the Central Appalachian Coalfields.* Office of Research and Development, National Center for Environmental Assessment, Washington, D.C.

USACE. (1995). *Intent to Prepare a Draft Environmental Impact Statement (DEIS) for the Proposed Reallocation of Storage at Jennings Randolph Lake in Mineral County, West Virginia, and Garrett County, Maryland Federal Register Doc No: 95-17179.* Retrieved 03 25, 2013, from http://www.gpo.gov/fdsys/pkg/FR-1995-07-13/html/95-17179.htm

USACE Baltimore District. (1995). *Jennings Randolph Lake Reallocation Feasibility Study.*

USACE Baltimore District. (1997). Letter From Dr. James F. Johnson, Chief Planning Division, USACE Baltimore District to J.L. Hearn, Director, Water Management Administration, Maryland Department of the Environment.

USACE Baltimore District. (1997). *Master Manual for Reservoir Regulation, North Branch Potomac River Basin - Appendix A.*

USACE Baltimore District. (2011). Discussion at 2011 Meeting of the Low Flow Allocation Agreement Signatories.

USACE Baltimore District. (2013). *Jennings Randolph Lake.* Retrieved 03 25, 2013, from http://www.nab.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/10470/Article/9071/jennings-randolph-lake.aspx

USACE Baltimore District. (Unpublished). *Draft, Jennings Randolph Lake Reallocation Feasibility Study: Integrated Feasibility and Environmental Impact Statement.*

USDA. (2004). *2002 Census of Agriculture, Pennsylvania State and County Data, Volume 1, Geographic Area Series, Part 38.*

USDA. (2009). *2007 Census of Agriculture.* U.S. Department of Agriculture. Retrieved 02 26, 2013, from www.agcensus.usda.gov/publications/2007/index.php

USFWS. (1983). *Flat-Spired Three-Toothed Snail Recovery Plan. Region 5.* Retrieved 02 20, 2013, from http://www.fws.gov/docs/recovery_plan/830509b.pdf

USFWS. (2009). *Critical Habitat - What is it? Fact Sheet.* Retrieved 02 22, 2013, from http://www.fws.gov/midwest/endangered/saving/CriticalHabitatFactSheet/html

USFWS. (2012). Federal Register. *77*(144). Retrieved 01 03, 2013, from www.gpo.gov/fdsys/pkg/FR-2012-07-26/pdf/2012-17950.pdf

USGS. (2002). *A Gap Analysis of West Virginia.* Retrieved 02 21, 2013, from http://www.nrac.wvu.edu/projects/gap/pub.htm#Data

USGS. (2009). *Estimated Use of Water in the United States in 2005.* U.S. Geological Survey. Retrieved 02 27, 2013, from http://pubs.er.usgs.gov/publication/cir1344

Veil, J. A. (2010). *Water Management Technologies Used by Marcellus Shale Gas Producers.* DOE, Office of Fossil Energy, National Energy Technology Laboratory. Retrieved 02 25, 2013, from http://www.ead.anl.gov/pub/dsp_detail.cfm?PubID=2537

Veil, J. A., Kupar, J. M., & Puder, M. G. (2003). *Use of Mine Pool Water for Power Plant Cooling, prepared for U.S. Department of Energy National Energy Technology Laboratory under contract W-31-109-Eng-38.*

Veil, J. A., Kupar, J. M., & Puder, M. G. (2010). *Use of Mine Pool Water for Power Plant Cooling: prepared for the DOE National Energy Technology Laboratory under contract W-31-109-Eng-38.*

Wahl, K. L., Thomas, Jr., W. O., & Hirsch, R. M. (1995). The stream-gaging program of the U.S. Geological Survey. *U.S. Geological Survey Circular*, p. 22.

Water Management Committee of the Irrigation Association. (2010). *Turf and Landscape Irrigation Best Management Practices.* Retrieved 02 25, 2013, from www.gcsaa.org/environment/resources/water-conservation/Course-Environment-WaterConservation-Connecticut-BMPs.pdf

West Virginia Division of Forestry. (2010). *West Virginia Statewide Forest Resource Assessment. A Comprehensive Analysis of the State's Forests and Related Natural Resources.* Retrieved 01 04, 2013, from http://www.wvforestry.com/DOF100Assessment_Revised_091310_Part1.pdf

West Virginia University, College of Business and Economics. (2012). *2013 West Virginia Economic Outlook.* West Virginia University, Bureau of Business & Economic Research, College of Business and Economics, Morgantown.

Wiley, J. B. (2006). Low-Flow Analysis and Selected Flow Statistics Representative of 1930-2002 for Stream Flow-Gaging Stations in or Near West Virginia. In USGS, *Scientific Investigations Report 2006-5002* (p. 190).

Wiley, J. B. (2008). Estimating Selected Streamflow Statistics Representative of 1930-2002 in West Virginia. In USGS, *Scientific Investigations Report 2008-5105* (p. 24).

Wiley, J. B. (2012). Comparison of Base Flows to Selected Streamflow Statistics Representative of 1930-2002 in West Virginia. In USGS, *Scientific Investigations Report 2012-5121* (p. 18).

Wiley, J. B., & Atkins, Jr., J. T. (2010). Estimation of flood-frequency discharges for rural, unregulated streams in West Virginia. *U.S. Geological Survey Scientific Investigations Report 2010-5033*, p. 78.

Wiley, J. B., & Atkins, Jr., J. T. (2010). Estimation of Selected Seasonal Streamflow Statistics Representative of 1930-2002 in West Virginia. In USGS, *Scientific Investigations Report 2010-5185* (p. 20).

Wiley, J. B., & Brogan, F. D. (2003). Comparison of Peak Discharges Among Sites With and Without Valley Fills for the July 8-9, 2001, Flood in the Headwaters of Clear Fork, Southern W.V. In USGS, *Open-File Report 03-133* (p. 12).

Wiley, J. B., Atkins, Jr., J. T., & Newell, D. A. (2002). Estimating the magnitude of annual peak discharges with recurrence intervals between 1.1 and 3.0 years for rural, unregulated streams in West Virginia. *U.S. Geological Survey Water-Resources Investigations Report 0-4164*, p. 73.

Wiley, J. B., Evaldi, R. D., Eychaner, J. H., & Chambers, D. B. (2001). Reconnaissance of Stream Geomorphology, Low Streamflow, and Stream Temperature in the Mountaintop Coal-Mining Region, Southern West Virginia, 1999-2000. In USGS, *Water-Resources Investigation Report 01-4092* (p. 34).

Wolock, D. M. (2003). Estimated Mean Annual Natural Ground-Water Recharge in the Conterminous United States. In USGS, *Open File Report 03-0311.*

WorkForce West Virginia. (2012). *Wage Data - Wages by Industry - Employment and Wages.* Retrieved 01 25, 2013, from http://www.workforcewv.org/lmi/WageData.html

Ziemkiewicz, P., Hause, J., Lovett, R., Locke, D., Johnson, H., & Patchen, D. (2012). *Zero Discharge Water Management for Horizontal Shale Gas Well Development: Final Report to the DEO under award DE-FE0001466.* Retrieved 11 19, 2012, from http://www.netl.doe.gov/technologies/oil-gas/Petroleum/projects/Environmental/Produced_Water/01466_ZeroDischarge.html

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.

Note: WV Code updated with legislation passed through the 2013 1st Special Session

The WV Code is an unofficial copy of the annotated WV Code, provided as a convenience. It has NOT been edited for publication, and is not in any way official or authoritative.

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

I. Map Viewer Overview 4

II. Navigation 4

III. View GIS Layers 5

IV. Tools 7

A. Bookmarks 7

B. Find Address 8

C. Search 9

i. Spatial Search 9

ii. Search by Attributes 11

iii. View Results 14

D. Identify 16

E. Legend 17

F. Export Layer to Shapefile 17

G. Paint 18

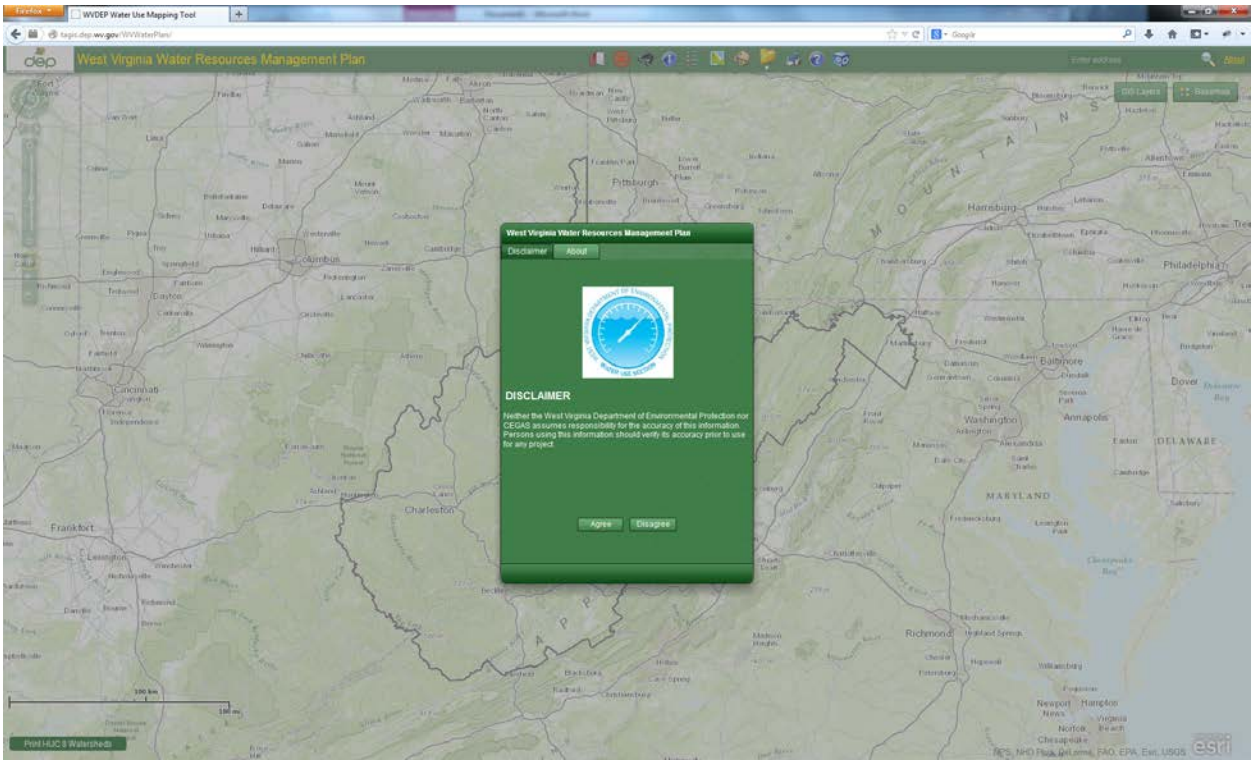
H. Links 20

I. Print 21

J. Instructions 22

K. Precipitation 23

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.

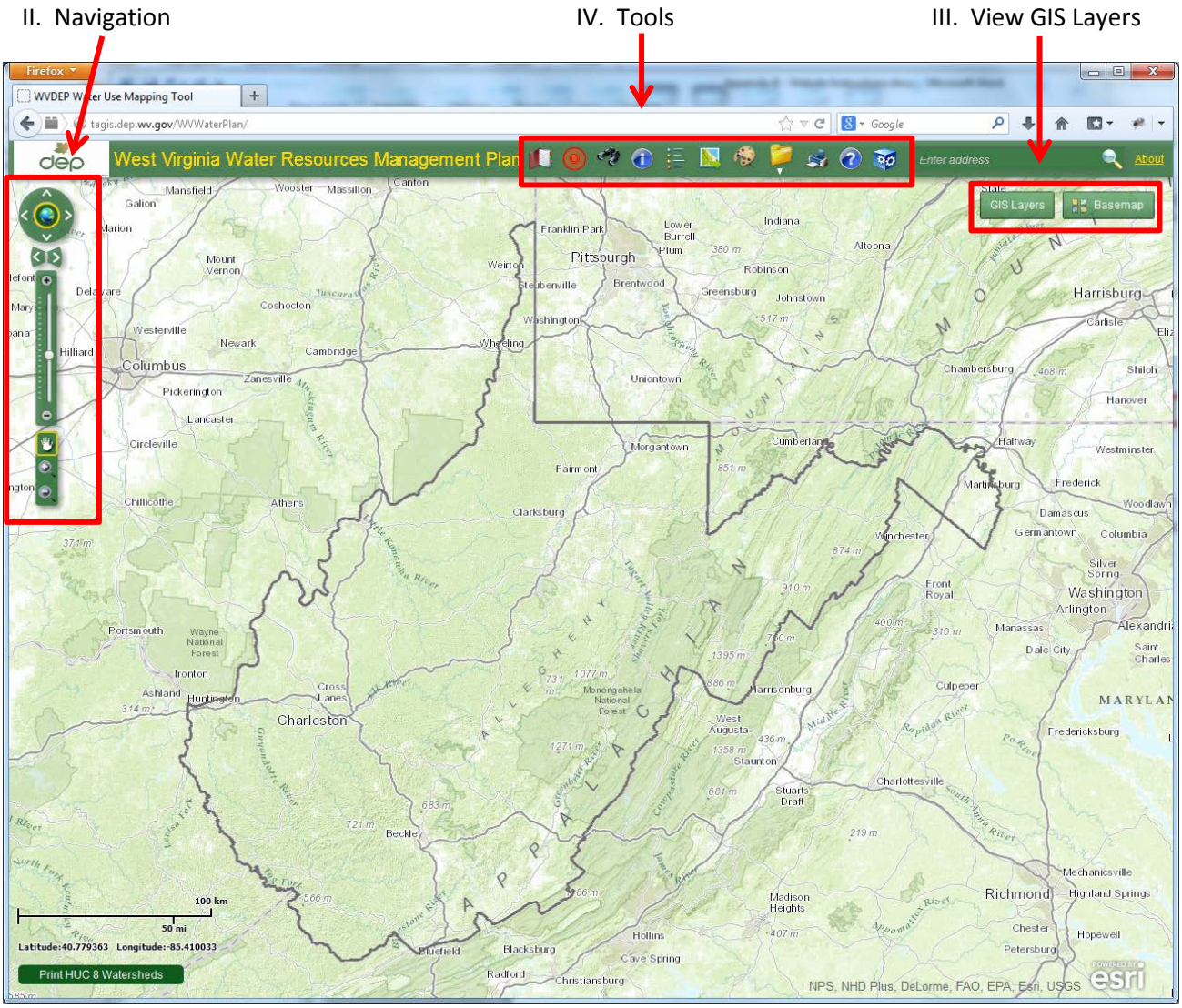


DISCLAIMER

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.

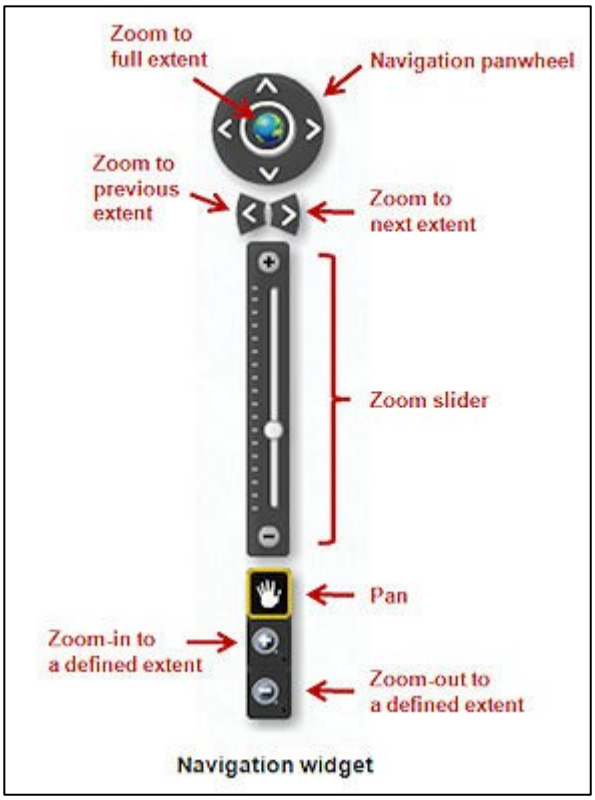
I. Map Viewer Overview

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.

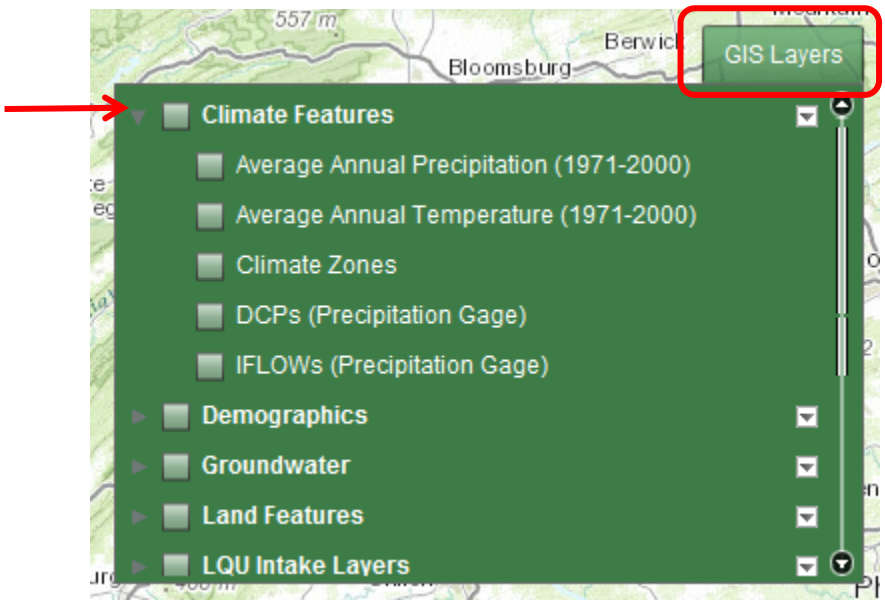


In addition to using the Zoom slider on the navigation widget, you can also roll the mouse wheel forward or backwards to zoom in or out respectively.

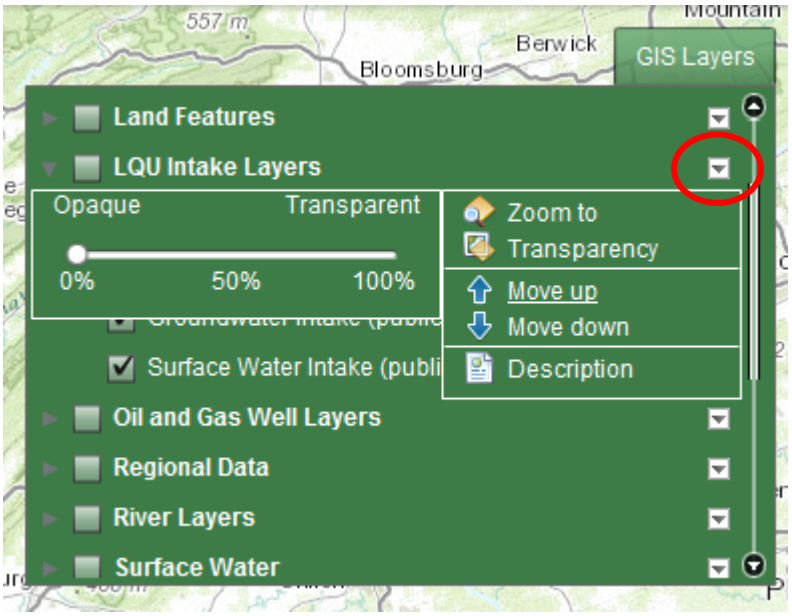
III. View GIS Layers

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.



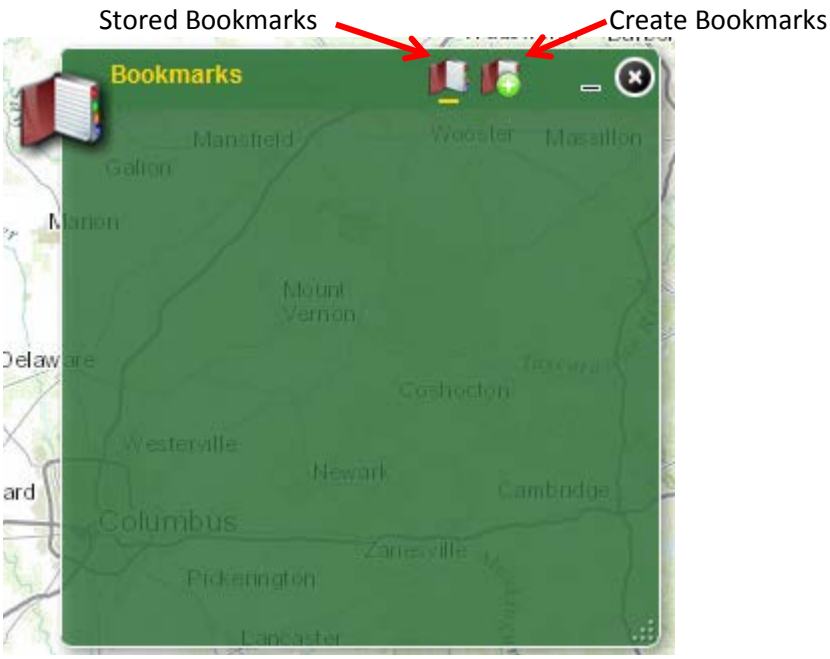
The transparency of layers can also be set by simply clicking the button on the right of the layers name. Additionally, you also have the option of zooming directly to those features, moving the layer up or down, and reading a description about the layers.



IV. Tools

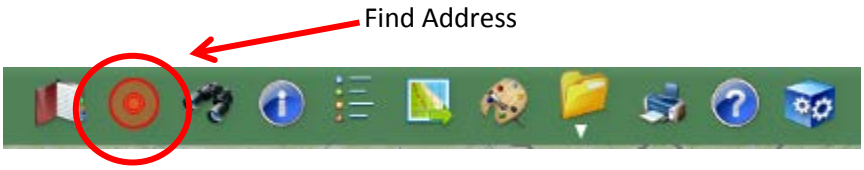
A. Bookmarks

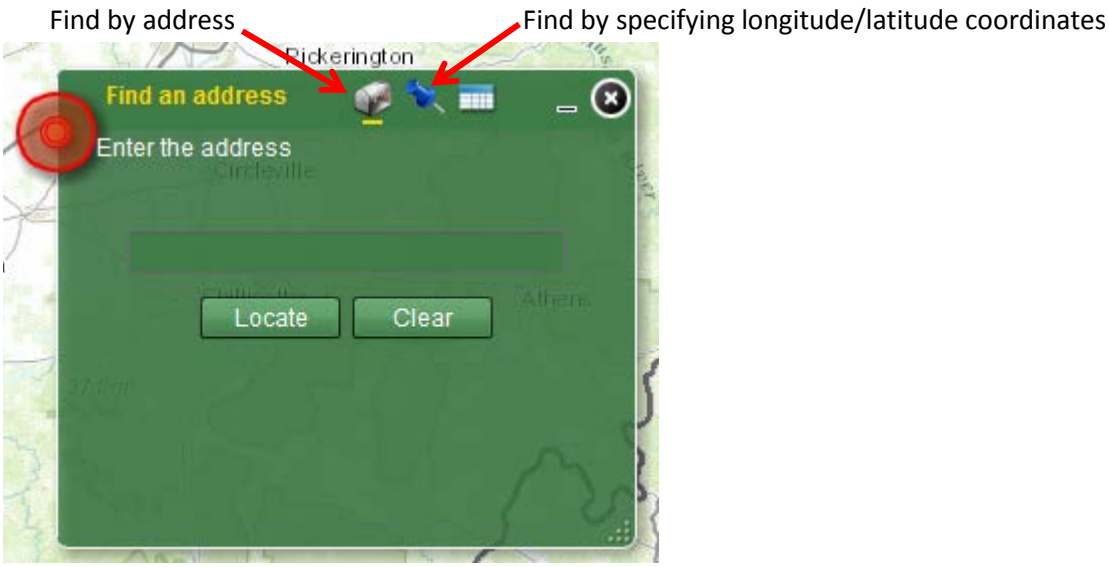
The Bookmark button allows you to save certain map view extents of the data contents displayed in the viewer.



B. Find Address

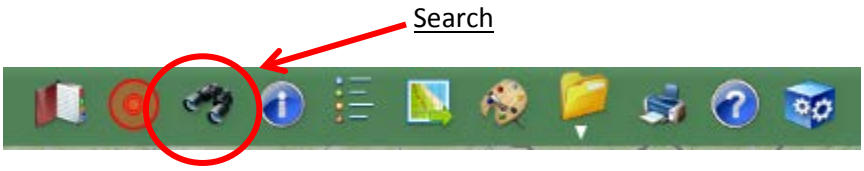
The Find Address button allows you to find a precise location on the map. The tool provides two ways to find a location: by either entering an address or by specifying a longitude/latitude coordinate value.





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.



i. Spatial Search

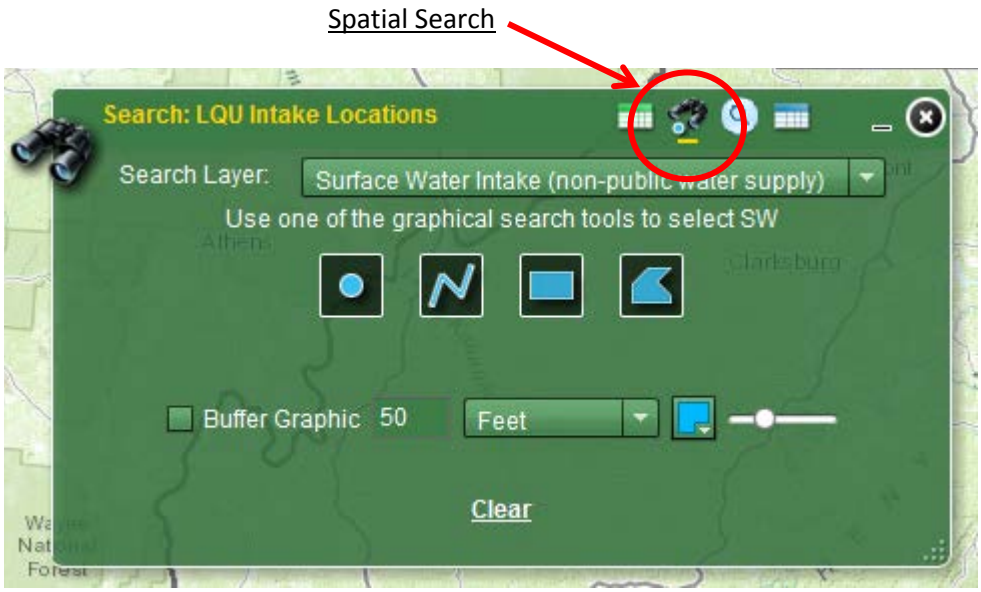
First select one of the following: Surface Water Intake (non-public water supply), Surface Water Intake (public water supply), Groundwater Intake (non-public water supply), or Groundwater Intake (public water supply) from the search layer dropdown box.

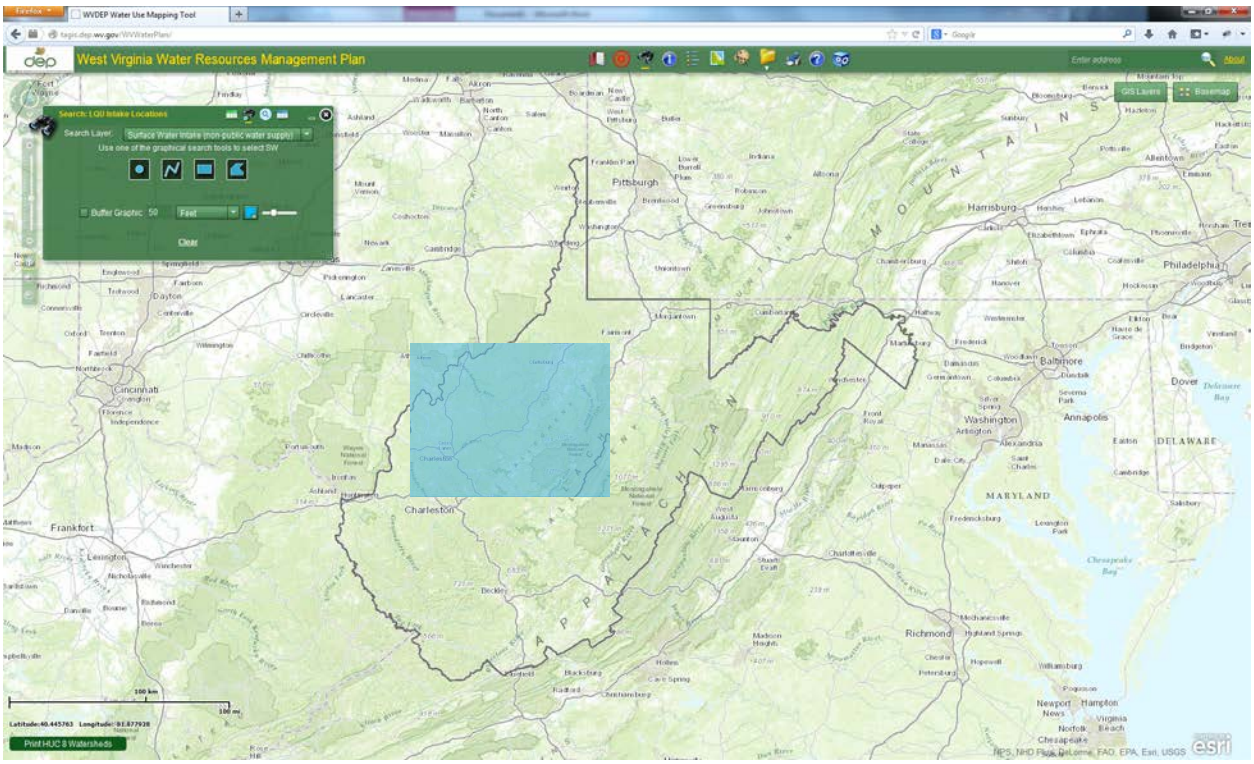
Choose one of the graphical search tools (from left to right):

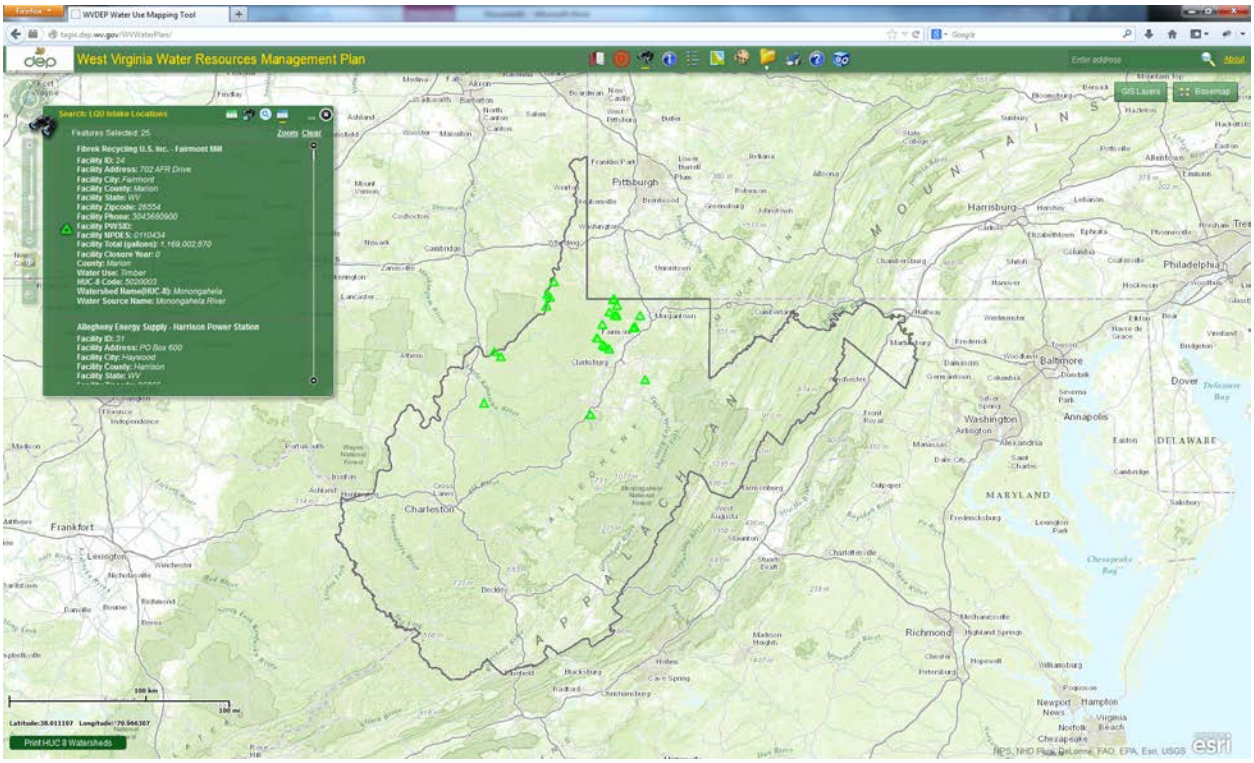
- point

- 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.







ii. Search by Attributes

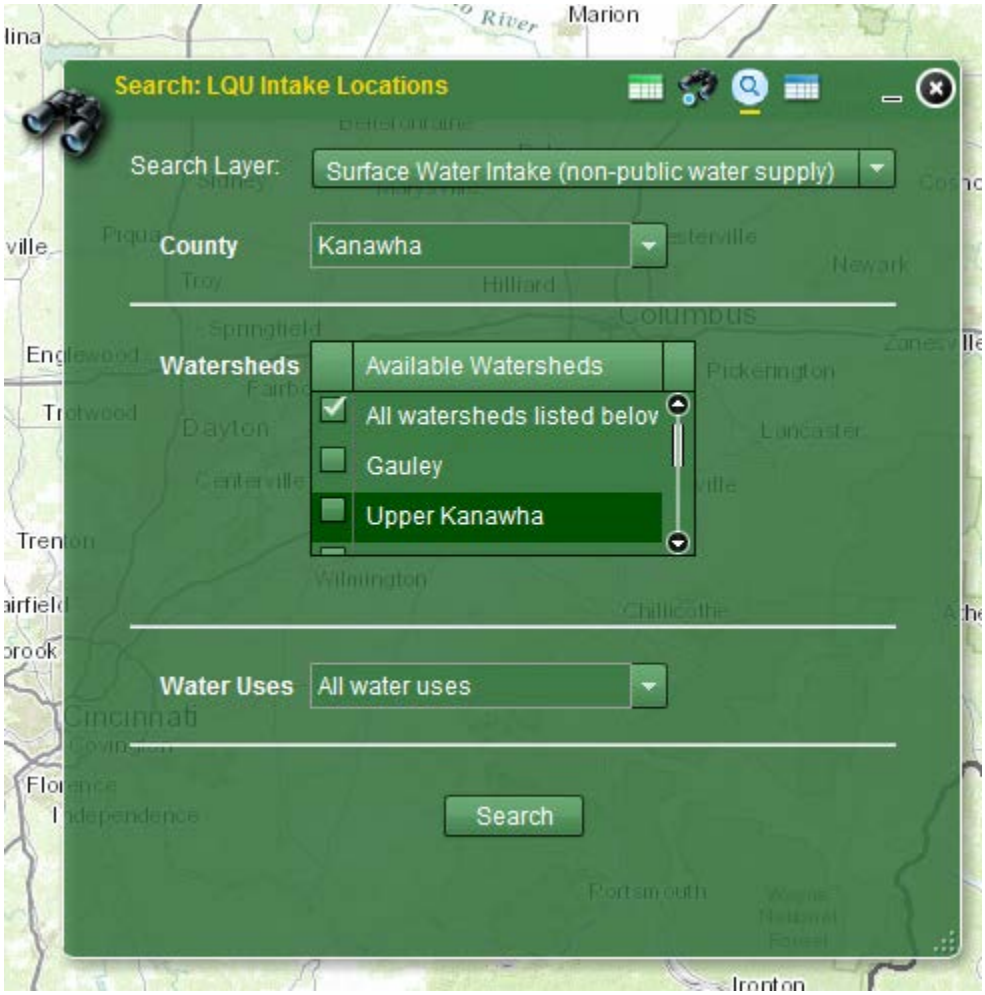
First select one of the following: Surface Water Intake (non-public water supply), Surface Water Intake (public water supply), Groundwater Intake (non-public water supply), or Groundwater Intake (public water supply) from the search layer dropdown box.

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

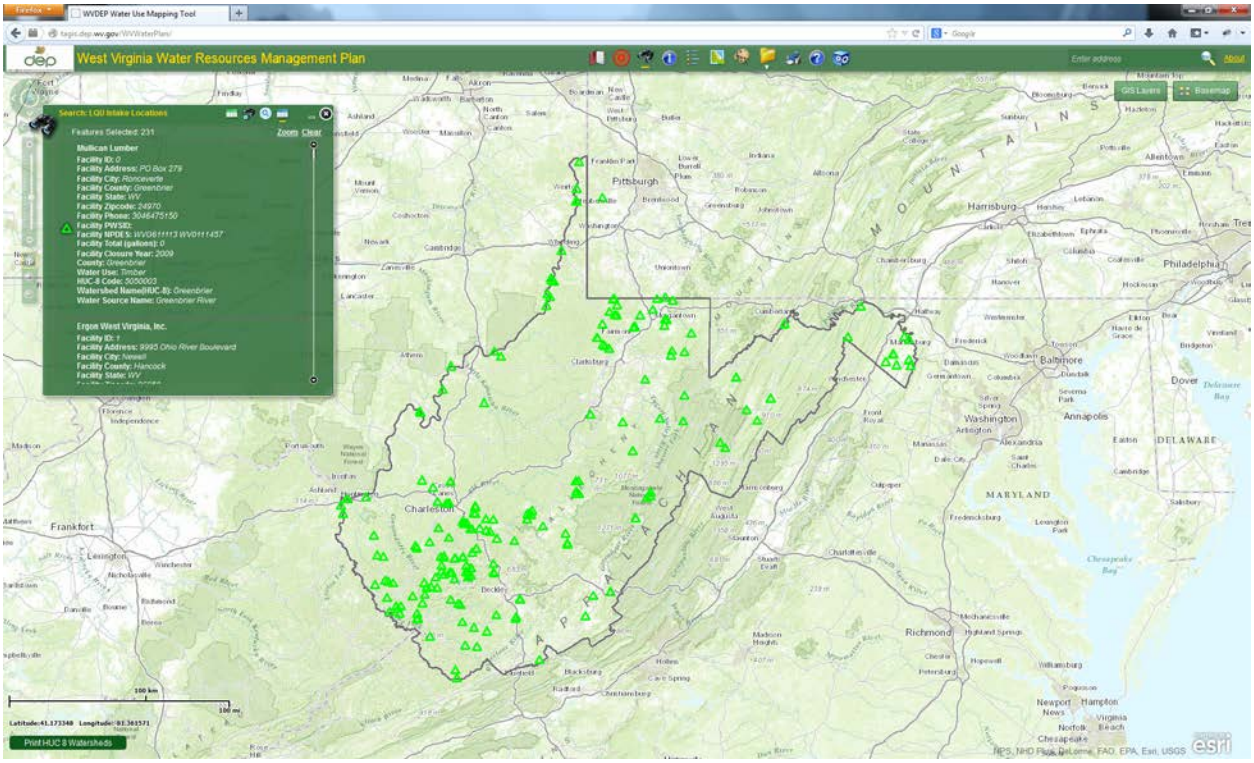
Search by Attribute

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.

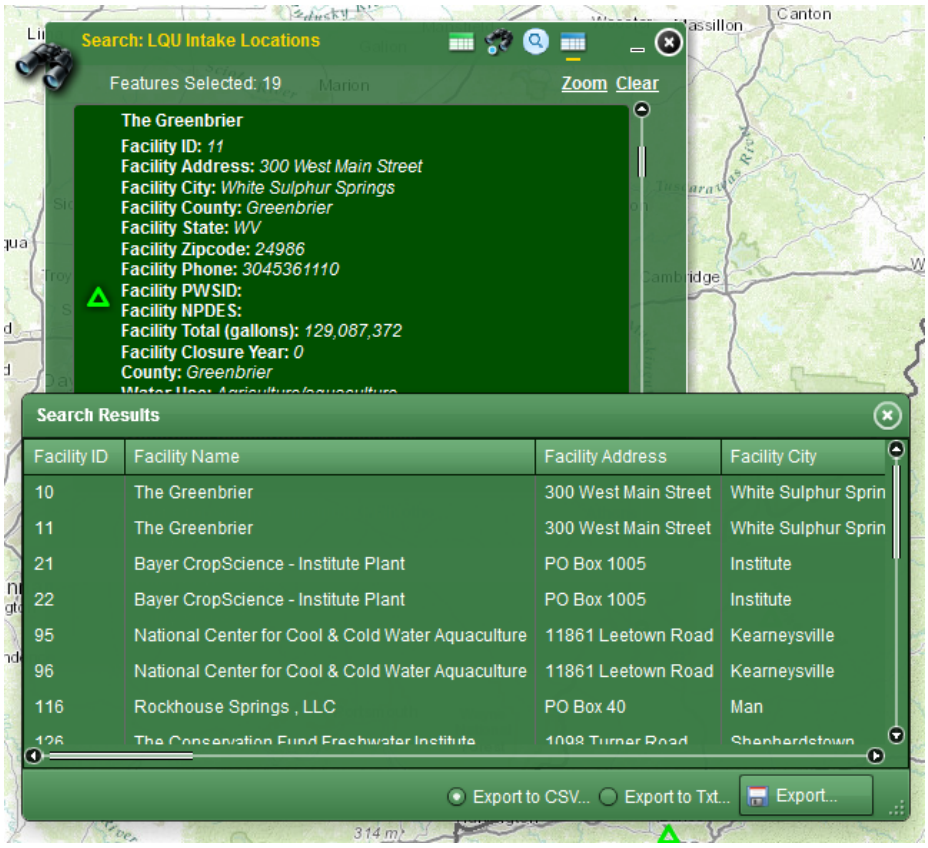


iii. View Results

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 △

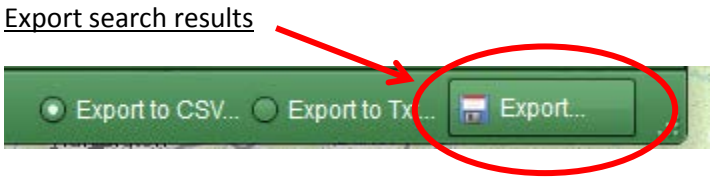


The search results can also be viewed in a table by selecting the "Show Results in Grid" button .



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.

<u>Export search results</u>



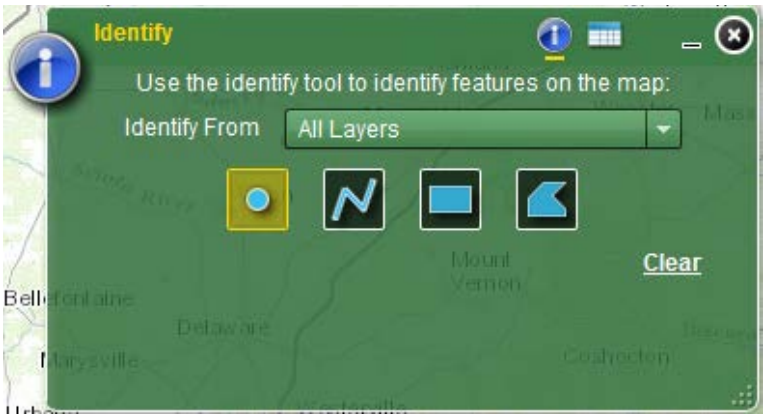
D. Identify

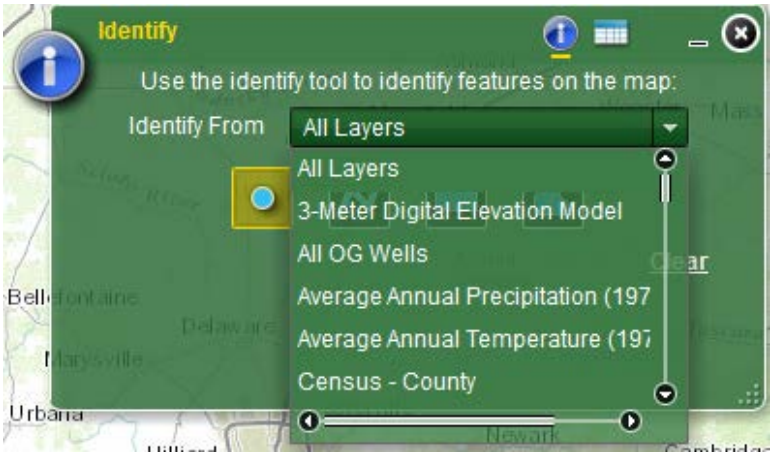
The Identify button displays certain attributes about the GIS layers that are visible on the map. See section III of this document for more information on displaying "GIS Layers".

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.

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

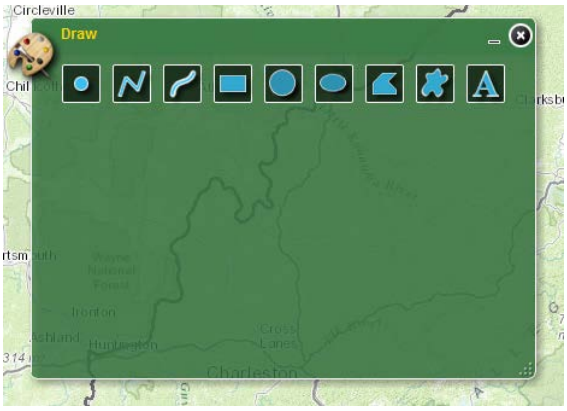
download a zipped shapefile.

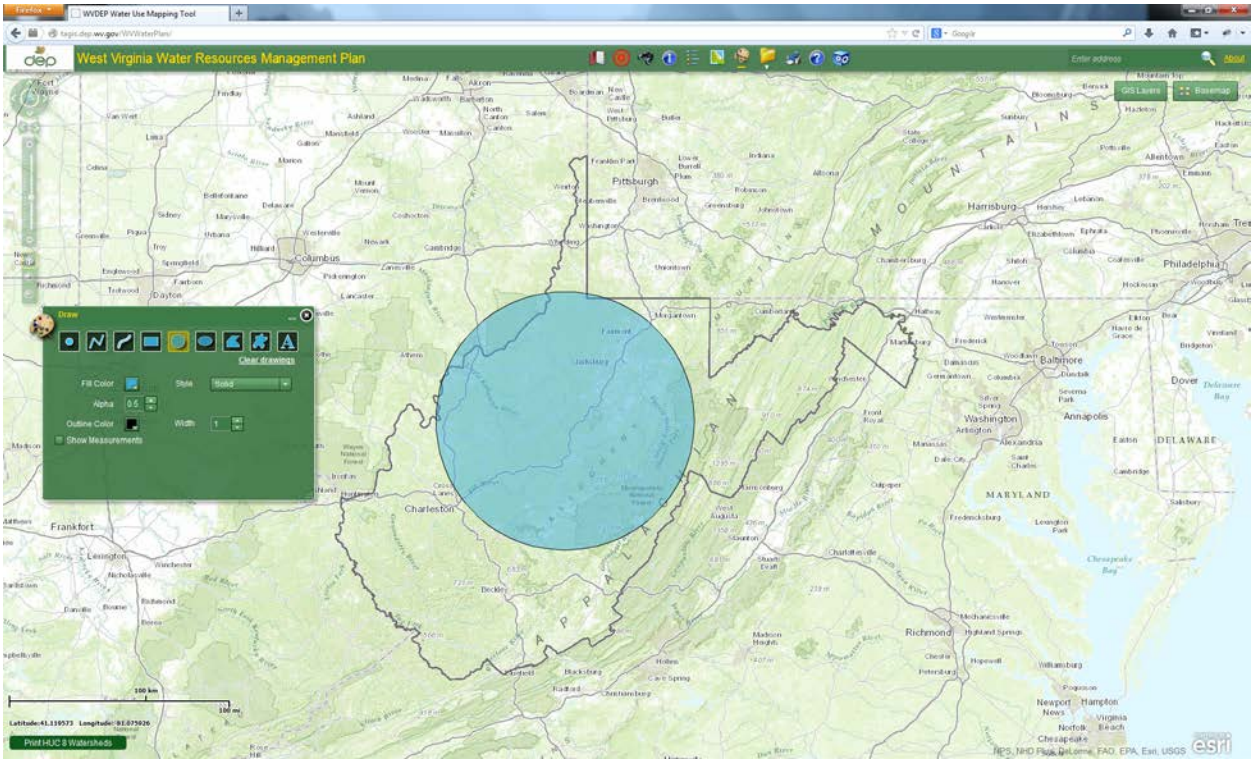
G. Paint

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)


Circleville
Draw
Charleston


WVDEP Water Use Mapping Tool
West Virginia Water Resources Management Plan
Draw
Clear drawings
Fill Color
Style
Solid
Alpha
Outline Color
Width
Show Measurements
Pittsburgh
Harrisburg
Philadelphia
Columbus
Baltimore
Washington
Annapolis
Dover
DELAWARE
MARYLAND
Charleston
Frankfort
Richmond
Print HUC 8 Watersheds

H. Links

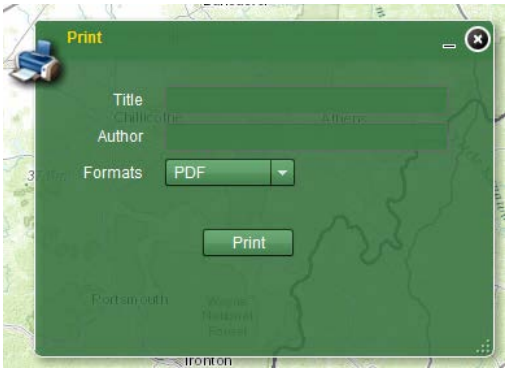
The Links button contains links to important documents and websites.

I. Print

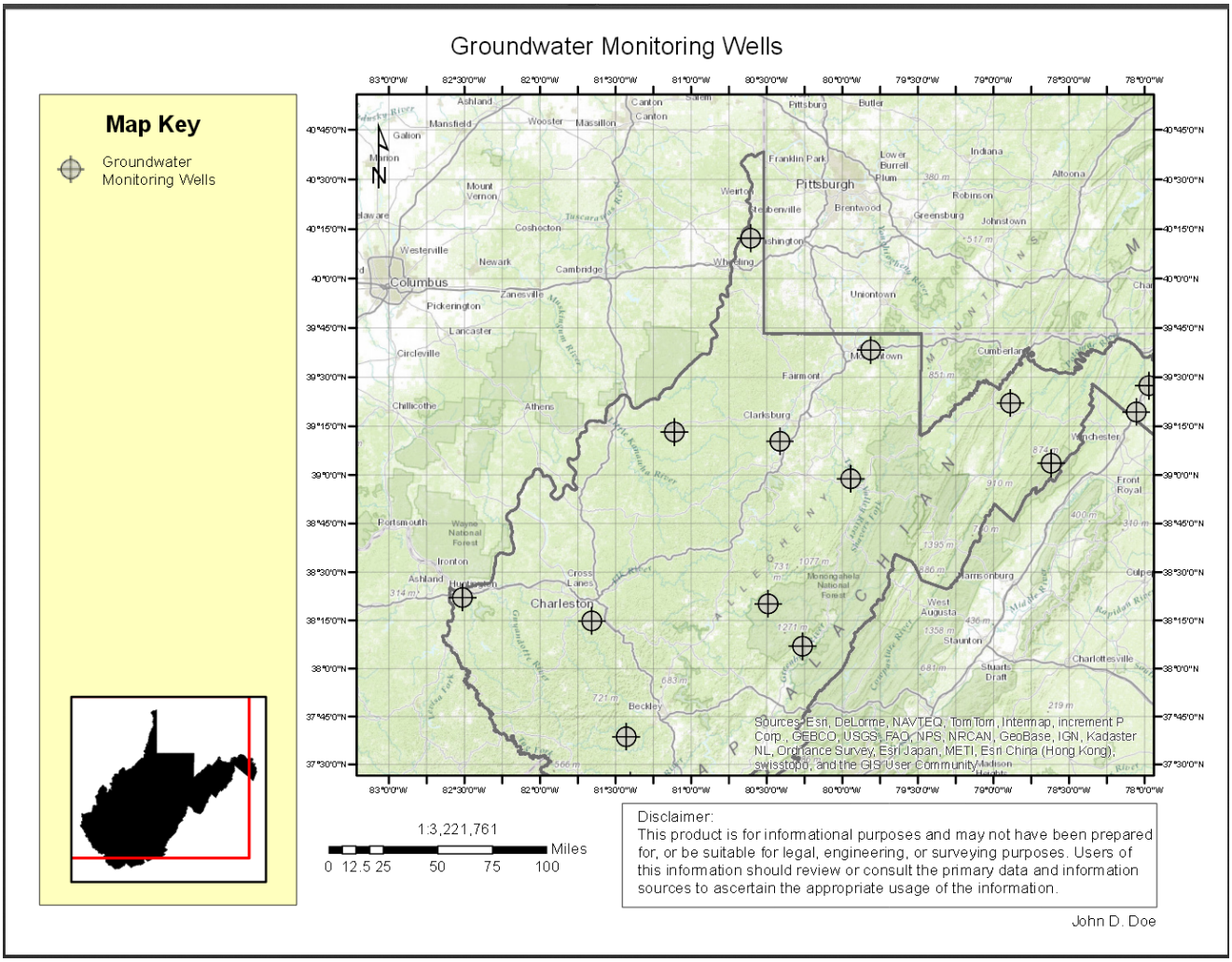
The Print button allows you to print what you see. All map display content that is currently visible will be printed.

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.

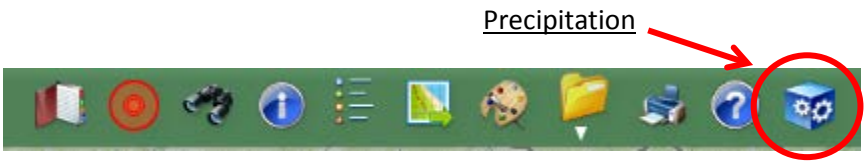


J. Instructions

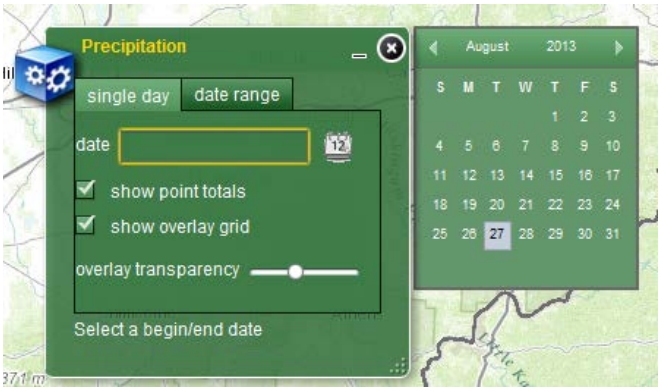
The Instructions button links you to a copy of the map viewer's instructions (like the one you are viewing now).

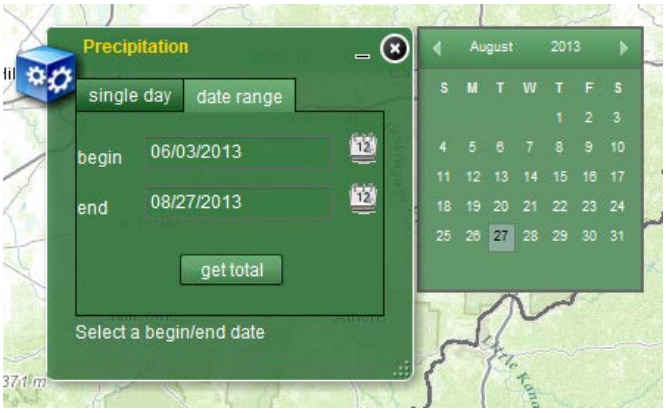
K. Precipitation

The Precipitation button allows you to view current and past precipitation values.

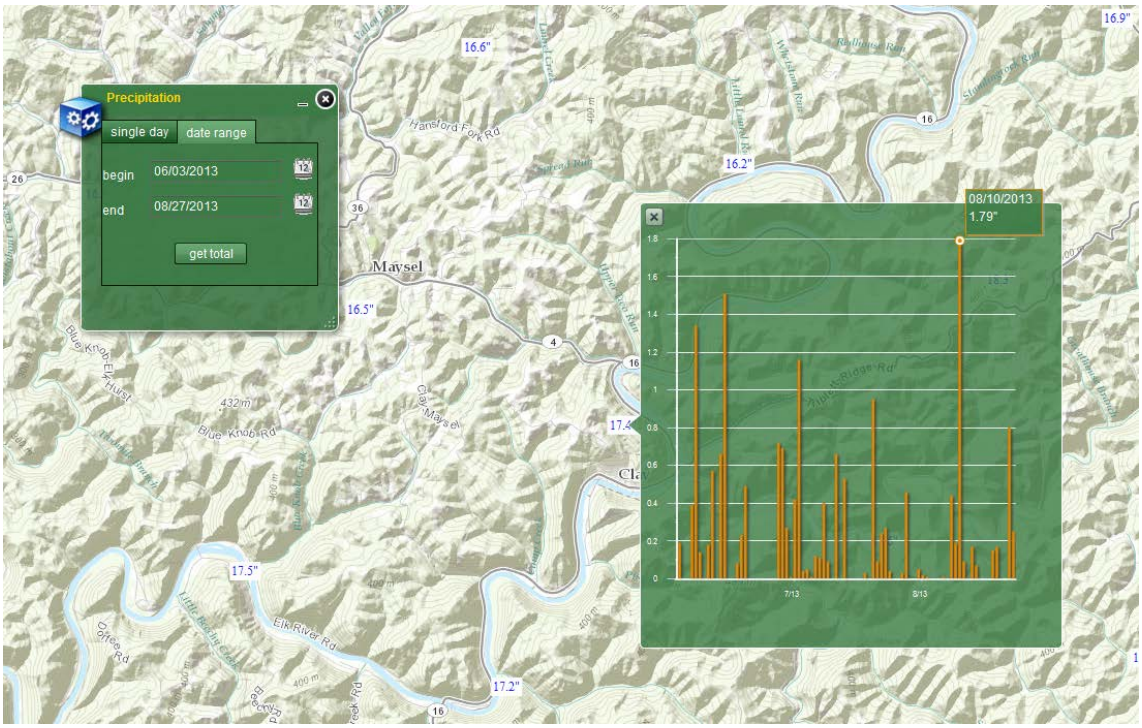


You can view a single day, or you may search a date range – as far back as to January 1st 2010.





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.

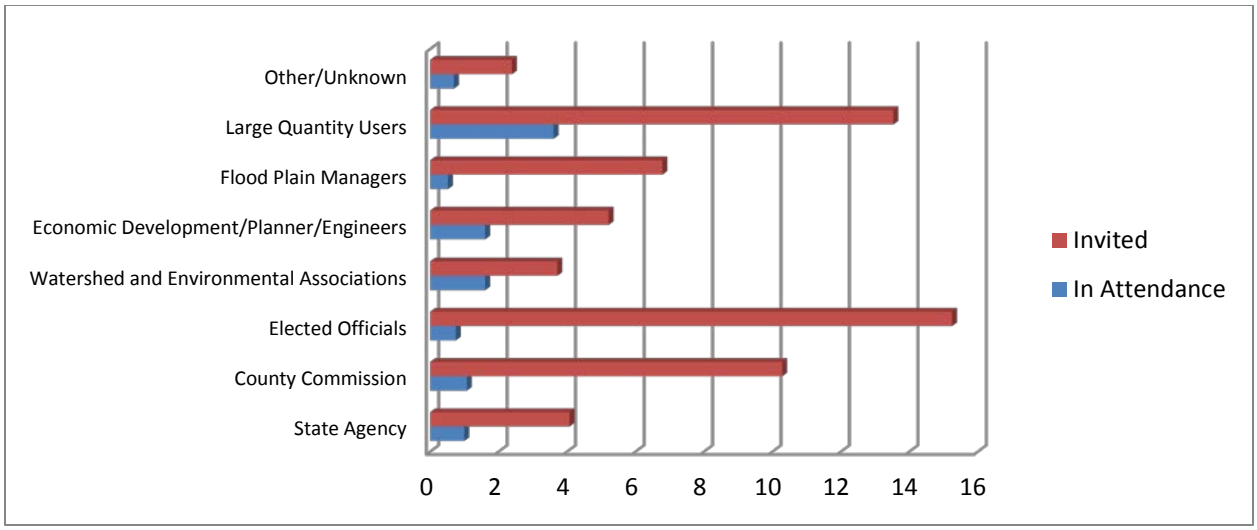


Figure 1 Average Invited Vs. In Attendance to Each Watershed Meeting by Group.

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.

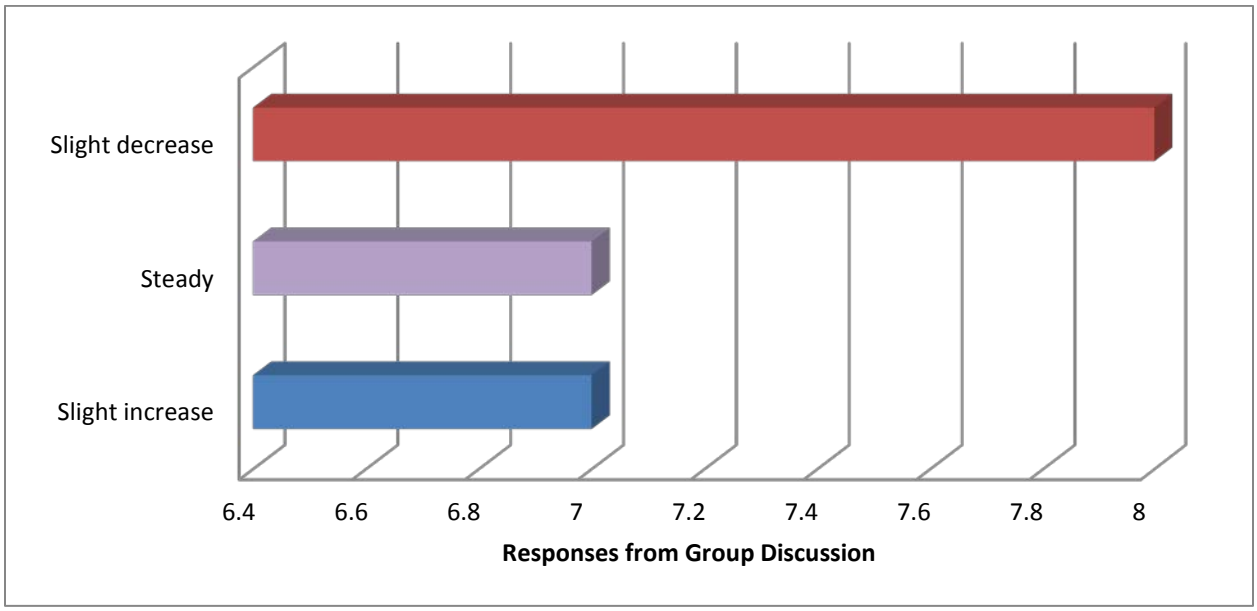


Figure 2 Group Question #2; How do you expect the local population to change in the next 10 years?

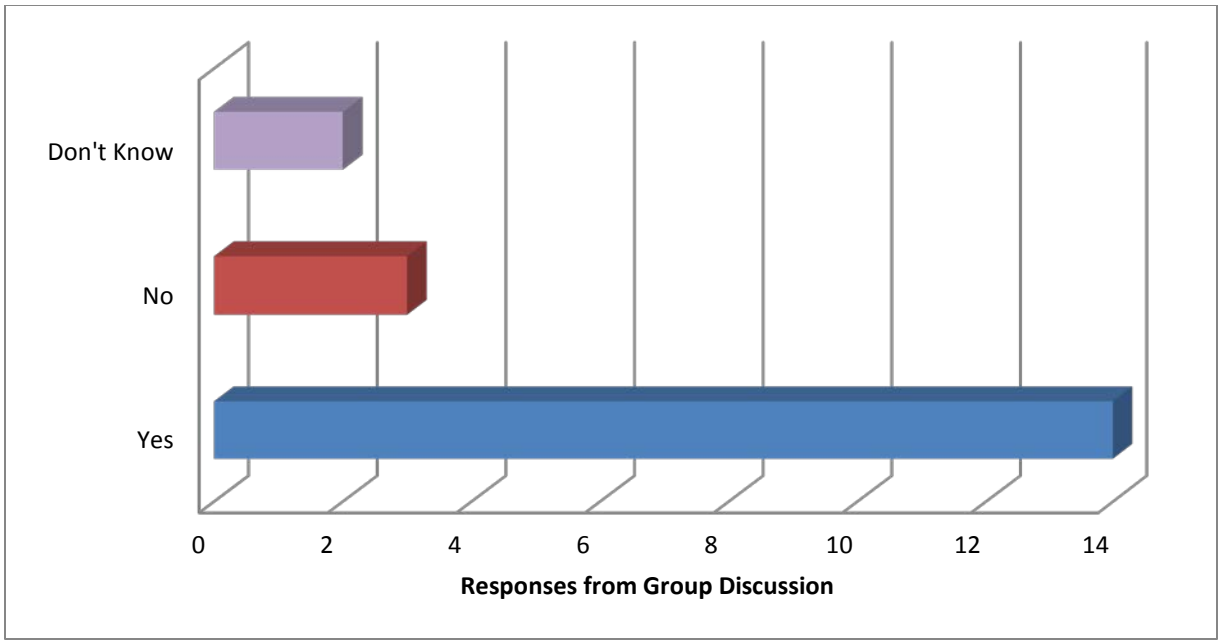


Figure 3 Group Question #3a; Are there new sub-divisions or commercial developments planned?

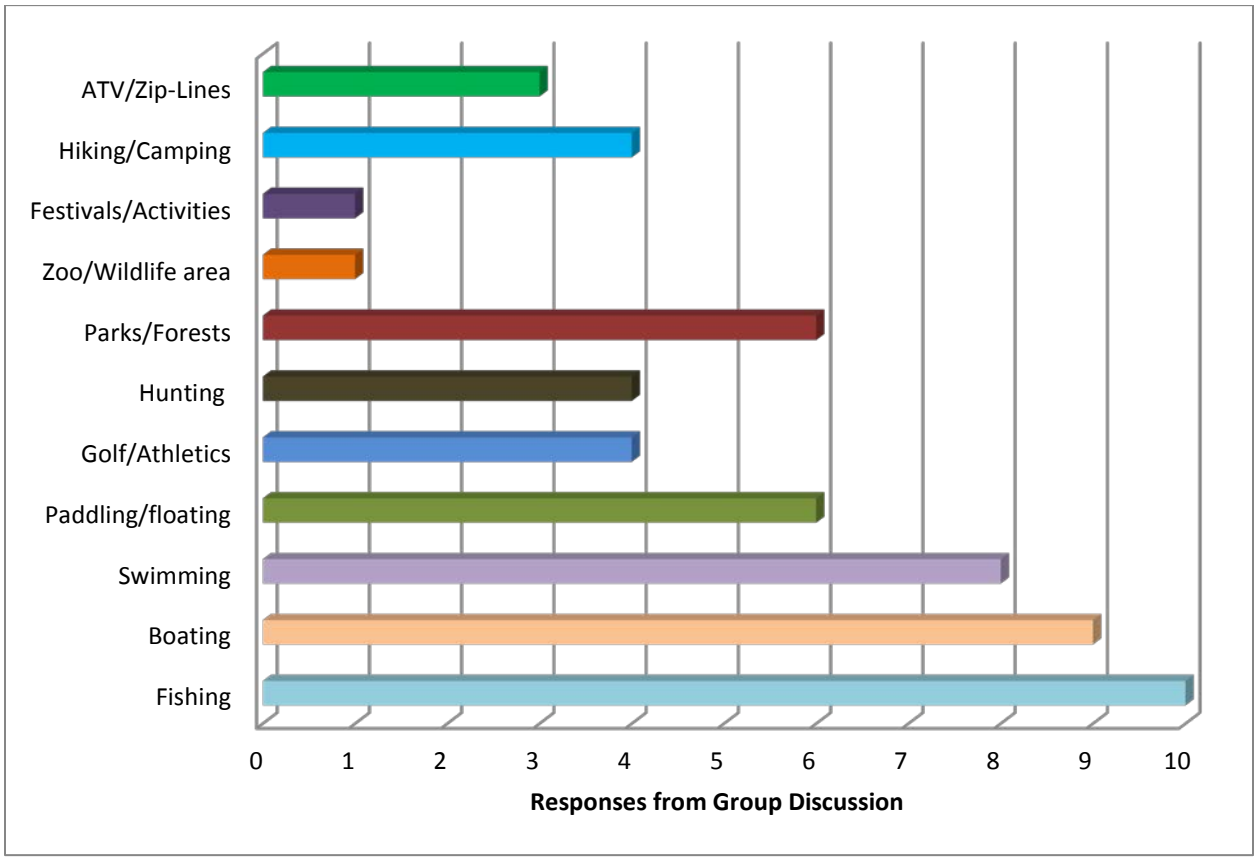


Figure 4 Group Question #4; What are the important recreational uses in the area that are dependent on water?

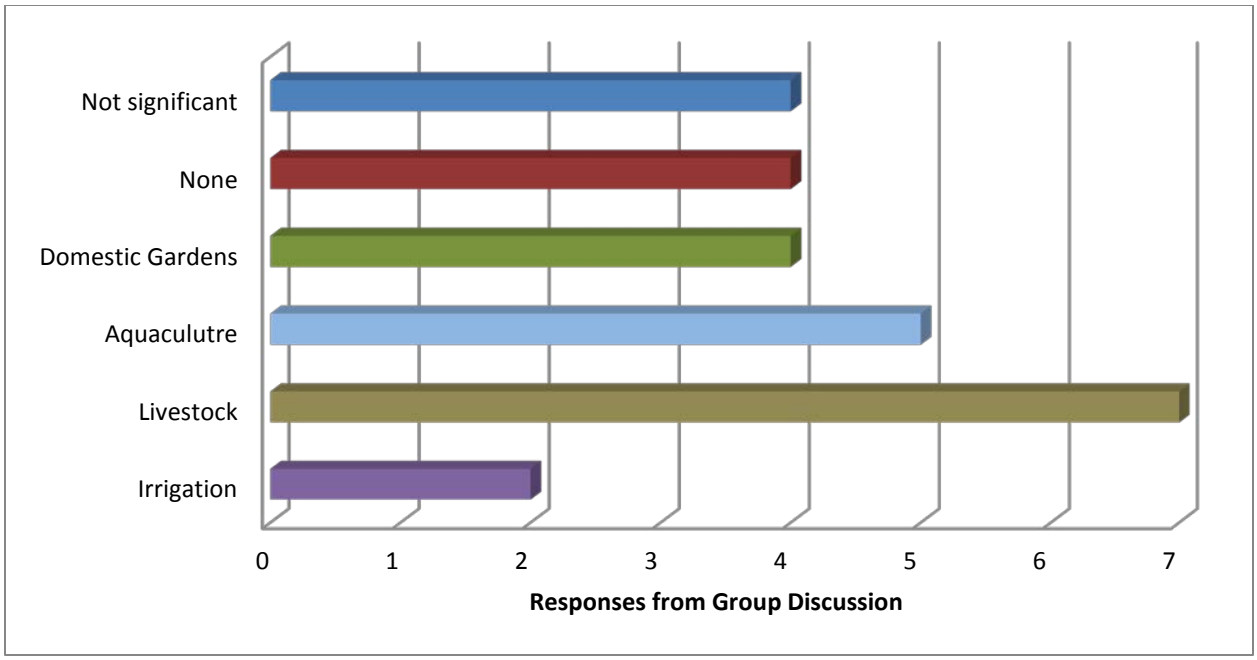


Figure 5 Group Question #6; What is the predominant agricultural water use in the area?

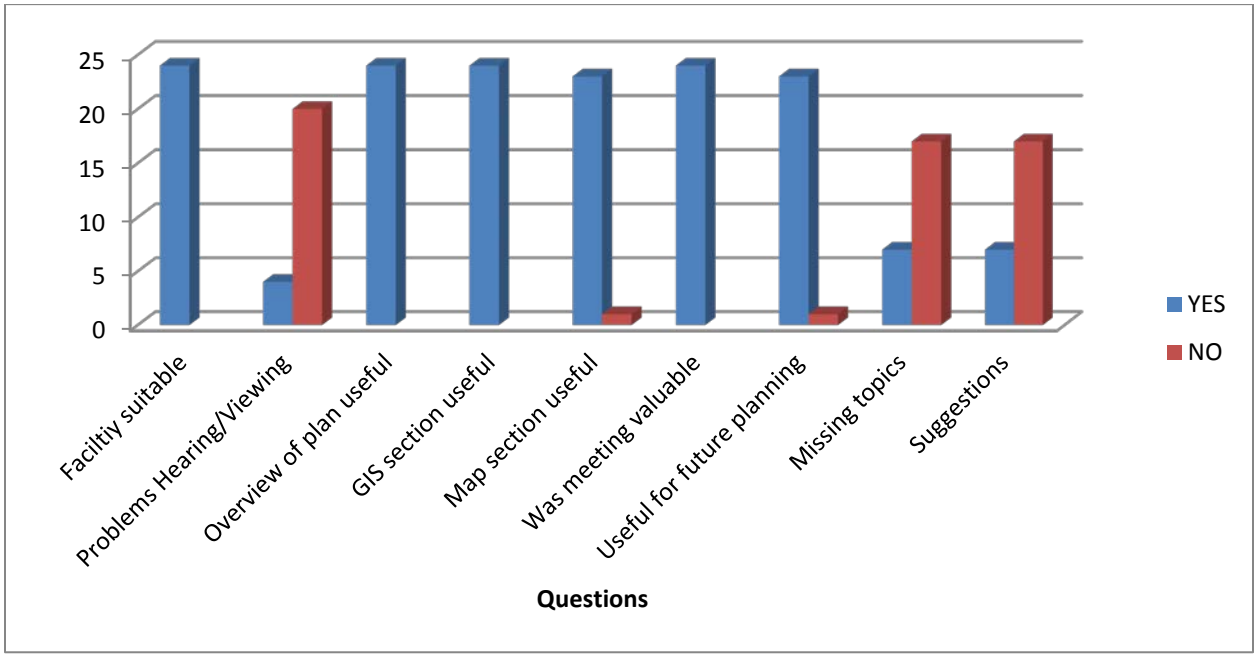


Figure 6 Final Questionnaire Responses from meetings in 2009, 2010, and 2012.

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

West Virginia Ownership Relative to its Border Waters ..... A

Public Rights in West Virginia Watercourses:
West Virginia Law Review, Larry George: ..... B

West Virginia Riparian Water Rights C

West Virginia State Code - Statutes ..... D

<u>CASE LAW</u>:

Ours v. Grace Property, 186 W.Va. 296 (1991) ---------- 1

Campbell Brown & Co. v. Elkins, 141 W.Va 801 (1956) ---------- 2

Morris Asscocs. V. Priddy, 181 W.Va. 588 (1989) ---------- 3

Snyder v. Callaghan, 168 W.Va. 265 (1981) ---------- 4

Gaston v. Mace, 33 W.Va. 14 (1889) ---------- 5

McCausland v. Jarrell, 136 W.Va. 569 (1951) ---------- 6

Union Sand & Gravel Co. v. Northcott, 102 W.Va. 519 (1926) ---------- 7

Roberts v. Martin, 72 W.Va. 92 (1913) ---------- 8

Taylor v. Chesapeake & O.R. Co., 84 W.Va. 442 (1919) ---------- 9

In ReFlood Litig., 216 W.Va. 534 (2004) ---------- 10

International Shoe Co. v. Heatwole, 126 W.Va. 888; 30 S.E.2d 537 (1944) ---------- 11

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.

Big Sandy River – 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.

Tug Fork River – 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

WEST VIRGINIA CODE – STATUES

WV CODE

§ 22-26-3	**Waters claimed by the state**
§ 22-4-16	**Water rights and replacement**
§ 22-3-24	**Water rights and replacement**
§ 22-6A-18	**Civil Action for contamination or deprivation of fresh water**

NATURAL RESOURCES

§20-13-1	**West Virginia Stream Partners Program Act.**
§20-13-2	
§20-13-3	
§20-13-4	

PUBLIC LAND CORPORATION

§5A-11-1	
§5A-11-2	**Members**
§5A-11-3	**Authority**

AGRICULTURE

§19-16A-1	**West Virginia Pesticide Control Act of 1990**
§19-16A-3	**Pesticides**
§ 22-12-5(b)	**Authority**
§ 22-12-5(d)	**Ground Water Protection Practice**
§ 22-12-5(e)	**Jurisdiction**
§ 22-12-5(h)	**Exclusion**

SURFACE COAL MINING AND RECLAMATION ACT

§22-3-10	**Definitions - Reclamation**
§22-3-13	**Permits**
§22-3-13a	**Blasting**

OIL AND GAS

§22-6-1
§22-6-3
§22-6-7
§22-6-21
§22-6-30
§22-6-36

HORIZONTAL WELL ACT

§22-6A-1
§22-6A-2
§22-6A-3
§22-6A-4
§22-6A-7
§22-6A-10
§22-6A-12
§22-6A-16
§22-6A-20
§22-7-3

PUBLIC SERVICE COMMISSION

§24-2-1a	**Authority**
§24-2-1b	**Transportation of Solid Waste**
§24-2-1c	**Permit**
§24-2-1i	

PUBLIC HEALTH

§ 16-1-1
§ 16-1-2
§ 16-1-4

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 mi^2	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 mi^2 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 mi^2 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 mi^2 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 mi^2	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 mi^2.
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									WDR remarks on regulation and diversion
					GH	Q	SV	Pr	WT	sK	pH	DO	Turb	
	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 mi^2	Type of data collected									WDR remarks on regulation and diversion
					GH	Q	SV	Pr	WT	sK	pH	DO	Turb	
	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									WDR remarks on regulation and diversion
					GH	Q	SV	Pr	WT	sK	pH	DO	Turb	
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 mi^2 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 mi^2 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 mi^2 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

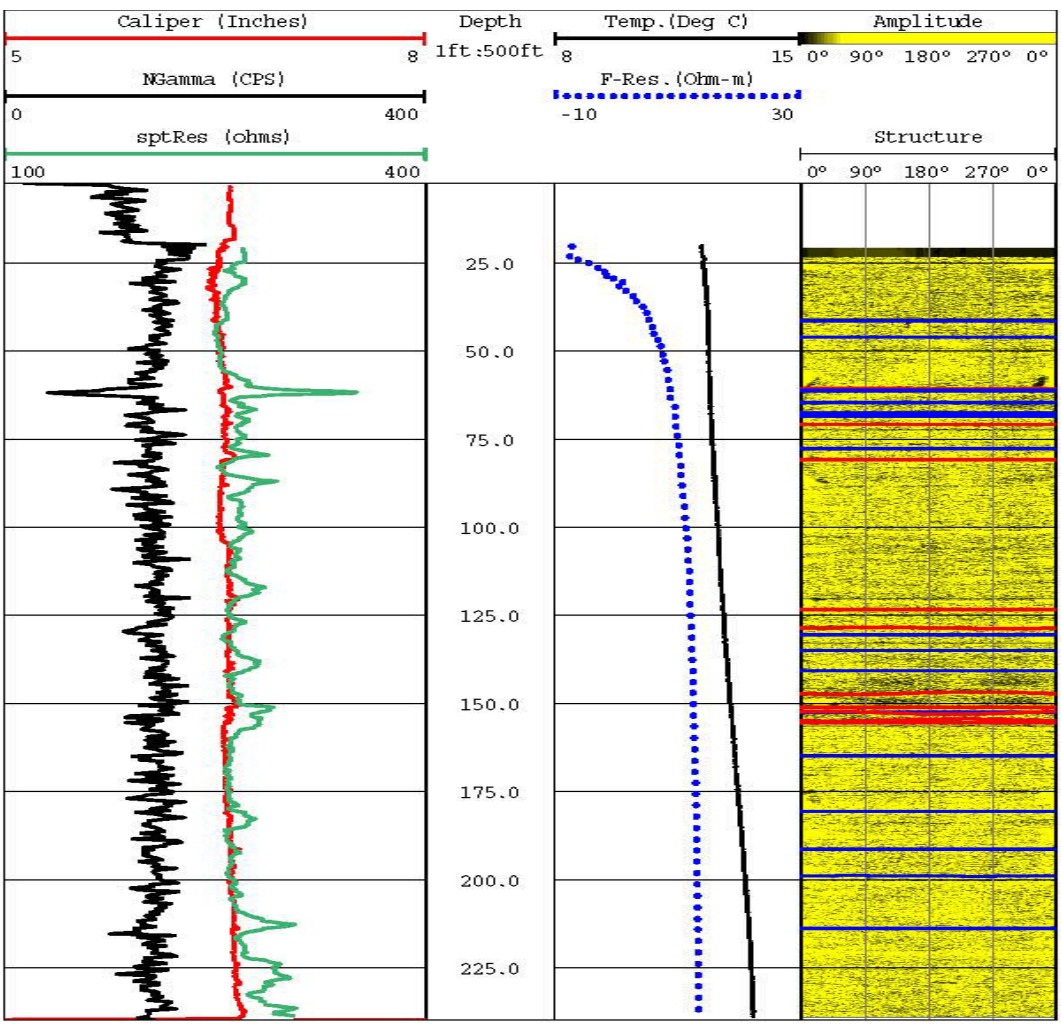


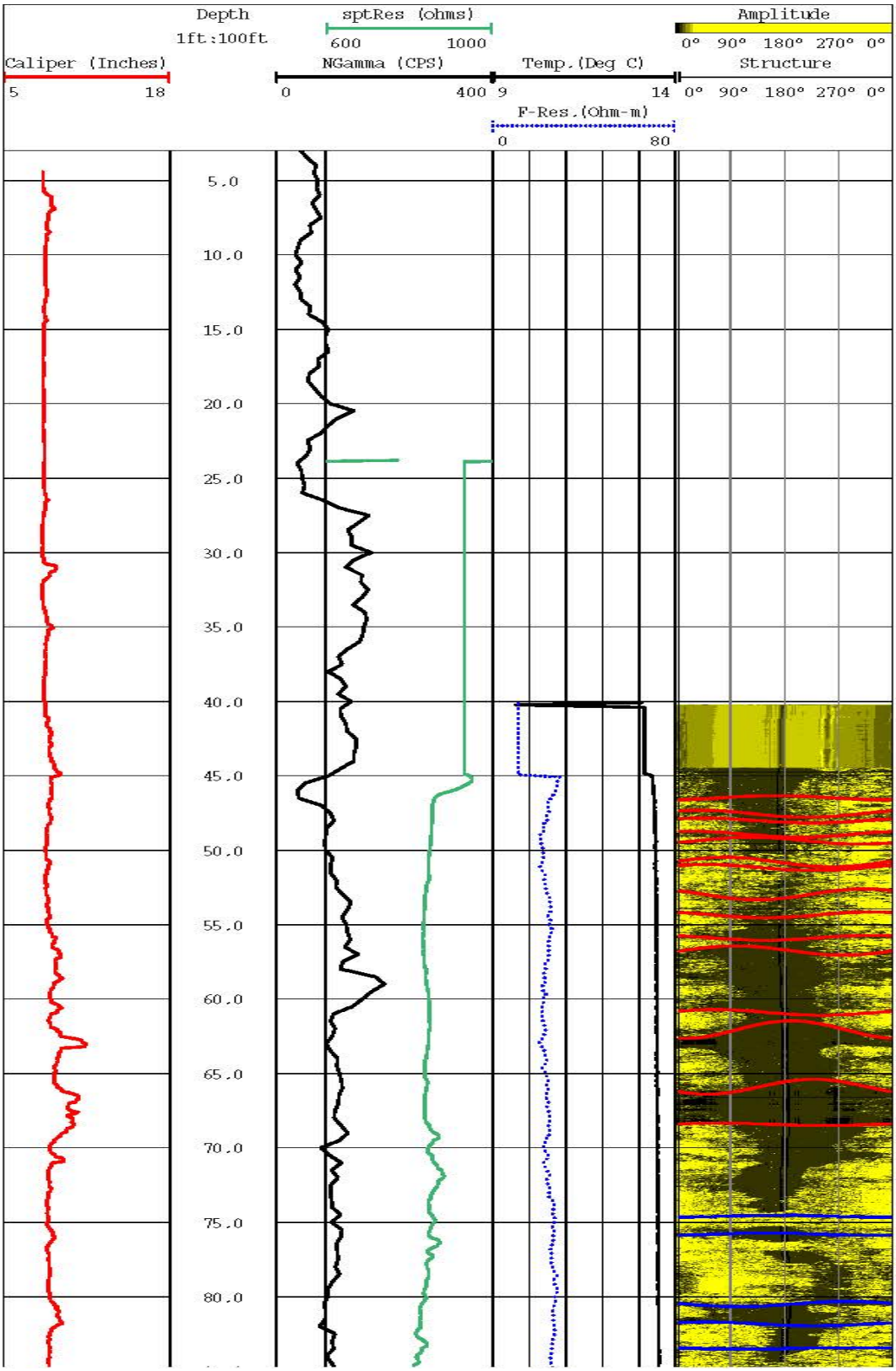
Figure 1: Mineral County #0173 geophysical well log.

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

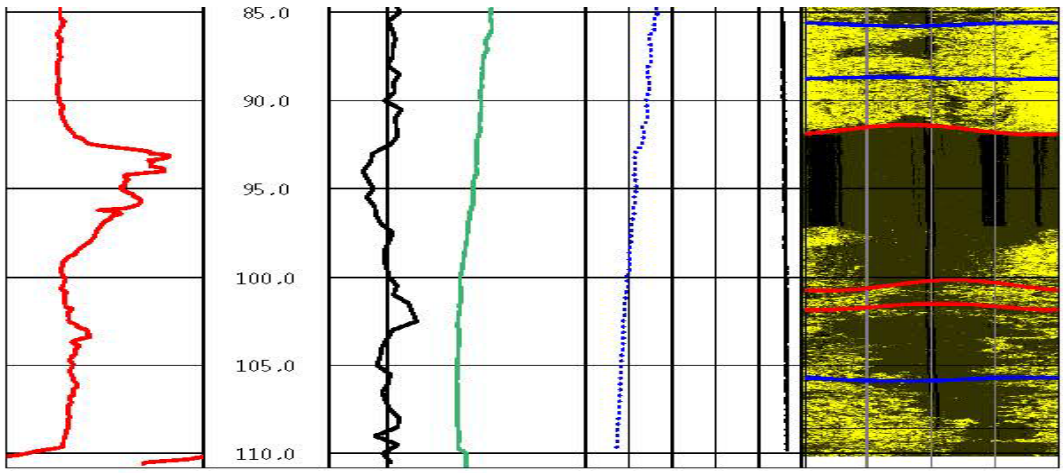


Figure 2: Harrison County #0165 geophysical well log.

Hrd-0301

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

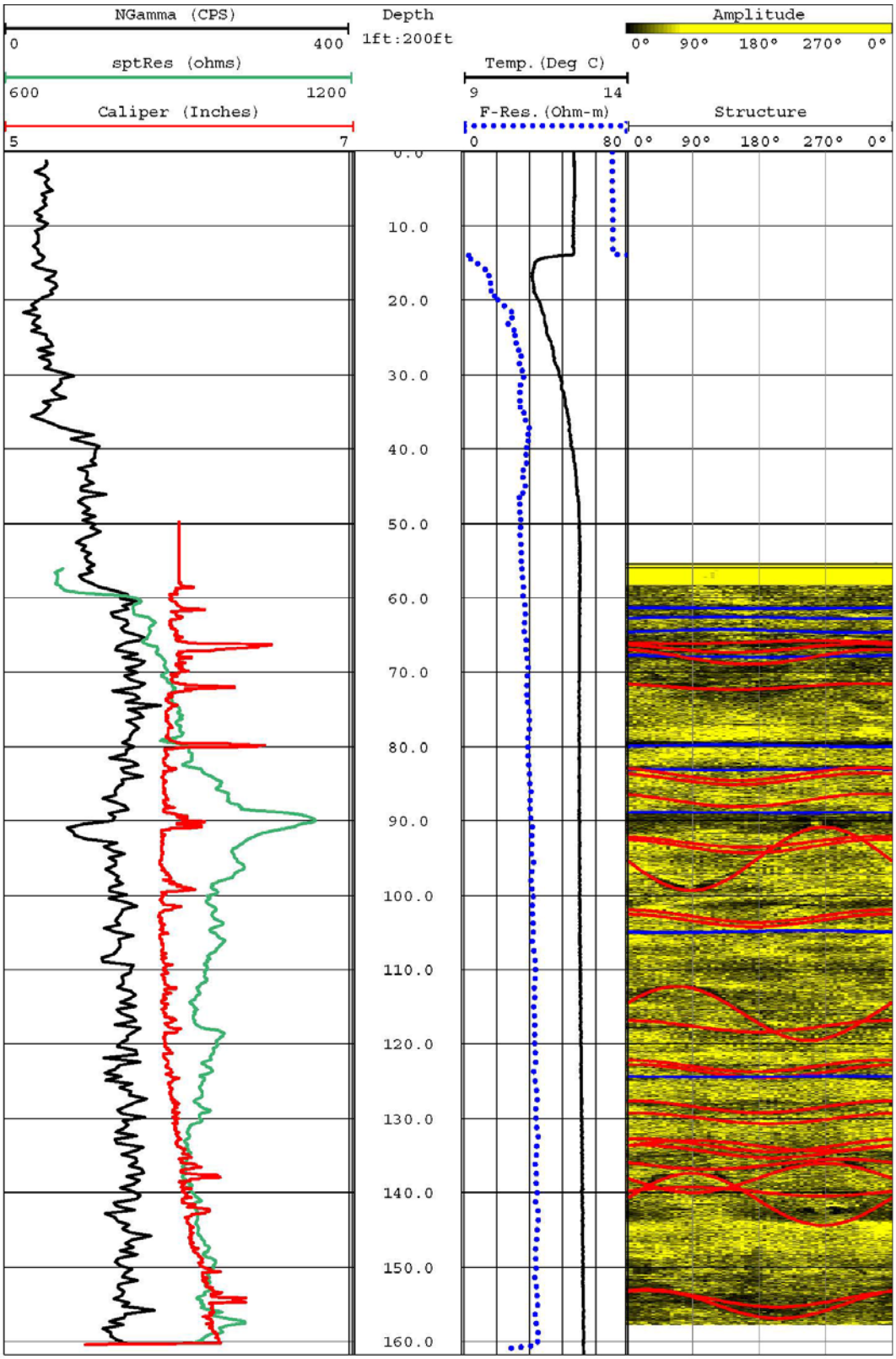


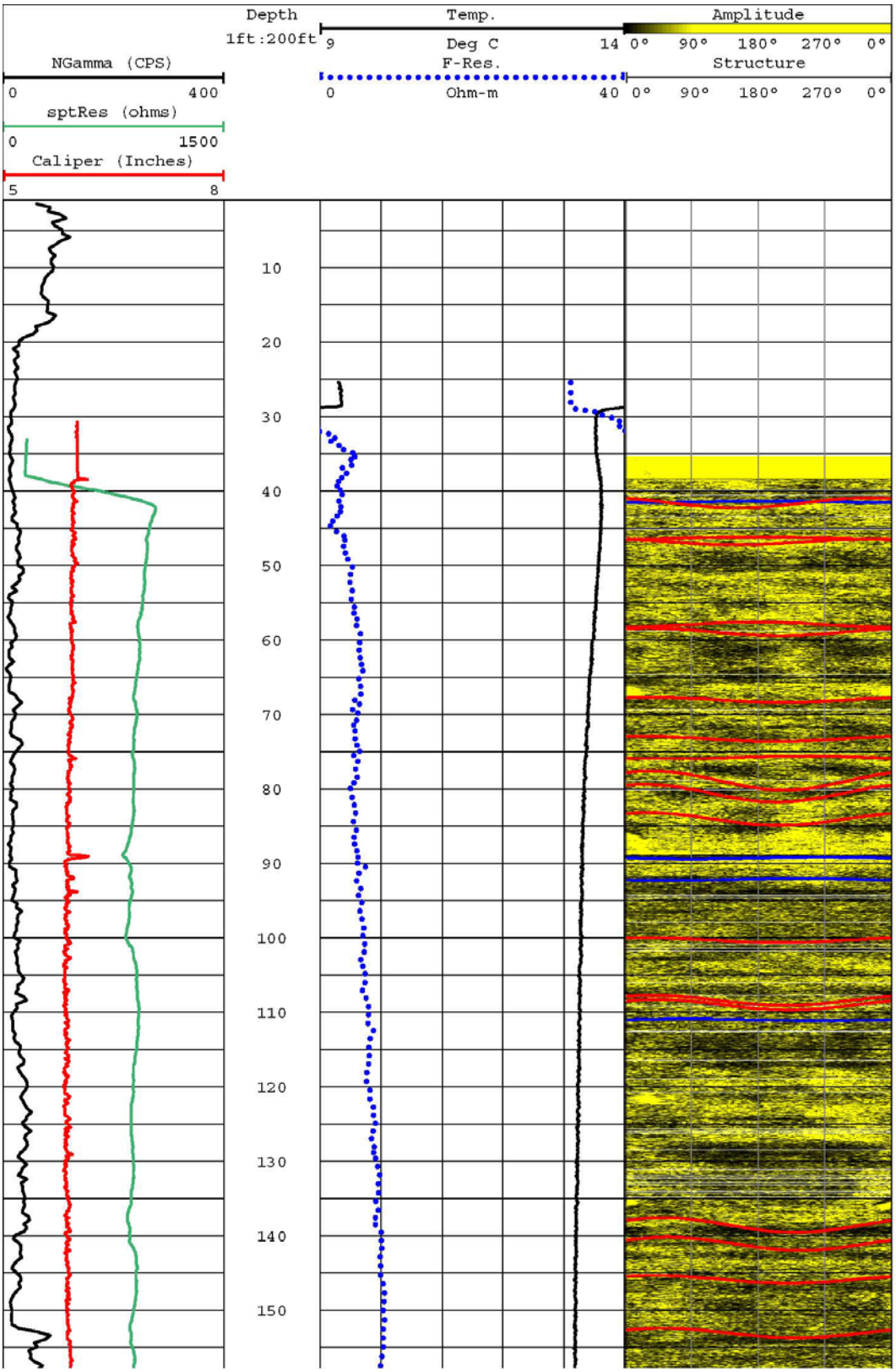
Figure 3: Hardy County #0301 geophysical well log.

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
Amplitude
0° 90° 180° 270° 0°
NGamma (CPS)
0
400
F-Res.
0
Ohm-m
40
Structure
0° 90° 180° 270° 0°
sptRes (ohms)
0
1500
Caliper (Inches)
5
8
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

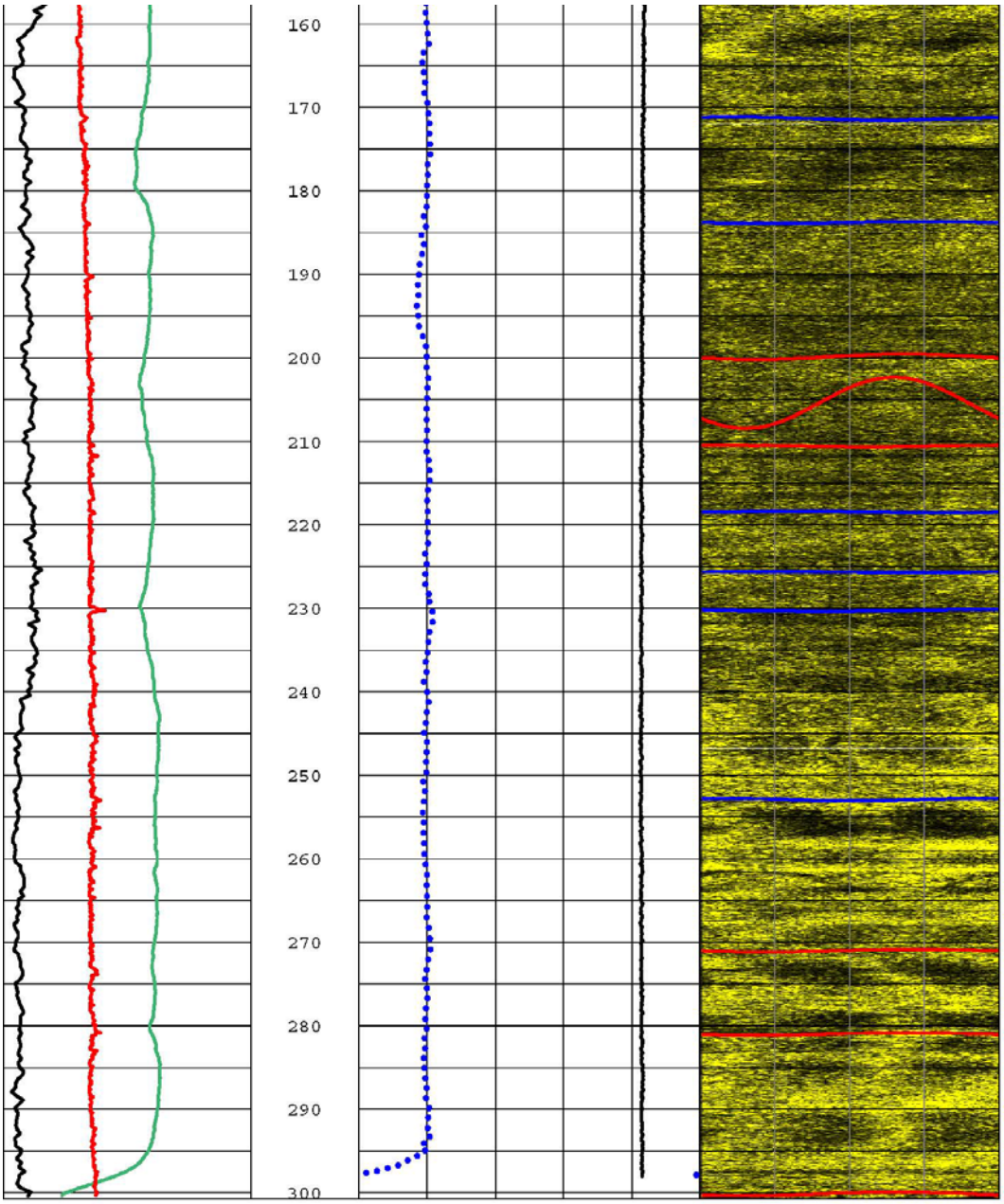


Figure 4: Berkley County #0840 geophysical well log.

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.

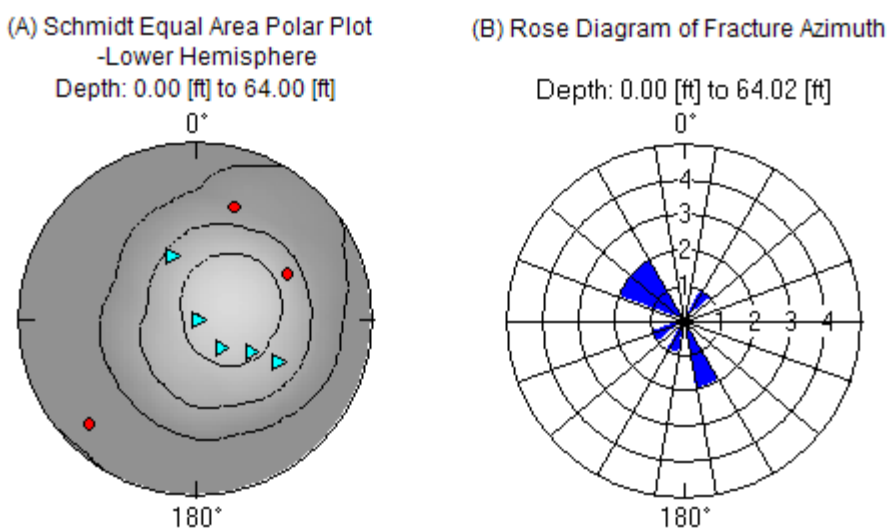


Figure 5: Summary of fracture measurements for borehole Wyo-0148. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.

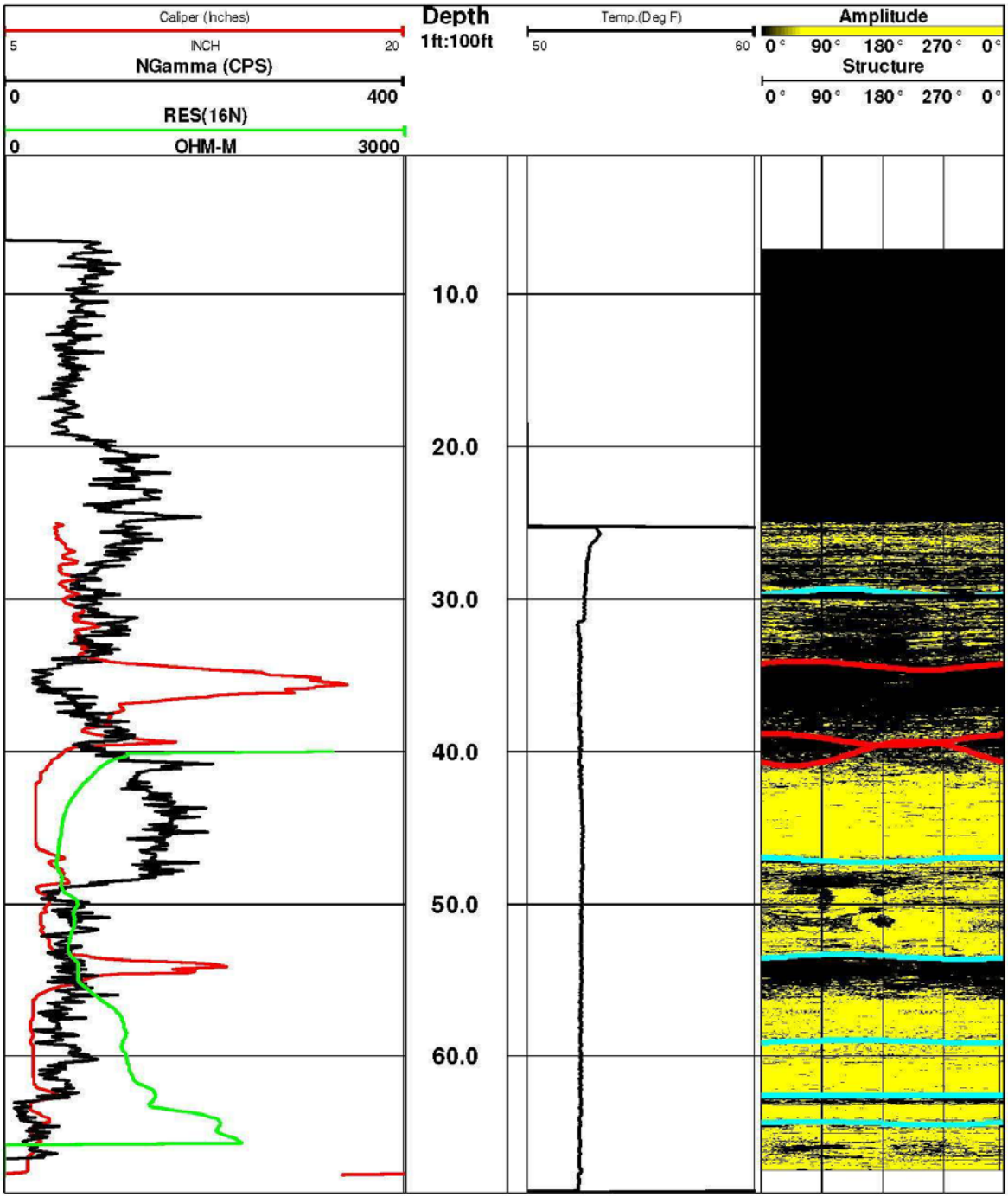


Figure 6: Wyoming County #0148 geophysical well log.

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.

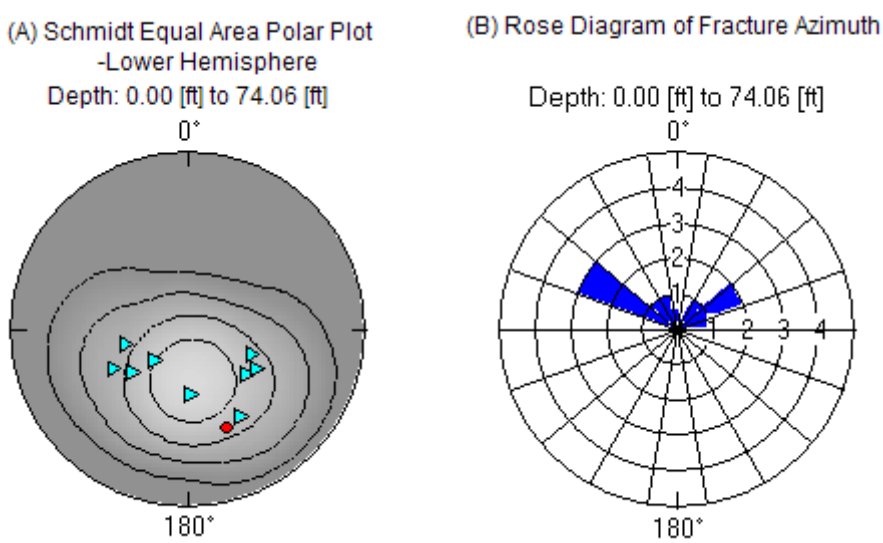


Figure 7: Summary of fracture measurements for borehole Web-0167. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.

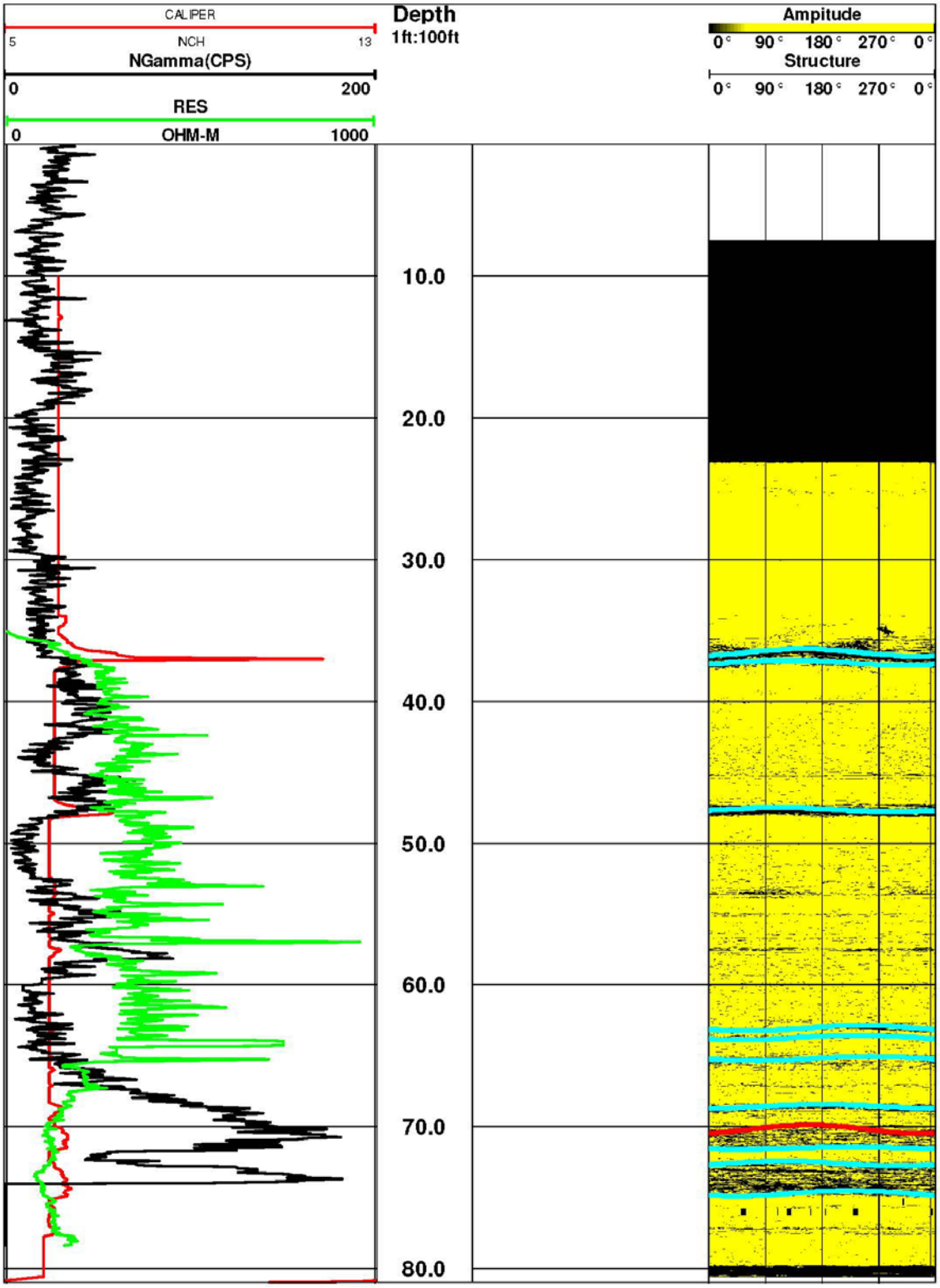


Figure 9: Webster County #0167 geophysical well log.

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.

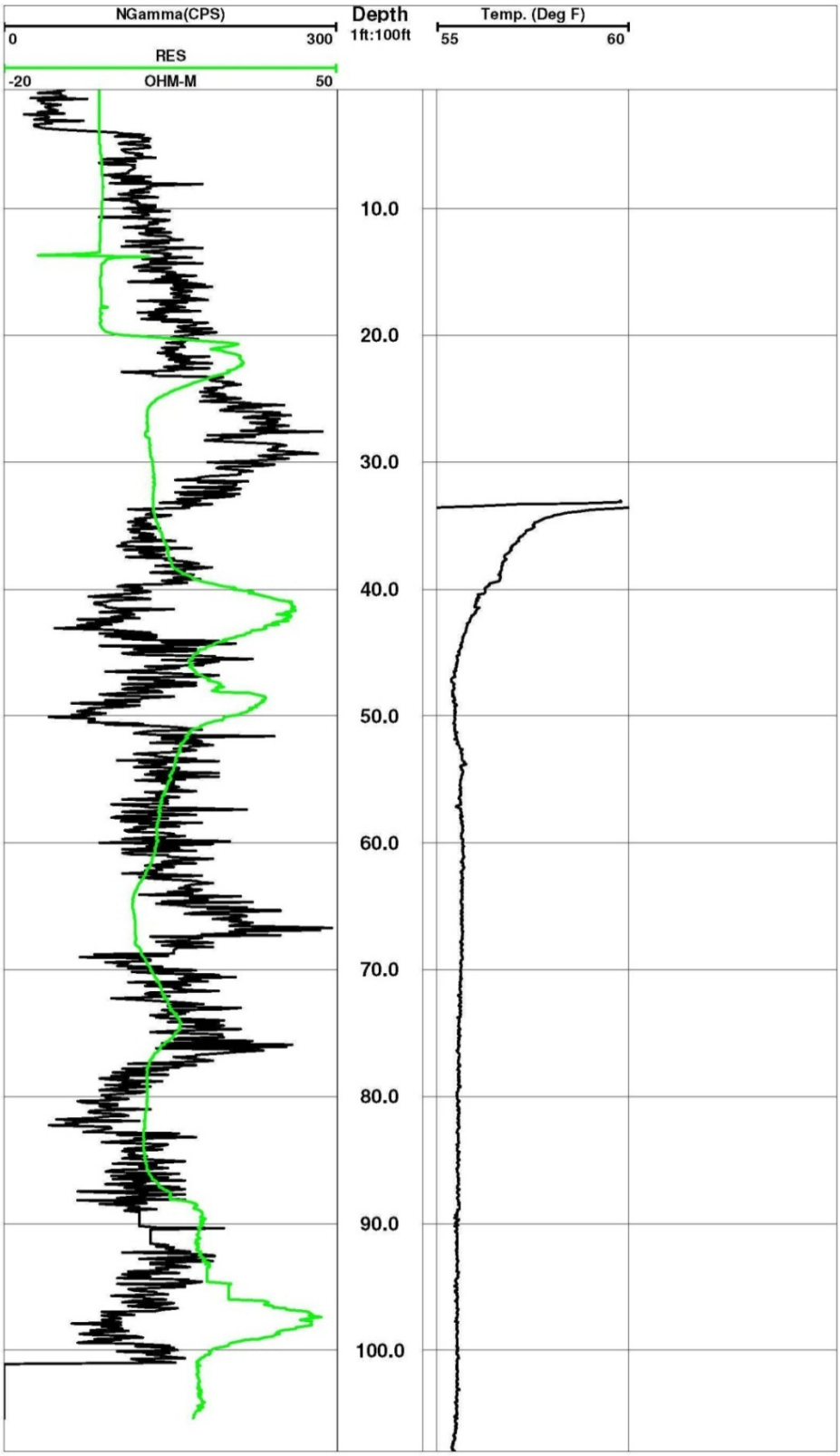


Figure 10: Wayne County #0144 geophysical well log.

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.

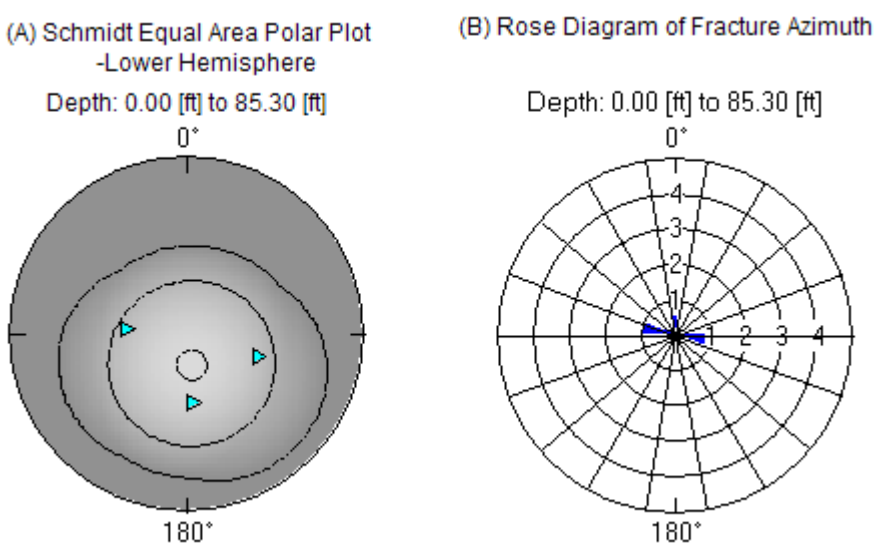


Figure 11: Summary of fracture measurements for borehole Poc-0256. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.

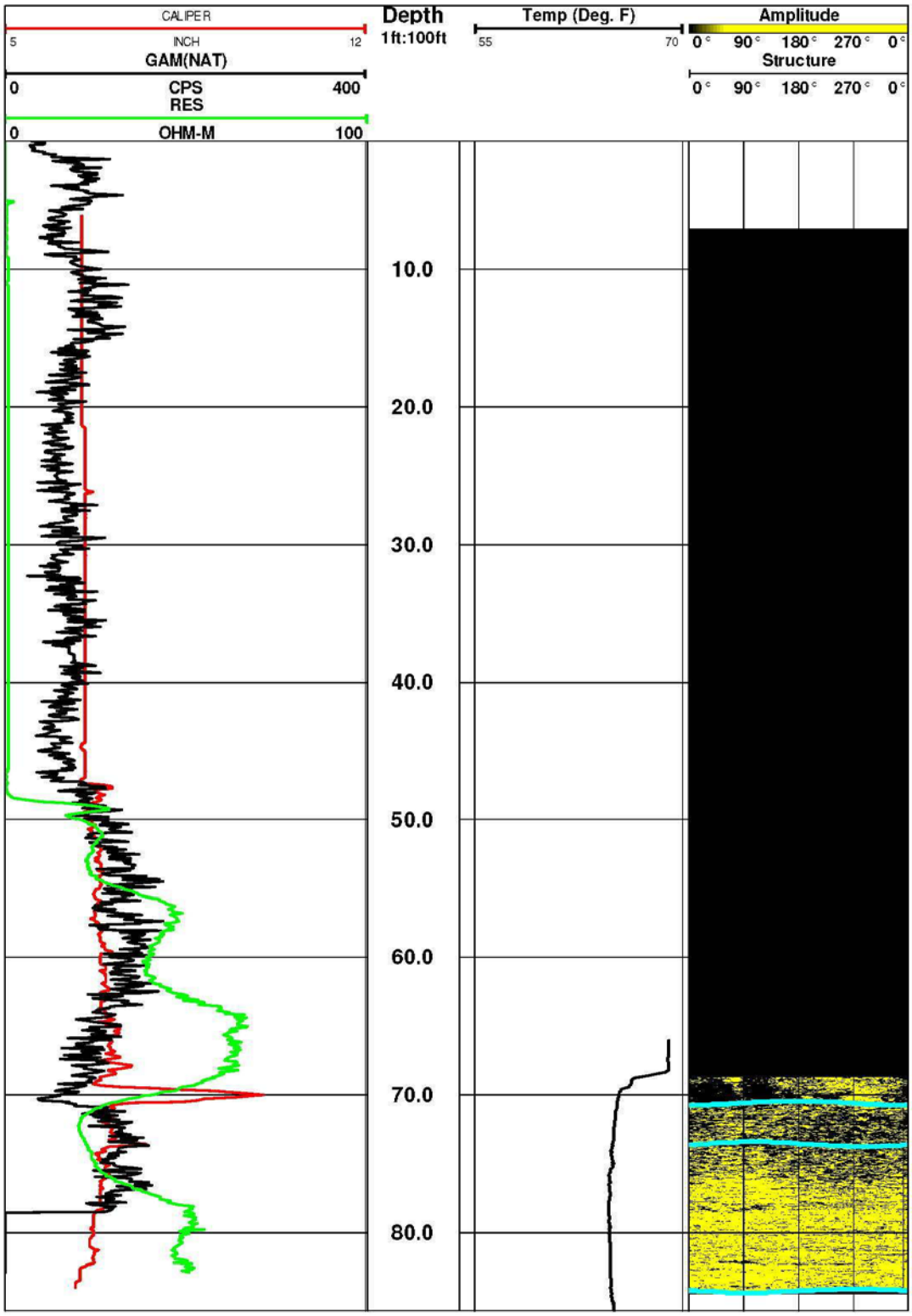


Figure 12: Pocahontas County #0256 geophysical well log.

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

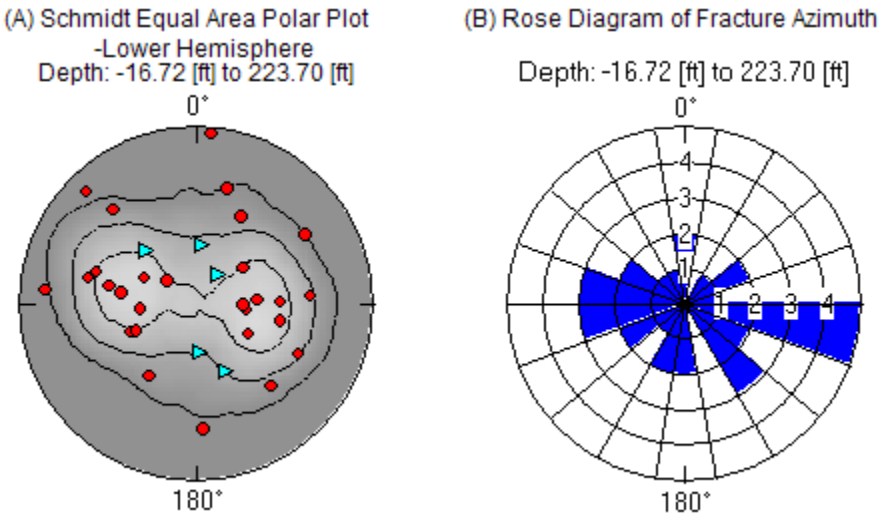
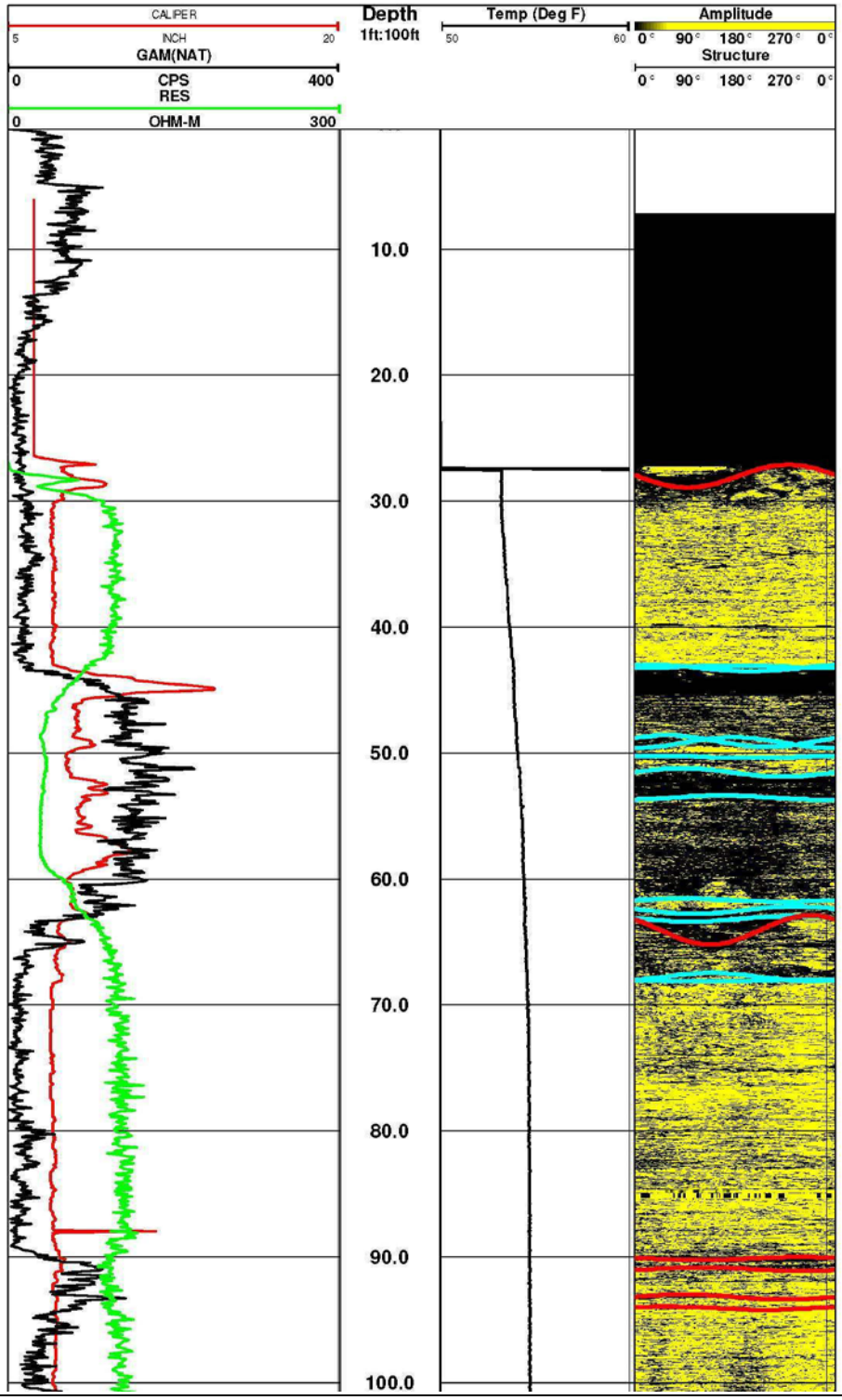


Figure 13: Summary of fracture measurements for borehole Mng-0585. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.


CALIPER
5
INCH
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

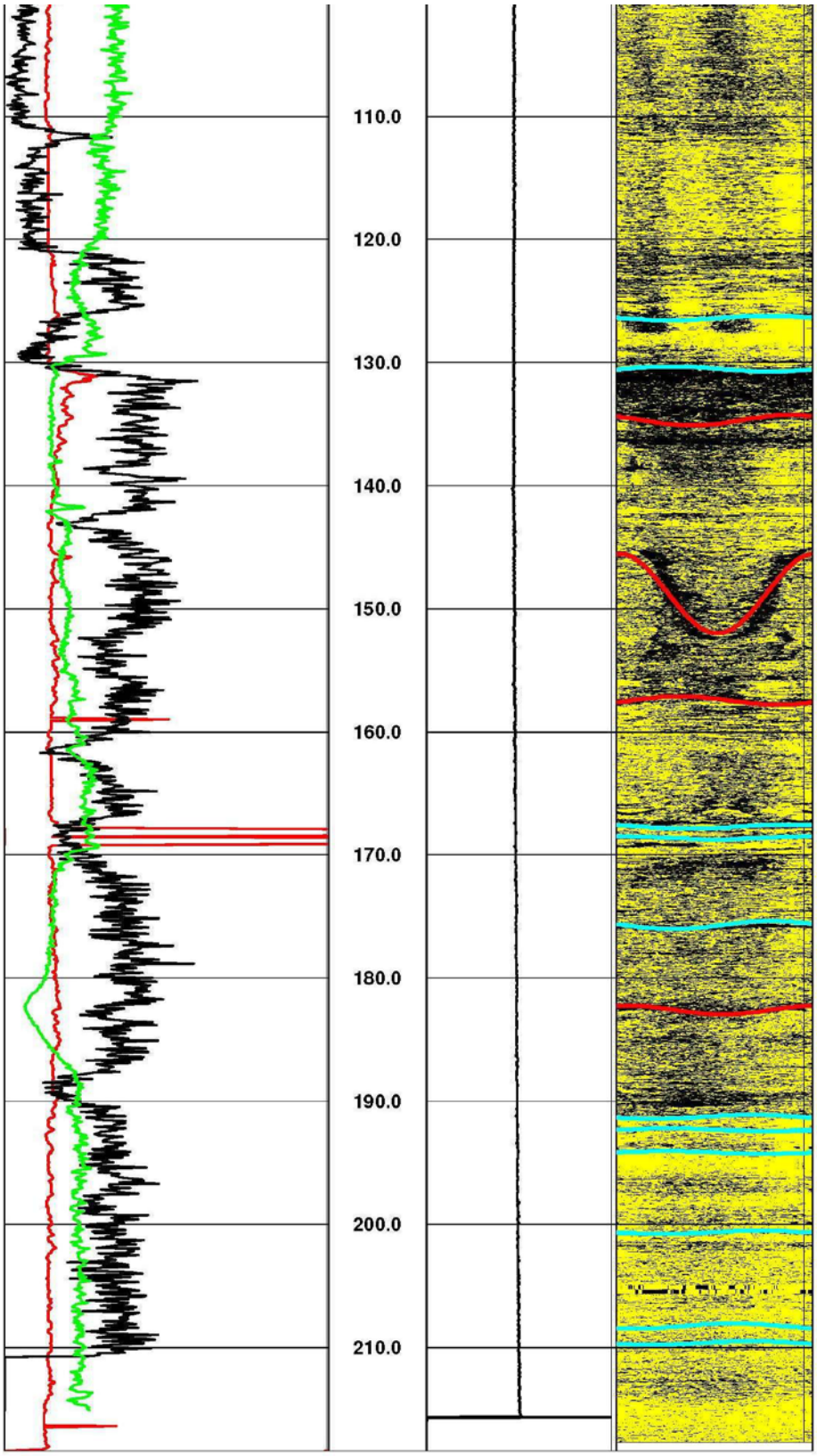


Figure 14: Monongalia County #0585 geophysical well log.

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.

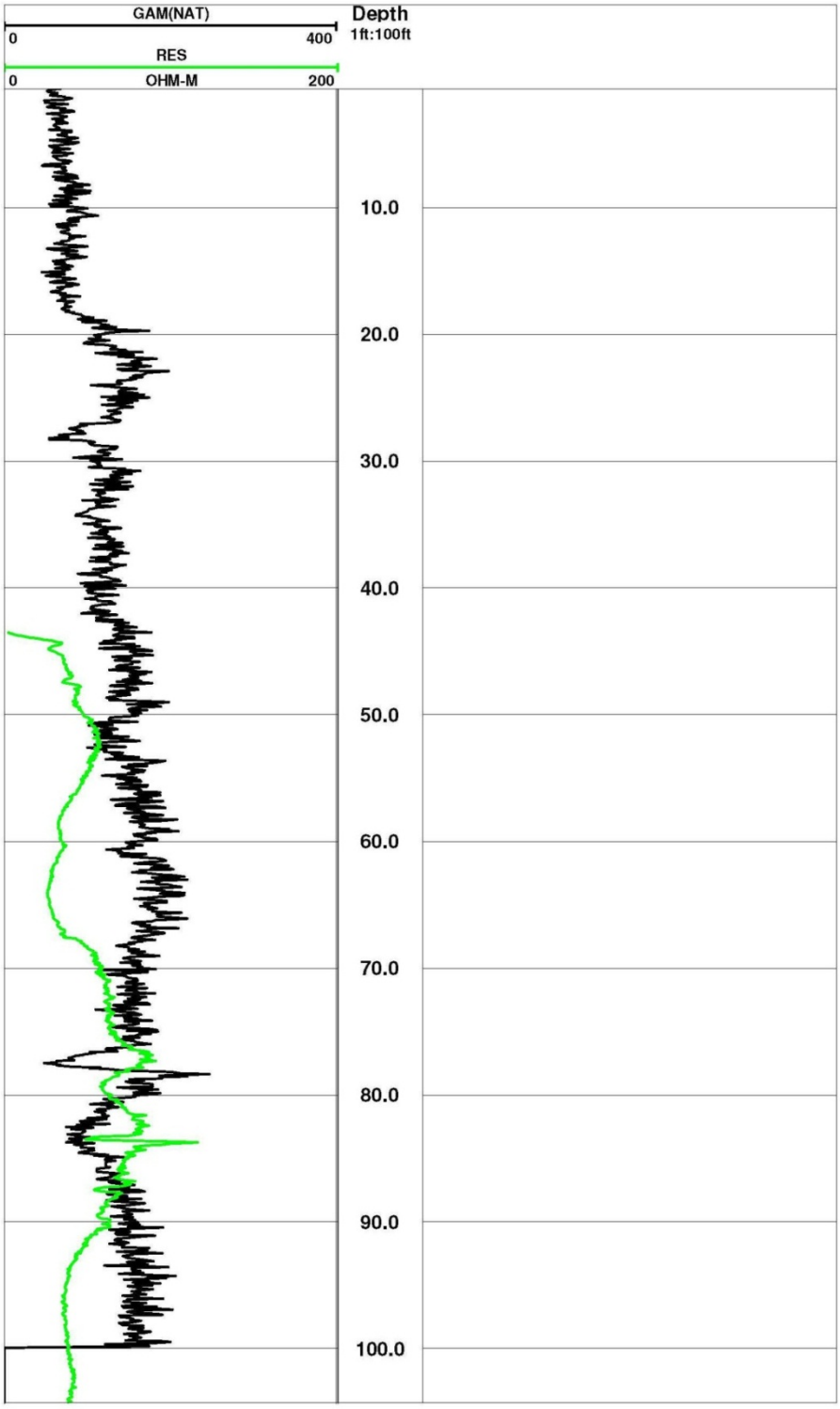


Figure 15: Kanawha County #0946 geophysical well log

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

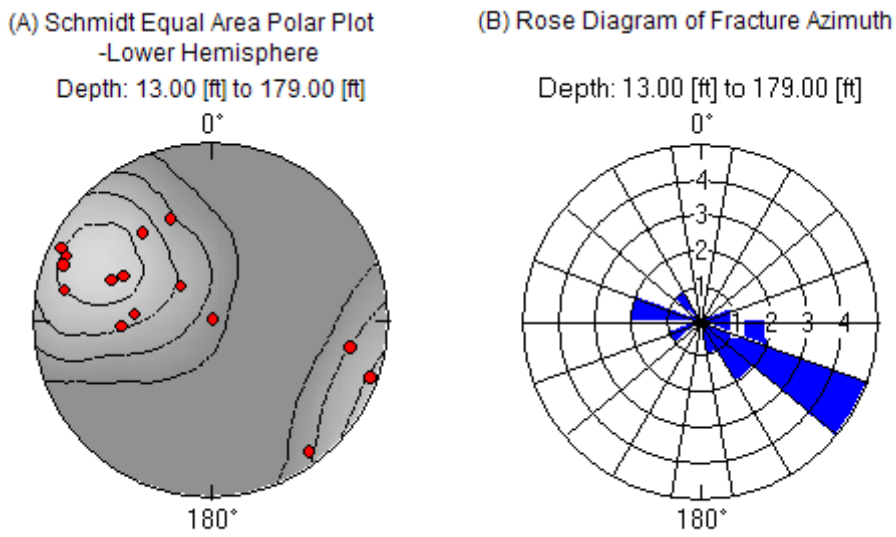
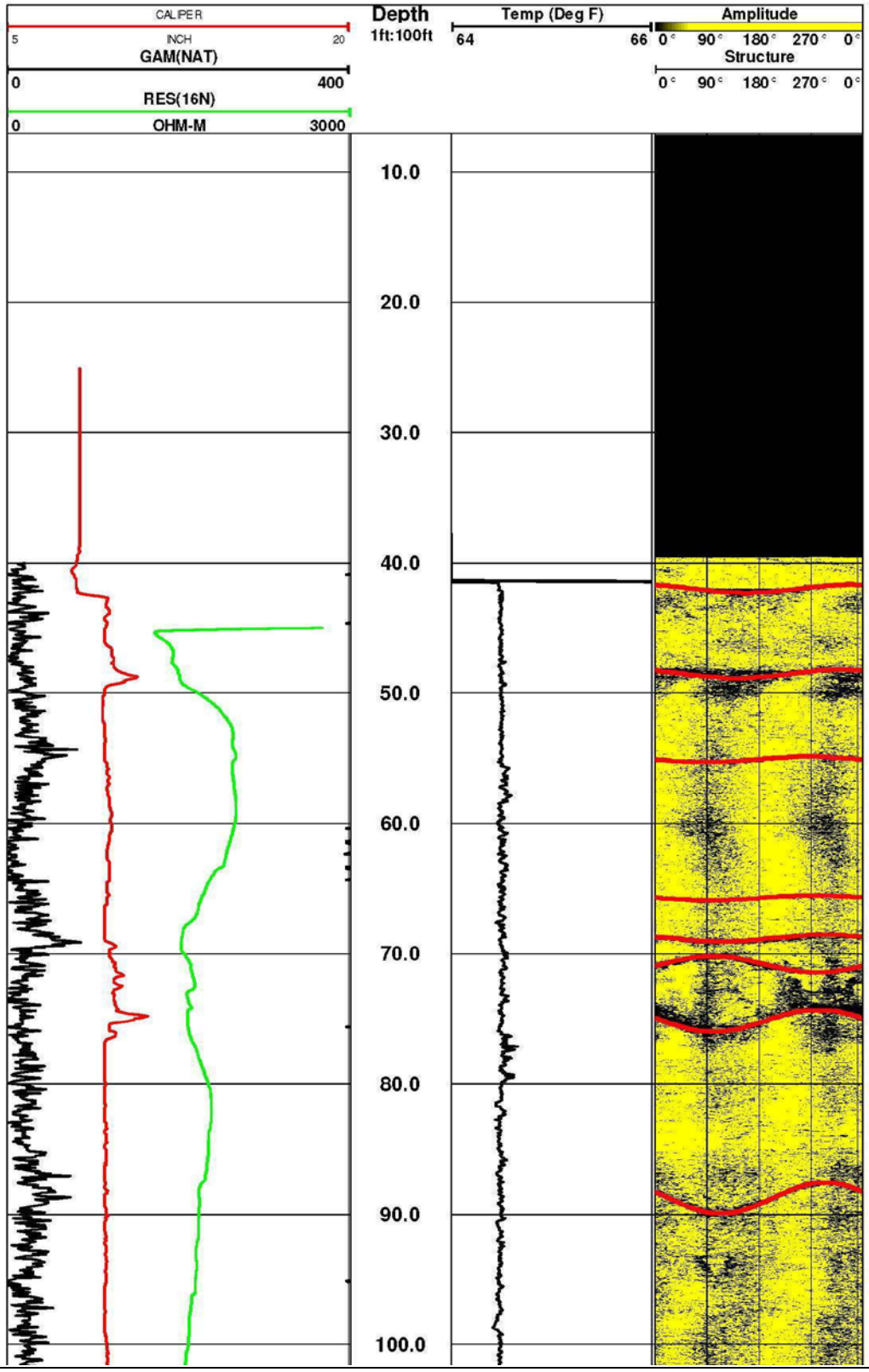
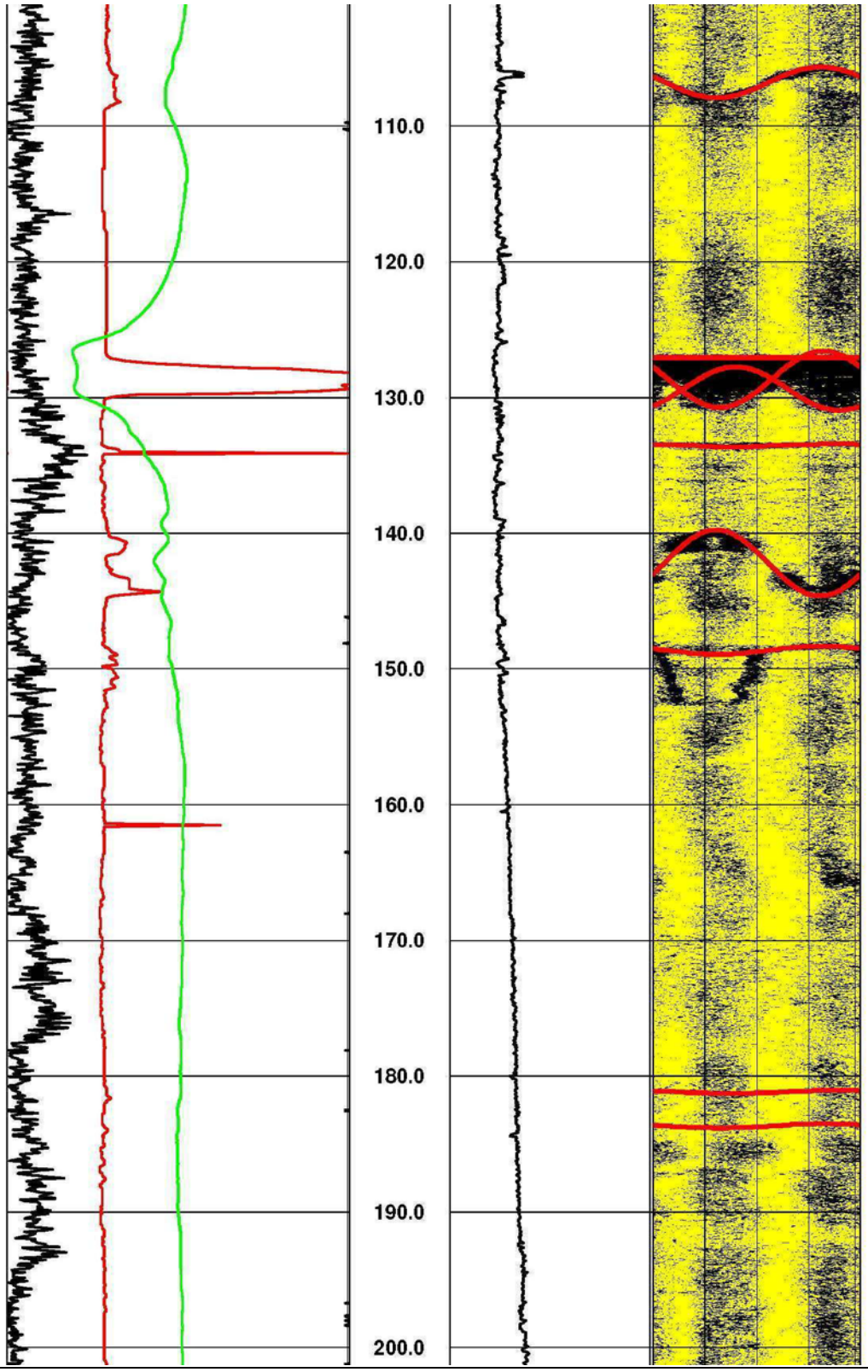


Figure 16: Summary of fracture measurements for borehole Ber-0445. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.


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

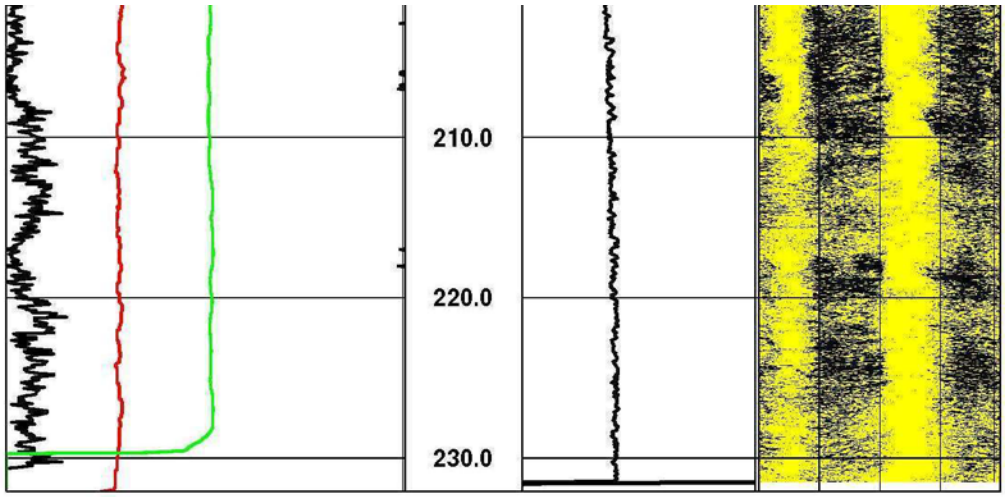


Figure 16: Berkeley County #0445 geophysical well log

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

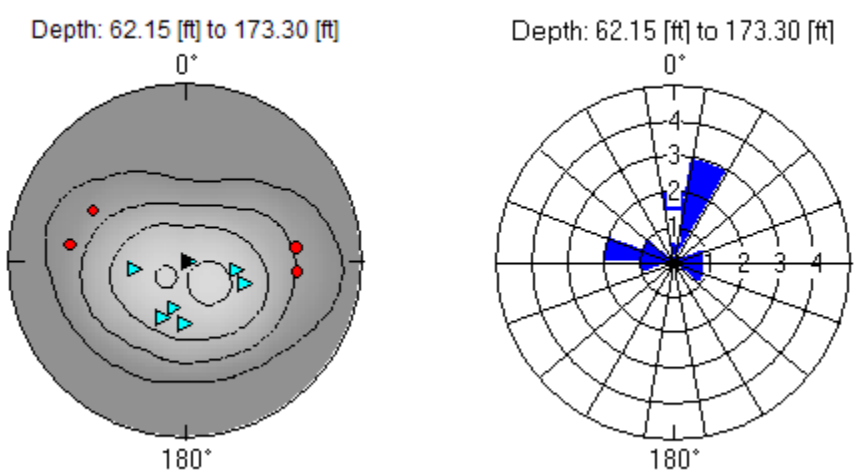
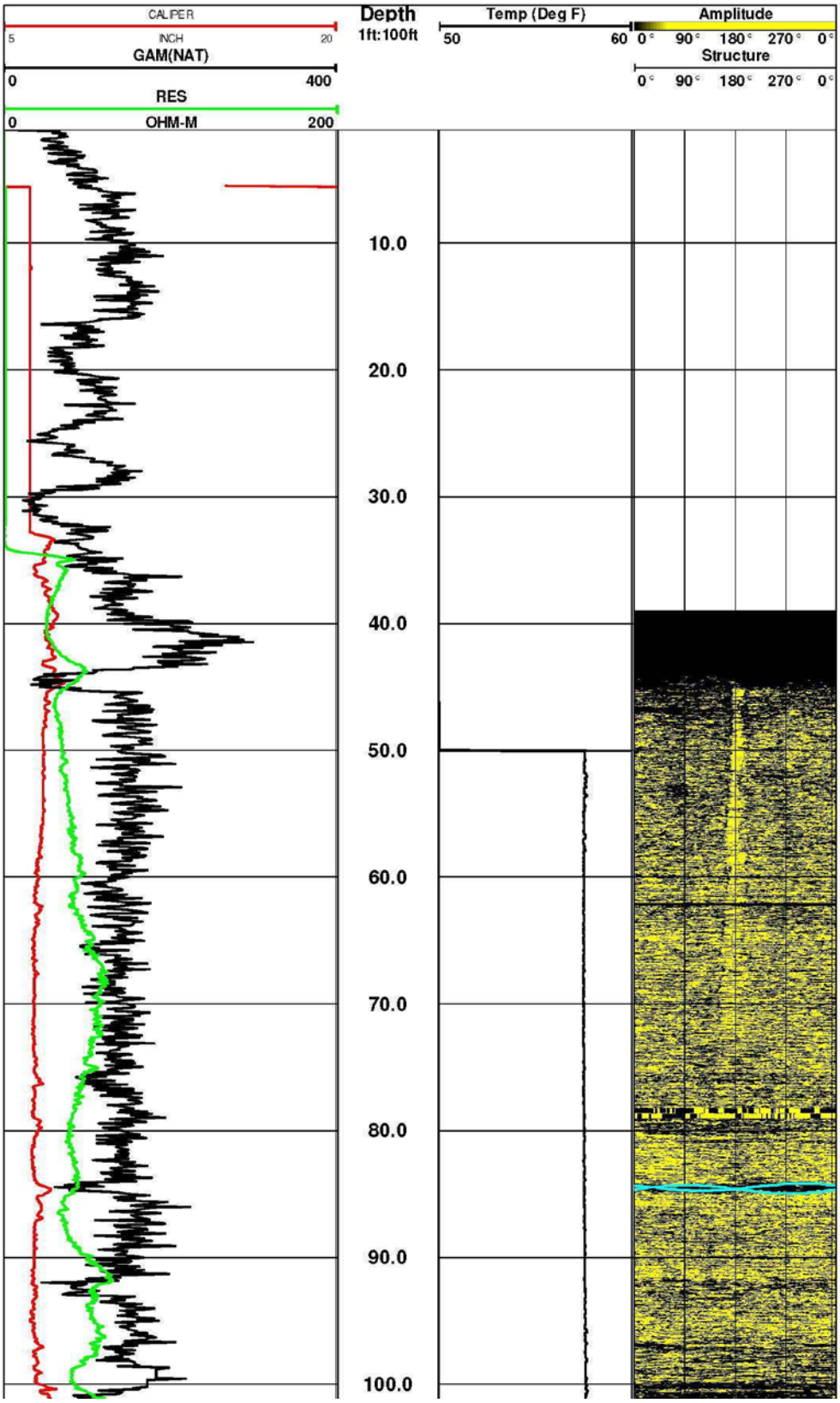


Figure 17: Summary of fracture measurements for borehole Bar-0135. (A) Schmidt lower hemisphere polar plot of fracture dip, and (B) Rose diagram of fracture azimuth.


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

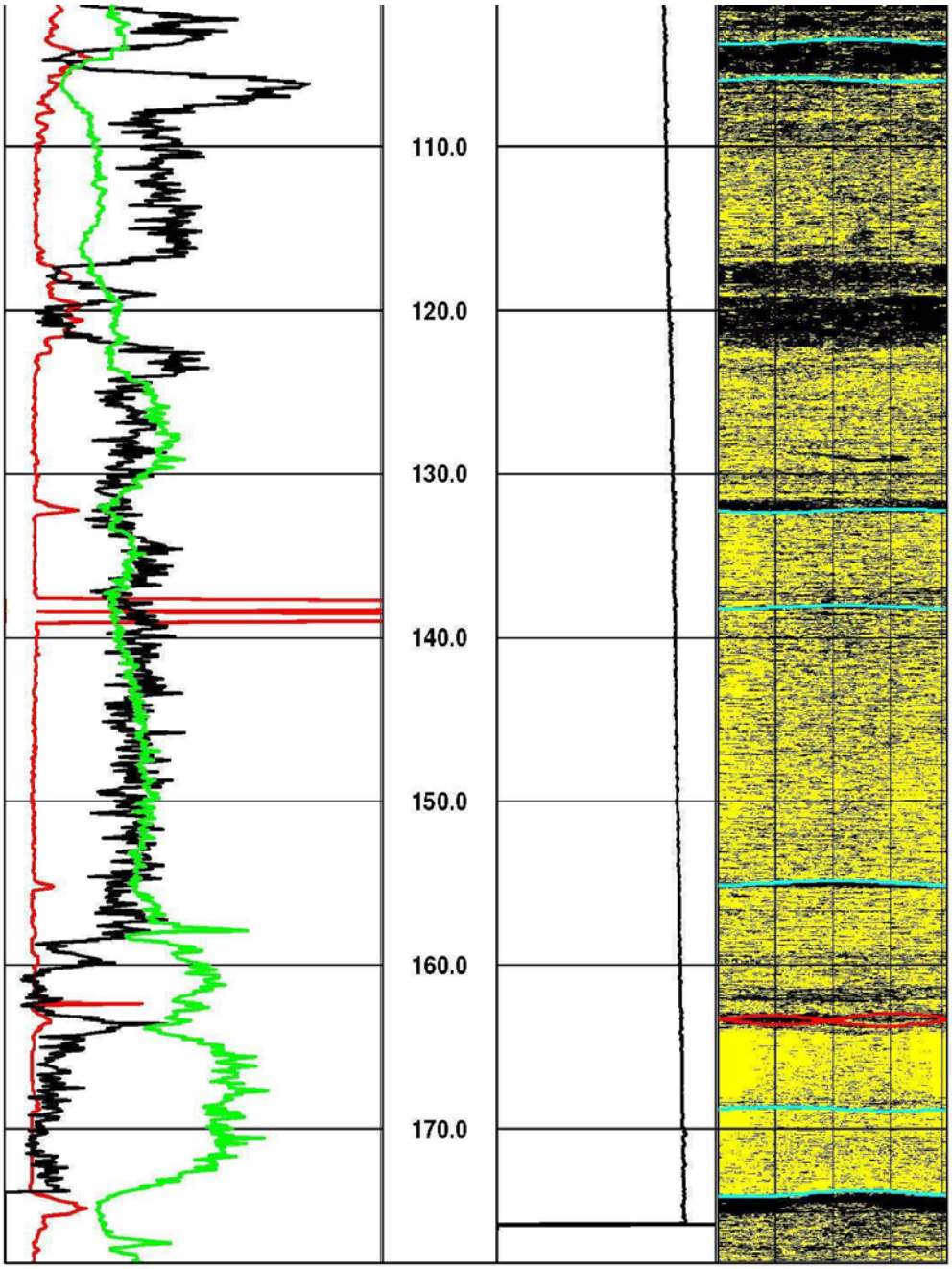


Figure 19: Barbour County #0136 geophysical well log

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 Division of Water http://water.ky.gov	All withdrawal, transfer, and diversion >10,000gpd EXEMPT 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) http://www.mde.state.md.us	All withdrawal activities regardless of planned amounts EXEMPT 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) Division of Soil and Water Resources 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) 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 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. Major: >90,000,000gpm of if filling, flooding, or alteration of stream flow occurs. 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 groundwater 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 EXEMPT Public Supply and Agriculture (conditionally) Withdrawals from basin that avg. >100,000gpd in 30 days EXEMPT Hydroelectric (conditionally) Diversions out of the basin that avg. >20,000gpd in 30 days EXEMPT 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) 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

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).

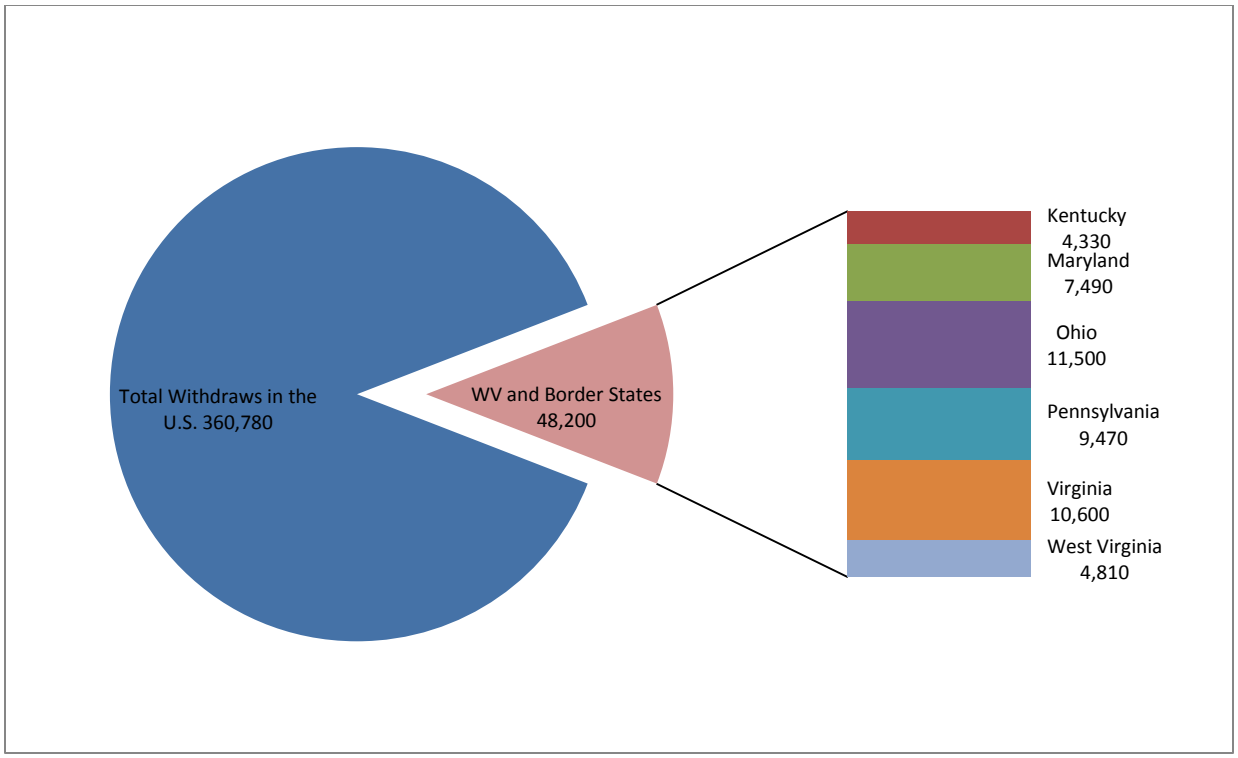


Figure 1 West Virginia and Border States' Contribution to the USGS Estimates of Total Water Withdrawals in the United States in 2005 in Mgal/day.

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).

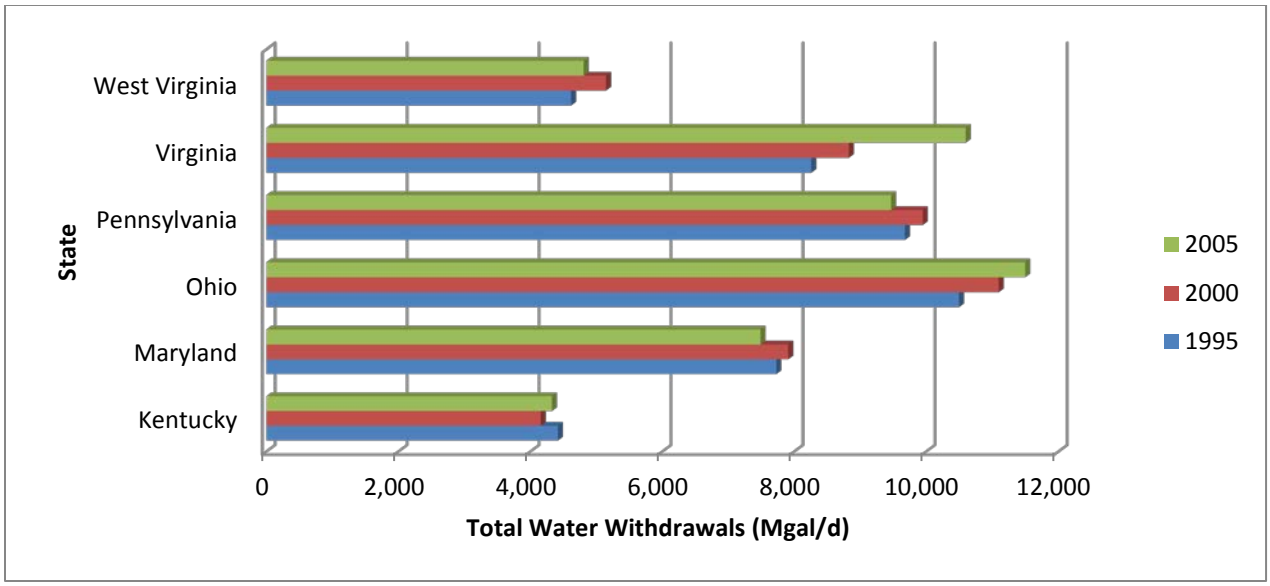
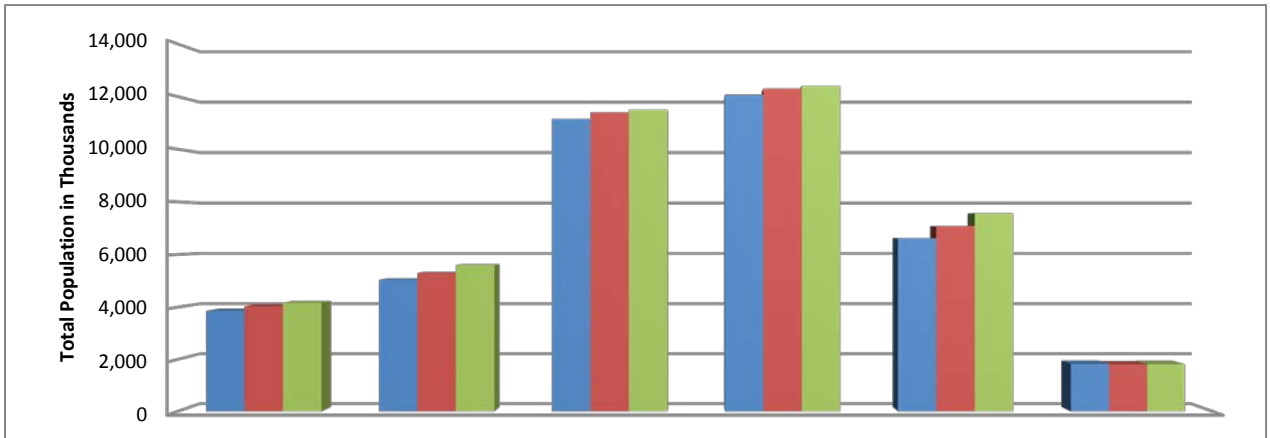


Figure 2 USGS Estimates of Total Water Withdrawals by State for 5 year Intervals in Mgal/day.



	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).

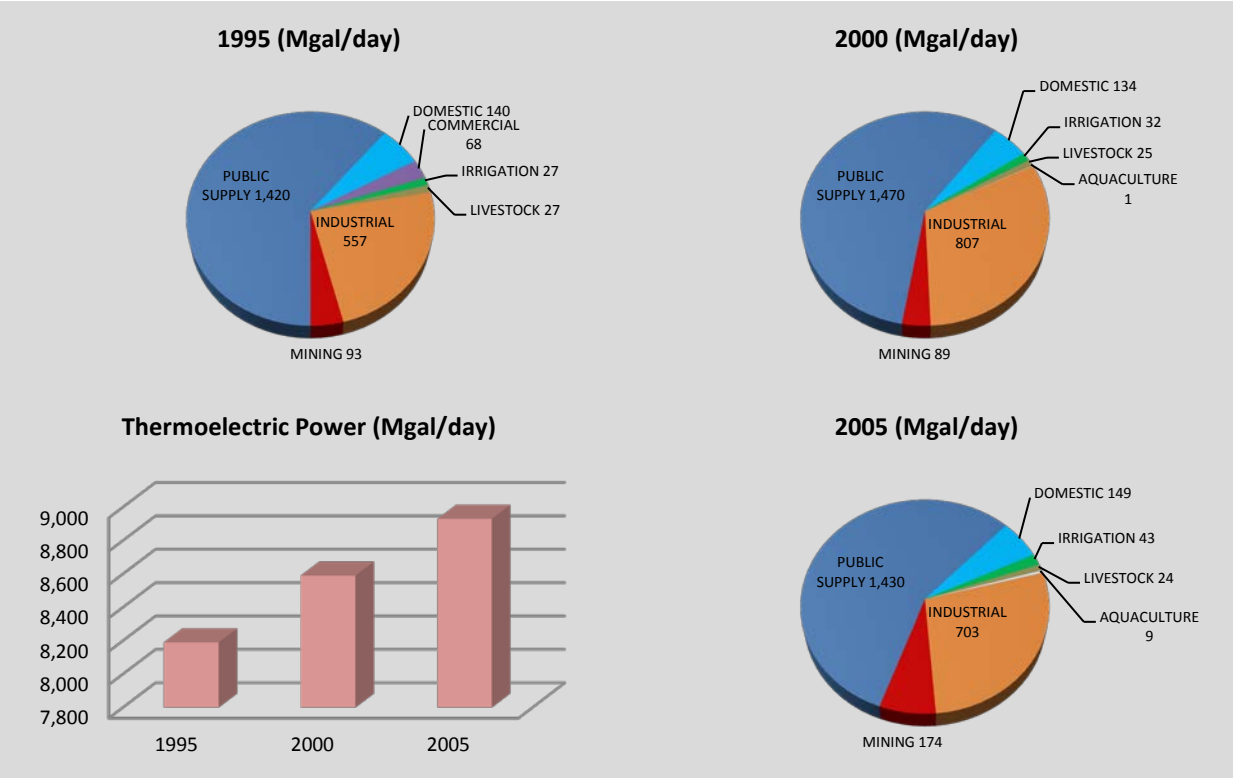


Figure 4 USGS Estimate of Ohio's Water Withdrawals (Mgal/day) by Category of Use and Year.

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).

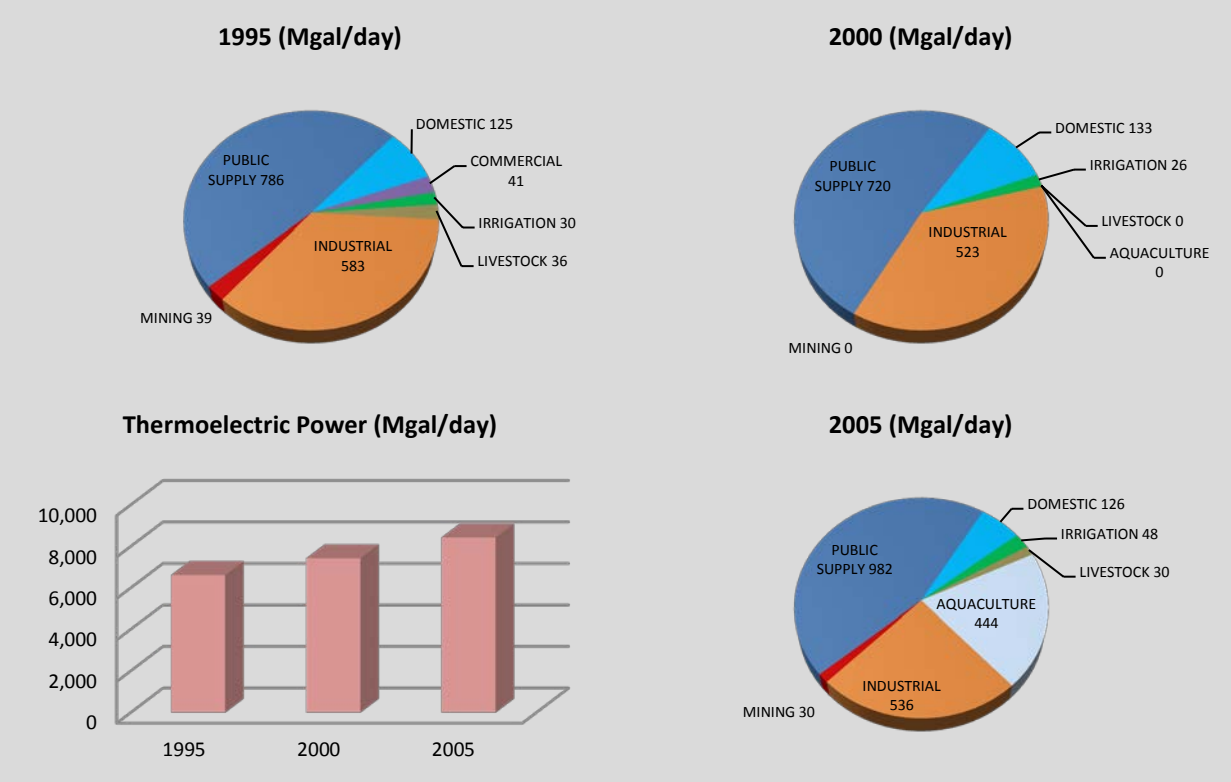


Figure 5 USGS Estimate of Virginia's Water Withdrawals (Mgal/day) by Category of Use and Year.

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).

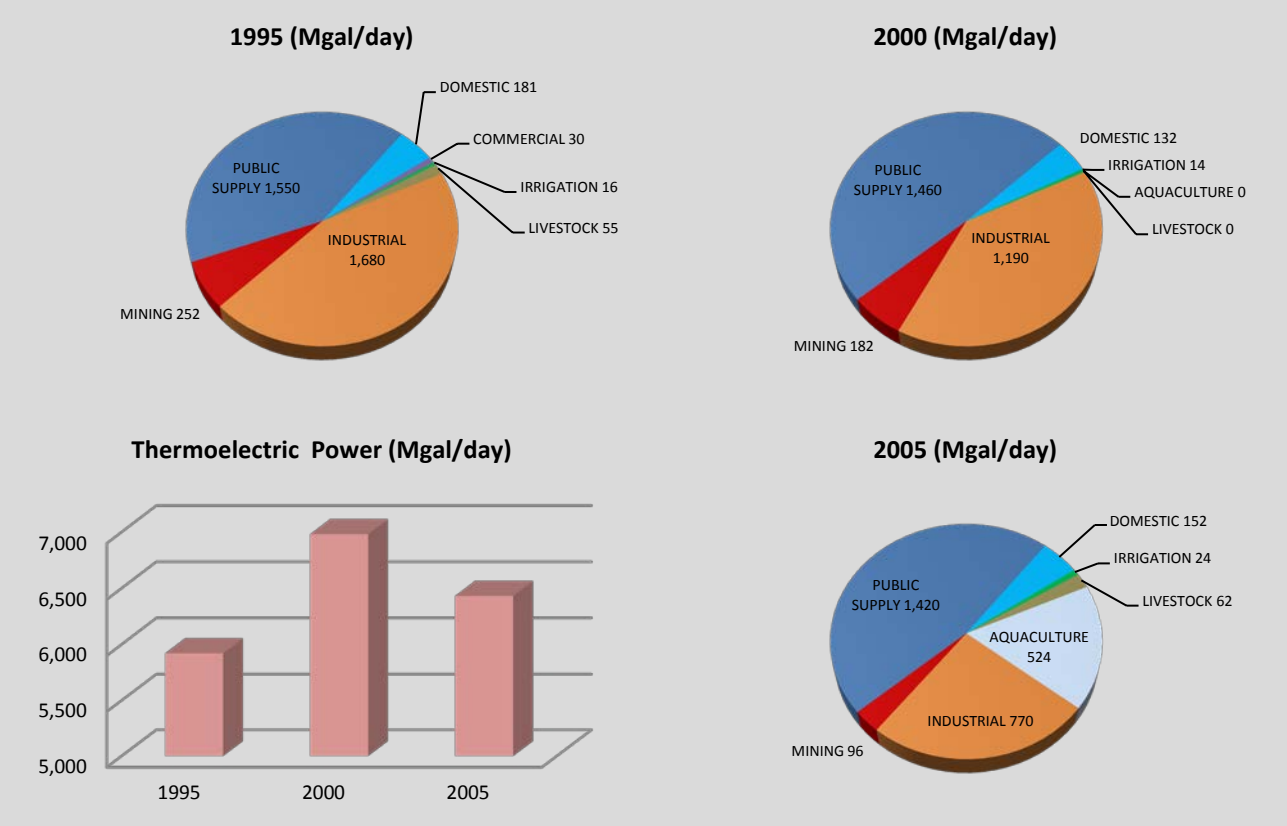


Figure 6 USGS Estimate of Pennsylvania's Water Withdrawals (Mgal/day) by Category of Use and Year.

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).

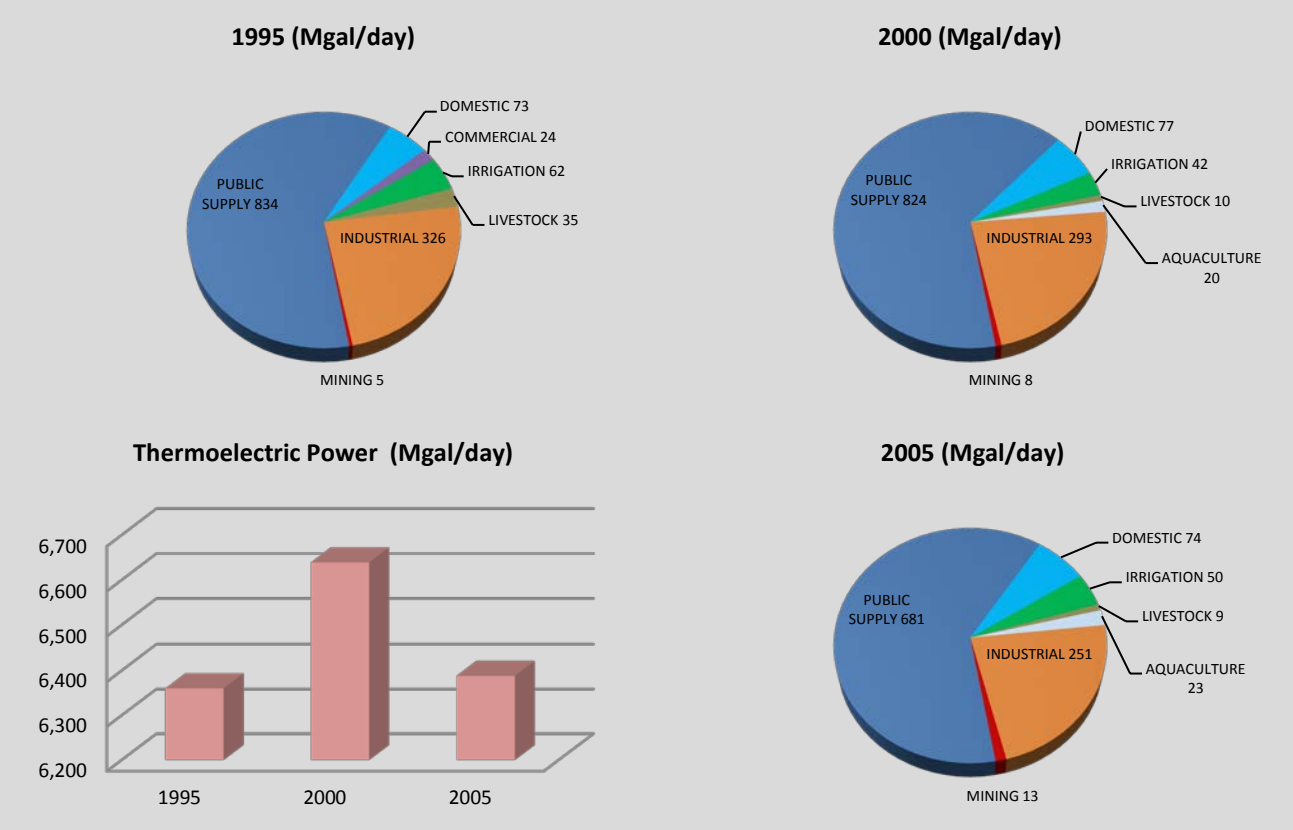


Figure7 USGS Estimate of Maryland's Water Withdrawals (Mgal/day) by Category of Use and Year.

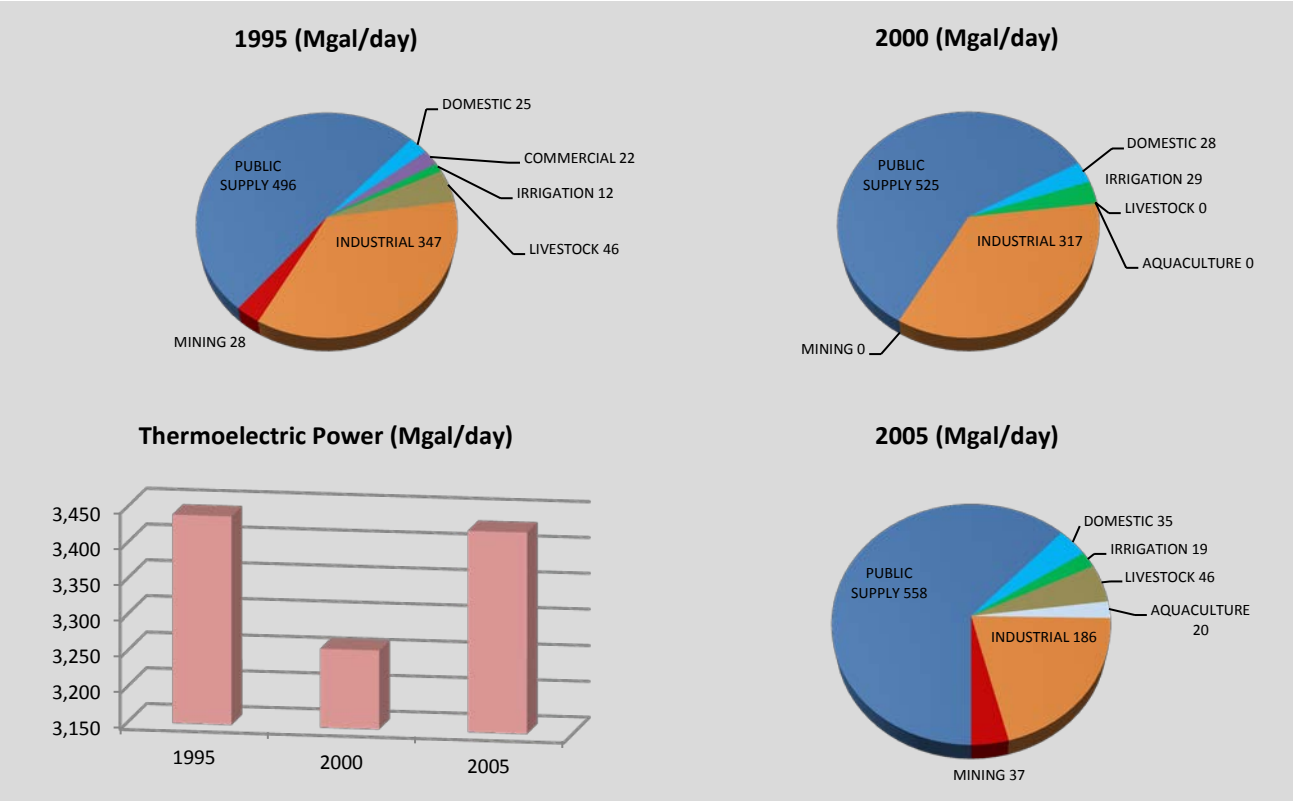


Figure8 USGS Estimate of Kentucky's Water Withdrawals (Mgal/day) by Category of Use and Year.

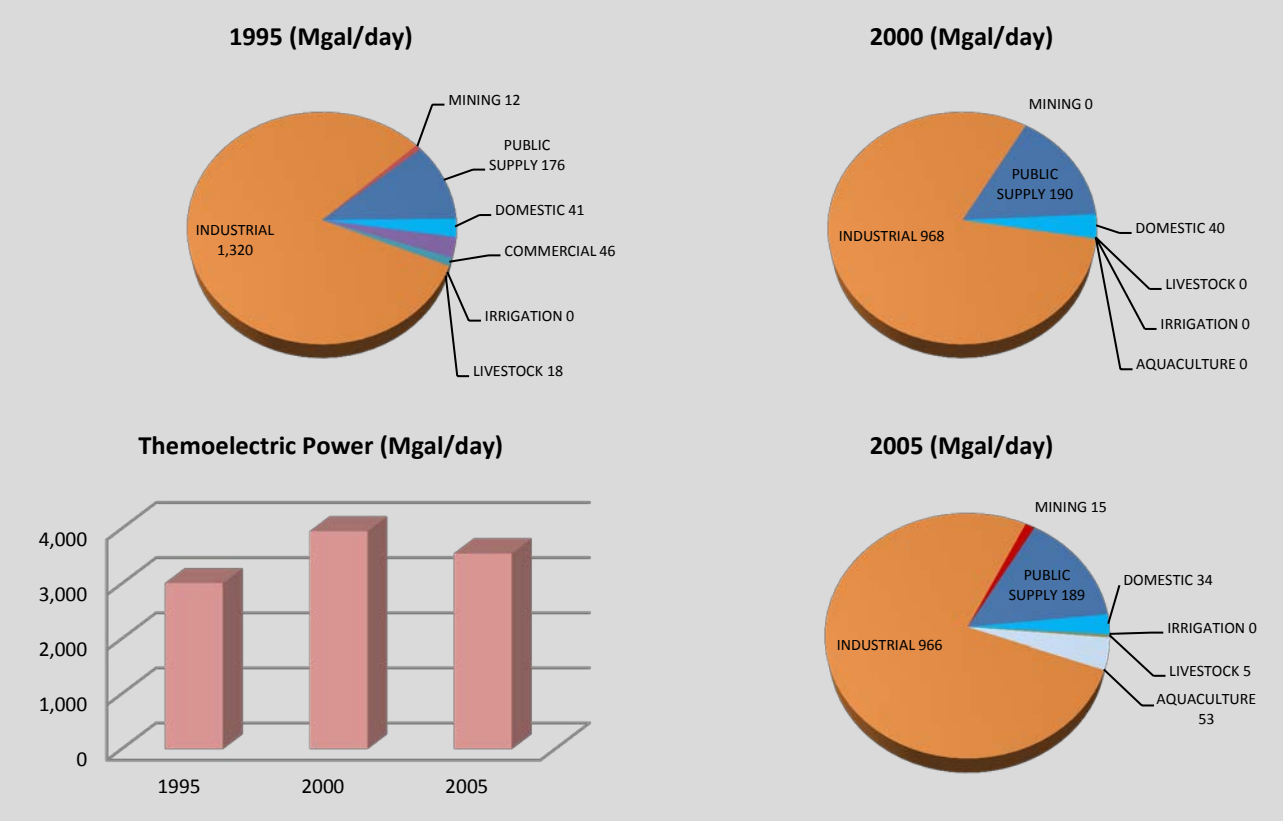


Figure 9 USGS Estimate of West Virginia's Water Withdrawals (Mgal/day) by Category of Use and Year.

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 ☐ Agriculture / Aquaculture ☐ Industrial ☐ Public Water Suppliers ☐ Chemical ☐ 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 ☐ Lower Pennsylvania ☐ Mississippian ☐ Upper Pennsylvanian & Permian ☐ Unknown ☐ Devonian/Silurian ☐ Ordovician & Cambrian ☐
9	Type of Rock *	Sandstone ☐ Sand & Gravel ☐ Shale ☐ Limestone/Dolomite ☐ Underground Mine ☐ Interbedded Sandstone & Shale ☐ Unknown ☐ 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 ☐ Agriculture / Aquaculture ☐ Industrial ☐ Public Water Suppliers ☐ Chemical ☐ Thermoelectric (Coal) ☐ Hydro Electric ☐

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).

2011 Groundwater Withdrawal (Gal/Month)	
January *	
February *	
March *	
April *	
May *	
June *	
July *	
August *	
September *	
October *	
November *	
December *	

	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

LARGE QUANTITY WATER USER REGISTRATION FORM FOR 2011
INDUSTRIAL USER

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	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
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 ☐ Upper Pennsylvanian & Permian ☐ Middle Pennsylvanian ☐ Lower Pennsylvanian ☐ Devonian / Silurian ☐ Ordovician/Cambrian ☐ Unknown ☐
Type of Rock *	Sandstone ☐ Sand & Gravel ☐ Shale ☐ Limestone/Dolomite ☐ Underground Mine ☐ Interbedded Sandstone & Shale ☐ Interbedded Sandstone, Limestone & Shale ☐ 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 100.00%		Boone 100.00%	11,073,226
4710	Rockspring Development-Camp Creek Mine/Prep Plant	Twelvepole 100.00%		Wayne 100.00%	134,171,417
3941	Rum Creek Coal Sales - Anna Branch Surface	Upper Guyandotte 100.00%		Logan 100.00%	8,096,667
1586	Second Sterling Corp - Keystone No. 1 Prep Plant	Tug Fork 100.00%		McDowell 100.00%	58,318,333
2439	Southern Minerals - Superior Preparation Plant	Tug Fork 100.00%		100.00% 0.00%	26,121,000
4004	U S Silica Company	Potomac Direct Drains 100.00%		Morgan 100.00%	388,230,585
4749	White Flame Energy - No. 9 Surface Mine	Tug Fork 100.00%		Mingo 100.00%	7,189,583
10103	Wolf Run Mining - Sentinel Complex	Tygart Valley 99.93%	West Fork 0.07%	Barbour 100.00%	81,209,500
Petroleum					
1112	Ergon West Virginia, Inc.	Upper Ohio North 100.00%		Hancock 38.67%	PA 61.33%	213,093,153
3558	Koppers Inc.	Upper Ohio North 100.00%		Brooke 100.00%	112,478,235
2960	Mars Water Supply Well	West Fork 100.00%		Harrison 100.00%	32,087,048
1590	New Martinsville Booster Plant	Middle Ohio North 100.00%		Wetzel 100.00%	78,556,680
1499	Rain CII Carbon LLC	Upper Ohio South 100.00%		Marshall 100.00%	48,722,299

Public Water Supply					
3569	Alderson Water Treatment Plant	Greenbrier 100.00%		Monroe 100.00%	154,730,000
2678	Alpine Lake Public Utilities Company	Youghiogheny 100.00%		Preston 100.00%	31,950,000
10009	Armstrong PSD	Upper Kanawha 100.00%		Fayette 100.00%	83,785,791
10065	Arthurdale Water Company	Monongahela 100.00%		Preston 100.00%	8,060,800
1325	Athens Water Plant	Upper New 100.00%		Mercer 100.00%	172,351,000
3077	Beckley Water Company	Lower New 89.45%	Upper Kanawha 10.55%	Raleigh 100.00%	3,269,161,633
10040	Beech Bottom Water Department	Upper Ohio South 100.00%		Brooke 100.00%	14,688,443
1972	Belington Water Treatment Plant	Tygart Valley 100.00%		Barbour 100.00%	80,445,667
10056	Benwood Municipal Utilities	Upper Ohio South 100.00%		Marshall 100.00%	68,721,667
7133	Berkeley County PSD - BHWTP	Potomac Direct Drains 100.00%		Berkeley 100.00%	636,676,000
10002	Berkeley County PSD - PRWTP	Potomac Direct Drains 100.00%		Berkeley 100.00%	1,015,631,333
7134	Berkeley County PSWD - GFU	Potomac Direct Drains 100.00%		Berkeley 100.00%	26,127,667
2547	Berkeley Springs Water Works	Potomac Direct Drains 100.00%		Morgan 100.00%	156,177,605
1142	Beverly Water Plant	Tygart Valley 100.00%		Randolph 100.00%	153,598,604
7906	Big Bend PSD	Greenbrier 100.00%		Summers 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 100.00%	Mercer 100.00%	219,013,396
10003	Boone Raleigh PSD	Coal 100.00%	Boone 100.00%	56,110,053
1768	Bradshaw Water Works	Tug Fork 100.00%	McDowell 100.00%	15,012,227
4757	Brenton PSD	Upper Guyandotte 100.00%	Wyoming 100.00%	17,075,200
1720	Buffalo Creek PSD	Upper Guyandotte 100.00%	Logan 100.00%	124,299,329
7764	Burnsville Public Utility	Little Kanawha 100.00%	Braxton 100.00%	29,581,340
1097	Burr Industrial Park	Potomac Direct Drains 100.00%	Jefferson 100.00%	26,513,300
1159	Cacapon State Park	Potomac Direct Drains 100.00%	Morgan 100.00%	25,577,333
10020	Cameron Water	Upper Ohio South 100.00%	Marshall 100.00%	41,178,792
3226	Canaan Valley State Park	Cheat 100.00%	Tucker 100.00%	27,256,869
8195	Cedar Grove Water Works	Upper Kanawha 100.00%	Kanawha 100.00%	215,774,333
4086	Charles Town Water Treatment Plant	Shenandoah Jefferson 100.00%	Jefferson 100.00%	616,400,487
5082	Cheat Mountain Water Company	Cheat 74.58% Elk 25.42%	Pocahontas 100.00%	10,911,345
10062	City of Belmont	Middle Ohio North 100.00%	Pleasants 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 100.00%	Wyoming 100.00%	7,089,167
10035	Cowen PSD	Gauley 100.00%	Webster 100.00%	118,313,467
4158	Craigsville PSD	Gauley 100.00%	Nicholas 100.00%	205,629,500
10018	Crumpler Community Water	Tug Fork 100.00%	McDowell 100.00%	9,690,000
4068	Danese Public Service District	Lower New 100.00%	Fayette 100.00%	78,059,847
7748	Davy Municipal Water Works	Tug Fork 100.00%	McDowell 100.00%	11,443,633
7934	Deerwood	Potomac Direct Drains 100.00%	Berkeley 100.00%	8,171,333
7959	Denmar Correctional Center	Greenbrier 100.00%	Pocahontas 100.00%	15,801,273
1900	Elkins Water Works	Tygart Valley 100.00%	Randolph 100.00%	789,237,288
10004	Flatwoods Canoe Run PSD	Elk 100.00%	Braxton 100.00%	208,389,667
1582	Follansbee Hooverson Heights	Upper Ohio North 100.00%	Brooke 100.00%	155,115,000
3137	Follansbee Municipal Water	Upper Ohio North 100.00%	Brooke 100.00%	311,318,500
3442	Fort Gay Water Works	Tug Fork 100.00%	Wayne 100.00%	100,301,033
1134	Fountain Public Service District	North Branch Potomac 100.00%	Grant 41.56% Mineral 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

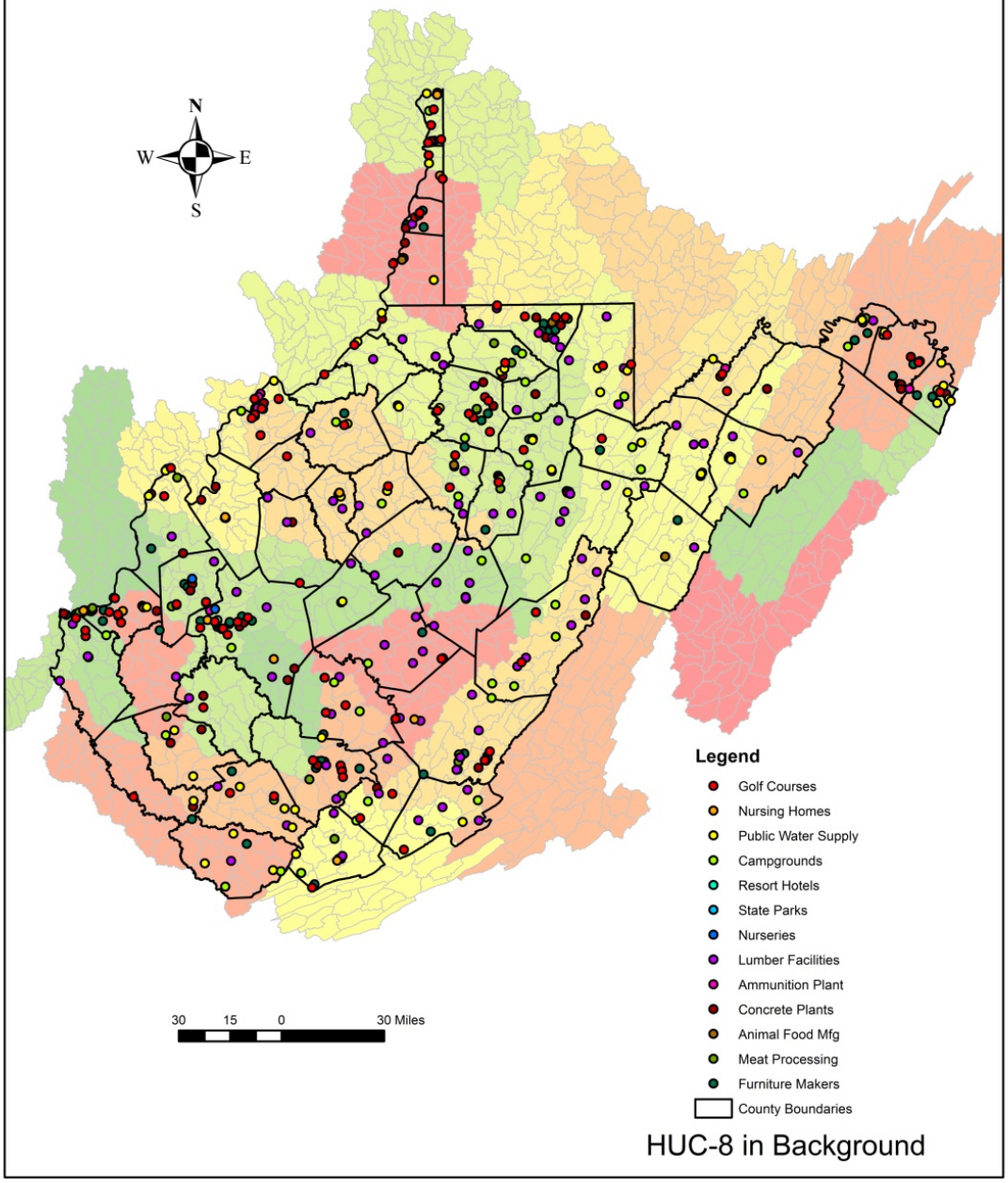
- Jails/Correction facilities
- Schools
- Resort hotels
- Parks
- Courthouses
- Cemeteries
- Nurseries
- Lumber facilities
- Chemical plants
- Paper plants
- Ammunition plants
- Concrete plants
- Pet food producers (from animal and food waste)
- Meat processors
- Industrial parks
- Furniture makers
- 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



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.

		2006 "to" class								
		Water (%)	Developed (%)	Barren (%)	Forest (%)	Shrubland (%)	Herbaceous (%)	Planted/Cultivated (%)	Wetlands (%)	Row Totals (%)
1992 "from" class		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 (%)
1992 "from" class						Unchanged				
		0.38	0.20	0.04	77.04	0.00	0.00	11.25	0.00	88.90
						Changed				
	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 (%)
1992 "from" class		Unchanged								
		0.03	0.00	0.00	94.60	0.00	0.00	0.00	0.00	94.63
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.01	0.03	0.03	84.19	0.00	0.00	5.23	0.00	89.50
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.58	0.71	0.22	75.38	0.00	0.00	8.46	0.00	85.37
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.76	2.71	0.05	67.24	0.00	0.00	9.41	0.00	80.17
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.08	0.23	0.11	74.75	0.00	0.00	8.24	0.00	83.41
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.39	0.21	0.09	60.62	0.00	0.00	15.34	0.38	77.03
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		5.37	7.48	0.07	53.61	0.00	0.00	7.81	0.00	74.35
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		1.62	2.75	0.04	64.19	0.00	0.00	10.66	0.00	79.27
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		1.45	0.73	0.01	80.68	0.00	0.00	5.19	0.00	88.05
		Changed								
	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

		2006 "to" class								
		Water (%)	Developed (%)	Barren (%)	Forest (%)	Shrubland (%)	Herbaceous (%)	Planted/Cultivated (%)	Wetlands (%)	Row Totals (%)
1992 "from" class		Unchanged								
		3.07	2.37	0.01	61.05	0.00	0.00	17.00	0.00	83.49
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.14	0.65	0.00	81.68	0.00	0.00	6.36	0.00	88.84
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.58	1.52	0.01	65.93	0.00	0.00	10.71	0.00	78.75
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.41	0.34	0.08	76.13	0.00	0.00	10.41	0.01	87.37
		Changed								
	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

		2006 "to" class								
		Water (%)	Developed (%)	Barren (%)	Forest (%)	Shrubland (%)	Herbaceous (%)	Planted/Cultivated (%)	Wetlands (%)	Row Totals (%)
1992 "from" class		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

		2006 "to" class								
		Water (%)	Developed (%)	Barren (%)	Forest (%)	Shrubland (%)	Herbaceous (%)	Planted/Cultivated (%)	Wetlands (%)	Row Totals (%)
1992 "from" class		Unchanged								
		0.46	0.37	0.41	83.48	0.00	0.00	2.54	0.17	87.43
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.86	3.01	0.29	81.85	0.00	0.00	0.42	0.00	86.44
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.32	0.66	0.08	88.59	0.00	0.00	1.62	0.00	91.27
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.86	3.65	0.02	71.83	0.00	0.00	7.95	0.00	84.32
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.11	1.03	0.32	80.57	0.00	0.00	0.86	0.00	82.88
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.17	0.79	0.17	82.60	0.00	0.00	0.28	0.00	84.01
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.10	1.72	0.03	77.40	0.00	0.00	2.26	0.00	81.51
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.15	0.95	0.18	82.66	0.00	0.00	0.26	0.00	84.19
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		1.32	2.93	0.04	61.44	0.00	0.00	5.40	0.00	71.14
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		5.36	5.97	0.00	56.55	0.00	0.00	9.22	0.02	77.13
		Changed								
	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 (%)
1992 "from" class		Unchanged								
		0.48	0.51	0.12	78.63	0.00	0.00	1.24	0.00	80.98
		Changed								
	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

Buffalo Creek PSD (B) (1720) 3302347 David Crawford 6

Supply Sources 6

Surface Water 6

Groundwater 6

Storage Reservoir 6

Counties Served District Office 6

Customer Sales 6

Distribution Integrity and Planned Maintenance Ratio: Water (hours) 7

Pumping Station Equipment (Buffalo Creek PSD, pg. 703A INSERT) 7

Reservoirs, Standpipes, and Water Treatment Plant (Buffalo Creek PSD, pg. 704A-704B INSERT) 7

Water Meters 7

WVIJDC 7

Century Volga PSD (B) 3300107 Linda Rice 8

Supply Sources 8

Surface/Purchase Water 8

Storage 8

Reservoir 8

Counties Served 8

District Office 8

Customer Sales 8

Distribution Integrity and Planned Maintenance Ratio: Water (hours) 9

Pumping Station Equipment (Century Volga PSD, pg. 703A INSERT) 9

Reservoirs, Standpipes, and Water Treatment Plant (Century Volga PSD, pg. 704A-704B INSERT) 9

Water Meters 9

WVIJDC 9

Project: Century Volga 9

Project: City of Philippi 10

Chestnut Ridge PSDs (B) 3300109 AND 102 Sharon Miller 11

Supply Sources 11

Surface/Purchase Water 11

Storage Reservoir 11

Counties Served 11
District Office 11
Customer Sales 11
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 12
Pumping Station Equipment (Century Volga PSD, pg. 703A – 703B INSERT) 12
Water Meters 12
WVIJDC 12
Project: City of Philippi 12
City of Cameron (C) (10020) 3302603 Mark Frazier 13
Supply Sources 13
Surface Water 13
Storage Reservoir 13
Counties Served 13
District Office 13
Customer Sales 14
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 14
Pumping Station Equipment (City of Cameron, pg. 702A INSERT) 14
Reservoirs, Standpipes, and Water Treatment Plant (City of Cameron, pg. 703A INSERT) 14
Water Meters 14
WVIJDC 14
Hurricane Municipal (A&B) (1871) 3304005 Charles McCallister 15
Supply Sources 15
Surface Water 15
Storage Reservoir 15
Counties Served 15
District Office 15
Customer Sales 15
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 16
Pumping Station Equipment (Hurricane Municipal WW, pg. 703A INSERT) 16
Reservoirs, Standpipes, and Water Treatment Plant (Hurricane Municipal WW, pg. 704A INSERT) 16
Water Meters 16
WVIJDC 16

City of Saint Marys (A&B) (10063) 3303704 Linda Wilson 17
Supply Sources 17
Groundwater 17
Storage Reservoir 17
Counties Served 17
District Office 17
Customer Sales 17
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 18
Pumping Station Equipment (City of St. Marys, pg. 703A INSERT) 18
Reservoirs, Standpipes, and Water Treatment Plant (City of St. Marys, pg. 704A INSERT) 18
Water Meters 18
WVIJDC 18
Project: Pleasants County Development Authority 18
Cool Ridge-FlatTop PSD (B) 3304139 Jerry Farley 20
Supply Sources 20
Surface/Purchase Water 20
Storage Reservoir 20
Counties Served 20
District Office 20
Customer Sales 20
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 21
Pumping Station Equipment (Cool Ridge-Flat Top PSD, pg. 702A INSERT) 21
Reservoirs, Standpipes, and Water Treatment Plant (Cool Ridge-Flat Top PSD, pg. 703A INSERT) 21
Water Meters 21
WVIJDC 21
City of Point Pleasant (B) (1945) 3302710 Amber Tatterson 22
Supply Sources 22
Groundwater 22
Storage Reservoir 22
Counties Served 22
District Office 22
Customer Sales 22

Distribution Integrity and Planned Maintenance Ratio: Water (hours) 23
Pumping Station Equipment (Point Pleasant Water Works, pg. 702A INSERT) 23
Reservoirs, Standpipes, and Water Treatment Plant (Point Pleasant Water Works, pg. 703A INSERT) 23
Water Meters 23
WVIJDC 23
Preston Co. PSD No. 4 (B) (1815) 3303923 Robert Bailey 24
Supply Sources 24
Groundwater 24
Storage Reservoir 24
Counties Served 24
District office 24
Customer Sales 24
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 25
Pumping Station Equipment (Preston Co. PSD #4, pg. 703A INSERT) 25
Reservoirs, Standpipes, and Water Treatment Plant (Preston Co. PSD #4, pg. 704A – 704B INSERT) ... 25
Water Meters 25
WVIJDC 26
Project: Preston Co. Sewer PSD (Valley Point) 26
Valley Water and Sewer Services (D) 3303314 Jeff Pippel 27
Supply Sources 27
Groundwater 27
Storage Reservoir 27
Counties Served 27
District Office 27
Customer Sales 27
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 28
Pumping Station Equipment (Valley Water and Sewer Services, Inc., pg. 702A – 702B INSERT) 28
Reservoirs, Standpipes, and Water Treatment Plant (Valley Water and Sewer Services, Inc., pg. 703A INSERT) 28
Water Meters 28
WVIJDC 28
NO PSC REPORT ONLINE: 29

Coal River Energy 29
District Office 29
Cavaland 29
District Office 29
Glen Haven 29
District Office 29
Zela Elem School 29
District Office 29

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) 946 Buckhannon Road Philippi, WV	**3300107**	**Linda Rice** 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

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

Storage

Reservoir

- 445,000 storage capacity
- Steel tanks

Counties Served

- Barbour

District Office

- Philippi

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

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

Storage Reservoir

- 350,000 storage capacity
- Steel tanks

Counties Served

- Barbour

District Office

- Philippi

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) 44 Main Street Cameron, WV	**3302603**	**Mark Frazier** 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

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

Storage Reservoir

- 28,000,000 storage capacity

Counties Served

- Putnam

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	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'Cl 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

418 Second Street Saint Marys, WV

Linda Wilson

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

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

Storage Reservoir

- 846,000 M.Gals. storage capacity
- Steel tanks

Counties Served

- Pleasant

District Office

- Wheeling

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%

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

Storage Reservoir

- 5 M.Gals. storage capacity
- Steel tanks

Counties Served

- Raleigh
- Summers
- Mercer

District Office

- Beckley

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

400 Viand Street Point Pleasant, WV

Amber Tatterson

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

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

Storage Reservoir

- 3500 M. Gals.
- 4 Steel tanks and 1 concrete tank

Counties Served

- Mason

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	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

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

Storage Reservoir

- No cumulative reservoir capacity reported.

Counties Served

- Preston
  - Brandonville, Valley Point, Glade Farms, Laurel Run, Shady Grove, Pisgah

District office

- Philippi

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
    - Collection system and wastewater treatment plant for Valley Point area.
- ➔ Project Cost - $1,821,000.00
    - 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
  - 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

Berkeley Co. PSWDs(A) 3300202 and 218 Paul Fisher 6

(7133 and 10002) 6

Supply Sources 6

Surface Water 6

Purchased Water 6

Counties Served District Office 6

Operational Programs 6

Customer Sales 7

Distribution Integrity and Planned Maintenance Ratio: Water (hours) 7

Pumping Station Equipment (Berkeley Co PSWD – Bunker Hill and Potomac River, pg. 703D, 703E, 703N, & 703O INSERT) 7

Reservoirs, Standpipes, and Water Treatment Plant (Berkeley Co PSWD – Bunker Hill and Potomac River, pg. 704A-704D INSERT) 7

Water Meters 8

WVIJDC 8

Cheat Mountain Water Co. (B) 3303808 Michael Ritter 9

(5082) 9

Supply Sources 9

Surface Water 9

Groundwater 9

Purchased Water 9

Storage Reservoir 9

Counties Served 9

District Office 9

Operational Programs 10

Customer Sales 10

Distribution Integrity and Planned Maintenance Ratio: Water (hours) 10

Pumping Station Equipment (Cheat Mountain Water Company, Inc., pg. 703A and 703B INSERT) 10

Reservoirs, Standpipes, and Water Treatment Plant (Cheat Mountain Water Company, Inc., pg. 704A INSERT) 10

Water Meters 11

WVIJDC 11
Project: Pocahontas County Public Service District (Sewer) 11
Project: Pocahontas County Public Service District (Sewer) 11
City of Ravenswood (B) 3301810 Kimberly D. Benson 12
(2102) 12
Supply Sources 12
Groundwater 12
Storage Reservoir 12
Monthly Water* 12
Counties Served 12
District Office 12
Operational Programs 12
Customer Sales 12
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 12
Pumping Station Equipment (City of Ravenswood, pg. 702A INSERT) 13
Reservoirs, Standpipes, and Water Treatment Plant (City of Ravenswood, pg. 703A INSERT) 13
Water Meters 13
WVIJDC 13
City of Romney (B) 3301405 Betty Colebank 14
(1794) 14
Supply Sources 14
Surface Water 14
Storage Reservoir 14
Counties Served 14
District Office 14
Operational Programs 14
Customer Sales 15
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 15
Pumping Station Equipment (City of Romney, pg. 703A INSERT) 15
Reservoirs, Standpipes, and Water Treatment Plant (City of Romney, pg. 704A INSERT) 15
Water Meters 15
WVIJDC 16

Ravencliff McGraws Salusville PSD (B) 3305518 Kathy Winfrey 17
(2601) 17
Supply Sources 17
Groundwater 17
Purchased Water 17
Counties Served 17
District Office 17
Operational Programs 18
Customer Sales 18
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 18
Pumping Station Equipment (Ravencliff-McGraws-Saulsville PSD, pg. 702A 702B 702C and 702D INSERT) 18
Reservoirs, Standpipes, and Water Treatment Plant (Ravencliff-McGraws-Saulsville PSD, pg. 703A 703B and 703C INSERT) 18
Water Meters 19
WVIJDC 19
Project: Ravencliff-McGraws-Saulsville PSD 19
Summersville Municipal Water (WTP) (A) 3303404 James Corbitt 20
(10029) 20
Supply Sources 20
Surface Water 20
Storage Reservoir 20
Counties Served 20
District Office 20
Operational Programs 20
Customer Sales 21
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 21
Pumping Station Equipment (Summersville Municipal Water, pg. 703A and 703B INSERT) 21
Reservoirs, Standpipes, and Water Treatment Plant (Summersville Municipal Water, pg. 704A and 704B INSERT) 21
Water Meters 21
WVIJDC 22

Project: City of Summersville 22
Town of Alderson (B) 3301315 Crystal Byer 23
(3569) 23
Supply Sources 23
Surface Water 23
Storage Reservoir 23
Counties Served 23
District Office 23
Operational Programs 23
Customer Sales 24
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 24
Pumping Station Equipment (Town of Alderson, pg. 703A INSERT) 24
Reservoirs, Standpipes, and Water Treatment Plant (Town of Alderson, pg. 704A INSERT) 24
Water Meters 24
WVIJDC 25
Town of Tunnelton (B) 3303918 Rita Nicholson 26
(4268) 26
Supply Sources 26
Purchase Water 26
Counties Served 26
District Office 26
Operational Programs 26
Customer Sales 27
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 27
Pumping Station Equipment (Tunnelton Municipal Water Works, pg. 703A INSERT) 27
Reservoirs, Standpipes, and Water Treatment Plant (Tunnelton Municipal Water Works, pg. 704A INSERT) 27
Water Meters 27
WVIJDC 27
Wayne Water Services (B) 3305007 Karen R. Clay 28
(1561) 28
Supply Sources 28

Surface Water 28
Storage Reservoir 28
Counties Served 28
District Office 28
Operational Programs 28
Customer Sales 29
Distribution Integrity and Planned Maintenance Ratio: Water (hours) 29
Pumping Station Equipment (Wayne Water Service, pg. 703A - 703E INSERT) 29
Reservoirs, Standpipes, and Water Treatment Plant (Wayne Water Service, pg. 704A and 704B INSERT) 29
Water Meters 29
WVIJDC 29
NO PSC REPORT ONLINE: 30
Coal River Energy 30
District Office 30
Aurora School 30
District Office 30
Carter Roag Coal Co. – Pleasant Hill Mine 30
District Office 30
Jefferson Utilities Inc. – Burr Industrial Park 30
District Office 30
Slab Fork 30
District Office 30
Zela Elem School 30
District Office 30

PSD NAME	*PWSID#*	*CONTACT*
Berkeley Co. PSWDs(A) (7133 and 10002) 83 Monroe Street Martinsburg, WV	**3300202 and 218**	**Paul Fisher** 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**
212 Walnut Street Ravenswood, WV		304-273-2621 kdbenson@cityofravenswood.com

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) 340 East Main Street Romney, WV	**3301405**	**Betty Colebank** 304-822-5118 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%

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

Storage Reservoir

- ➔ 1.72 M. Gallon capacity

Counties Served

- ➔ Nicholas
  - o Summersville
  - o Glade Creek

District Office

- ➔ Beckley

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
  - 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
  - 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%

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

Counties Served

- Preston
  - Tunnelton
  - Denver (Resale Customer)

District Office

- Philippi

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
  - 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:

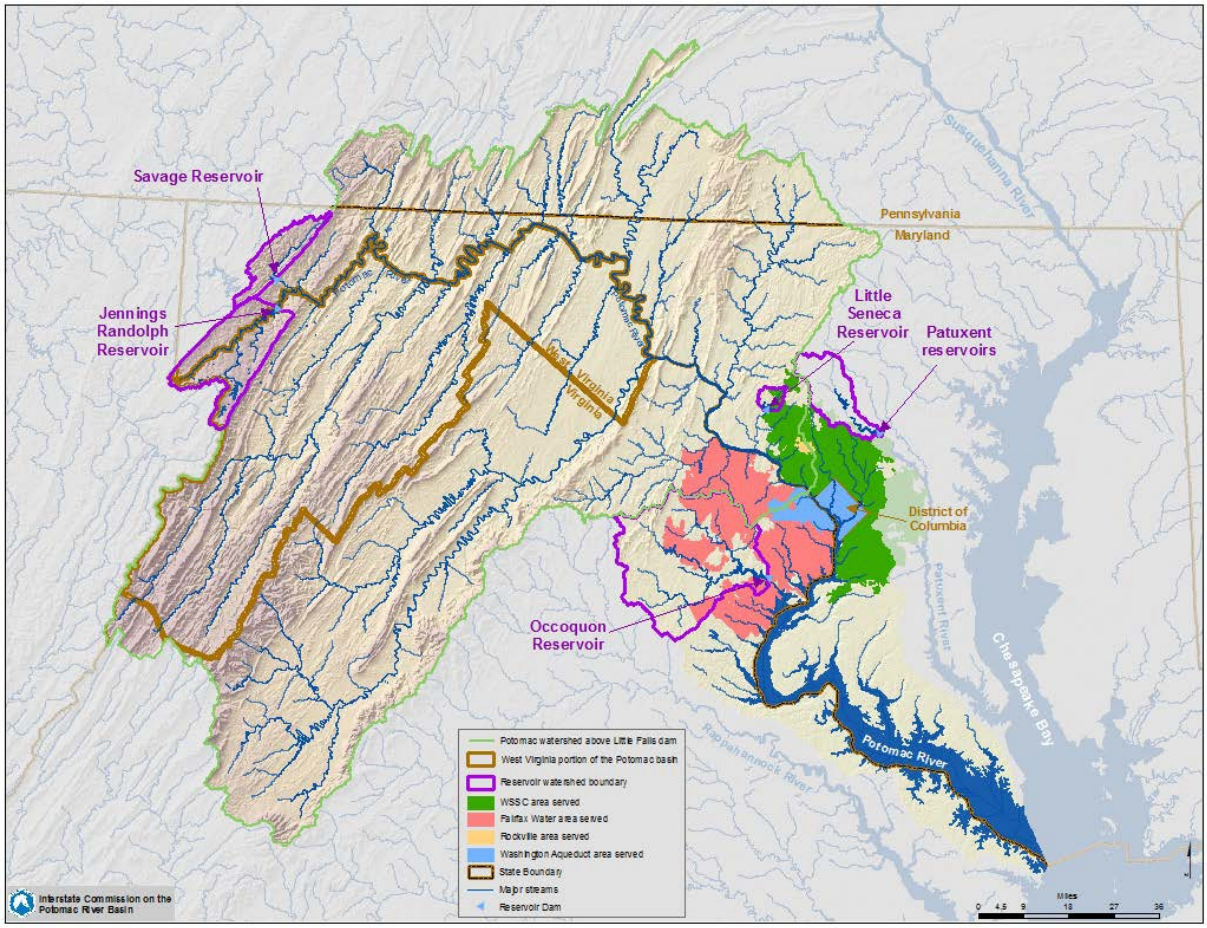
- Washington Aqueduct Division of the U.S. Army Corps of Engineers (Aqueduct), serving the District of Columbia via the D.C. Water and Sewer Authority (DC Water), and parts of northern Virginia;
- Washington Suburban Sanitary Commission (WSSC), serving parts of Maryland; and
- Fairfax Water, serving 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

Fritz Boettner – Project Manager
Evan Hansen – Water Resource Analyst
Brandon Ashby - Hydrogeologist
Jason Clingerman – Aquatic Ecologist
Sam Lamont – Hydrologist
Nathan Askins – Environmental Analyst
Lynmarie Knight – Pocahontas County Water Resources Task Force Coordinator

Downstream Strategies
building capacity for sustainability

TABLE OF CONTENTS

EXECUTIVE SUMMARY **5**

1. SURFACE WATER RESOURCES - §22-26-8 (C)(1) **6**

1.1 SURFACE WATER MONITORING PLAN 6
1.2 SAFE YIELD 8
1.2.1 Background *8*
1.2.2 Calculations *8*
1.2.3 Stream statistics *9*
1.2.4 Classification of HUC-12s by relationship with gaging stations *14*
1.2.5 Surface water safe yields *19*
1.3 INVENTORY OF LARGE QUANTITY CONSUMPTIVE USES - §22-26-8 (c)(2) 19

2. GROUNDWATER RESOURCES - §22-26-8 (C)(3) **21**

2.1 GROUNDWATER MONITORING PLAN 21
2.2 HISTORICAL GROUNDWATER USE 21
2.3 PROJECTED GROUNDWATER USE 22
2.4 IDENTIFICATION OF AQUIFER SYSTEMS 24
2.6 HYDROSTRATIGRAPHY 25
2.6.1 Quaternary system *25*
2.6.2 Pennsylvannian system *25*
2.6.3 Mississippian system *25*
2.6.4 Devonian system *25*
2.7 GROUNDWATER FLOW AND YIELD 28
2.7.1 Pennsylvannian system *28*
2.7.2 Mississippian system *28*
2.7.3 Devonian System *29*
2.8 GROUNDWATER QUALITY 29
2.9 DELINEATION OF GROUNDWATER BASINS 30
2.10 GROUNDWATER SAFE YIELD 30
2.11 GROUNDWATER BUDGET 38
2.12 CRITERIA FOR THE PROTECTION OF NON-CONSUMPTIVE GROUNDWATER USES 38
2.13 IDENTIFICATION OF PRIME RECHARGE AREAS 38
2.14 RELATIONSHIP TO STREAM BASEFLOW 39
2.15 GROUNDWATER CONCLUSIONS & RECOMMENDATIONS 41

3. CONSUMPTIVE AND NON-CONSUMPTIVE USE DEMANDS - §22-26-8 (C)(5) **41**

4. NON-CONSUMPTIVE USE NEEDS FOR UNIQUE AREAS - §22-26-8 (C)(4) **45**

4.1 DEFINITION OF UNIQUE AREAS 45

5. WATER AVAILABILITY OR CONFLICTS AMONG WATER USES - §22-26-8 (C)(6) **47**

5.1 LOW FLOW CONDITIONS 47
5.2 CURRENT USES THAT EXACERBATE CONDITIONS 48

6. CRITERIA FOR DESIGNATION OF CRITICAL PLANNING AREAS- §22-26-8 (C)(7) **48**

6.1 DEFINITION OF STRATEGIC RESOURCE AREAS 49
6.1.1 Methodology for the identification of strategic resource areas and subsequent planning actions *49*

7. OTHER IMPORTANT REQUIREMENTS OF THE ACT **49**

7.1 PUBLIC WATER SUPPLY CAPABILITY - §22-26-8 (c)(8) 49

7.2 ASSESSMENT OF FLOOD PLAIN AND STORMWATER MANAGEMENT PROBLEMS - §22-26-8 (c)(9) 49
7.3 IMPROVE DATA COLLECTION, REPORTING AND WATER MONITORING WHERE PRIOR REPORTS HAVE FOUND DEFICIENCIES - §22-26-8 (c)(10) 53
7.4 WATER CONSERVATION PROJECTS AND PRACTICES - §22-26-8 (c)(11) 53
7.5 ADDRESSING WATER AVAILABILITY PROBLEMS - §22-26-8 (c)(11) 54
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) 54
7.7 IMPLEMENTATION PLAN - §22-26-8 (c)(15) 55

REFERENCES 56

APPENDIX A : WATER RESOURCE MANAGEMENT PLAN GEODATABASE 58

APPENDIX B : POCAHONTAS WATER RESOURCE TASK FORCE 60

APPENDIX C : GROUNDWATER MONITORING PLAN 61

TABLE OF TABLES

Table 1: WV state plan requirements 5
Table 2: Categories and associated gages for each HUC-12 12
Table 3: Stream statistics for HUC12s in Pocahontas County (cfs) 16
Table 4: Safe yields for HUC12s in Pocahontas County using Method 1: Protect 7Q10 flow plus 10% (cfs) 17
Table 5: Safe yields for HUC12s in Pocahontas County using Method 2: Protect annual D75 flow, plus additional protections if headwaters or ungaged (cfs) 18
Table 6: Consumption Data 19
Table 7: Description of groundwater use in Pocahontas County 21
Table 8: Groundwater use in Pocahontas County from 1985-2005 22
Table 9: Projected groundwater use in Pocahontas County from 2010-2035 23
Table 10: Generalized hydrogeologic framework of Pocahontas County 26
Table 11: Estimated groundwater safe yield by Tessman method 33
Table 12: Estimated groundwater safe yield by modified WVDEP method 35
Table 13: Comparison of groundwater safe yield methods 37
Table 14: Projected surface water withdrawals in Pocahontas County from 2010-2035 (cfs) 44
Table 15: Water use coefficients 44
Table 16: Projected surface water consumption in Pocahontas County from 2010-2035 (cfs) 45
Table 17: Inventory of unique areas within Pocahontas County 47
Table 18: NRCS field performance measures for conservation practices supporting water conservation in Pocahontas County 54

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

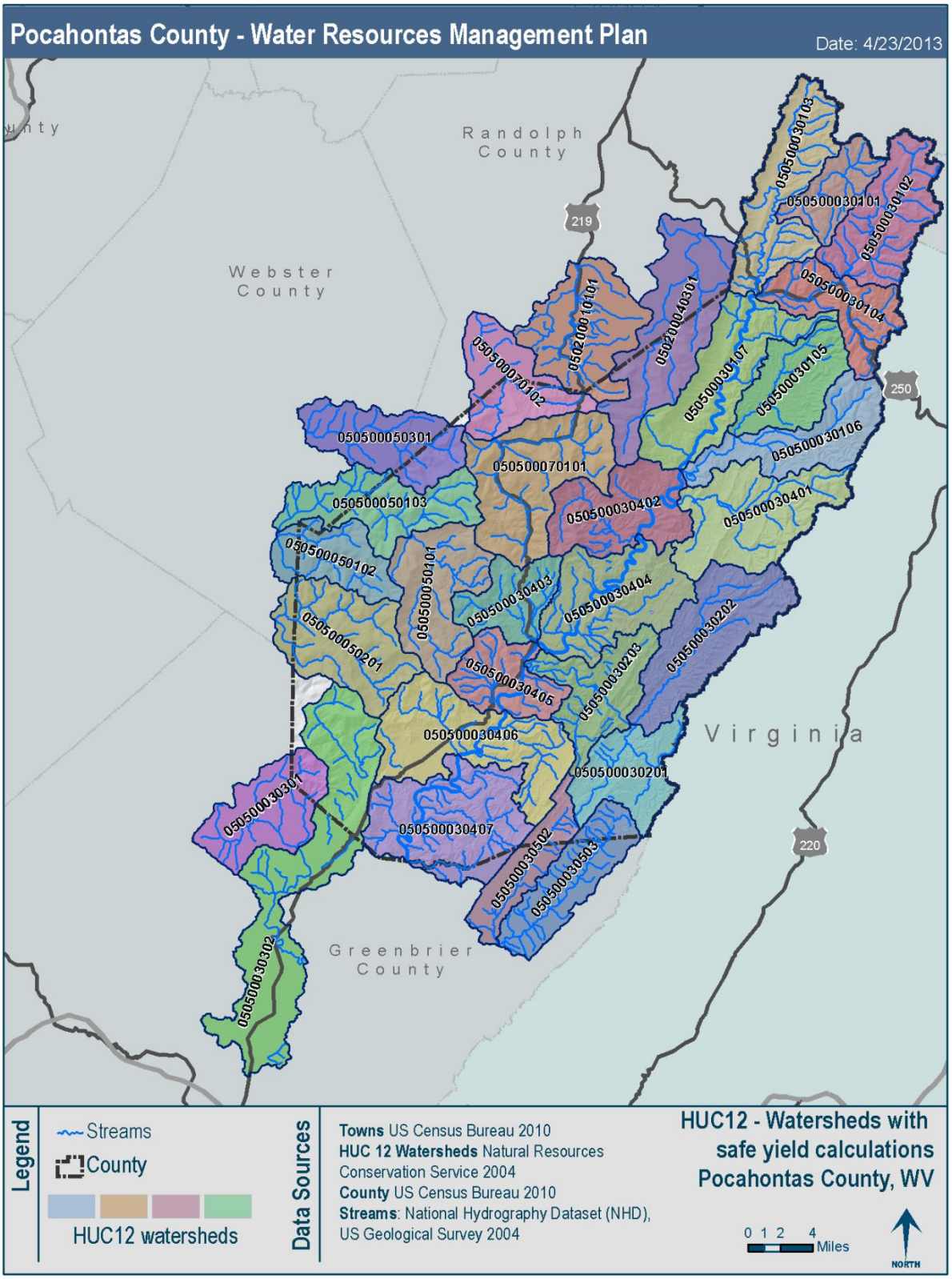


Table 2: Categories and associated gages for each HUC-12

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

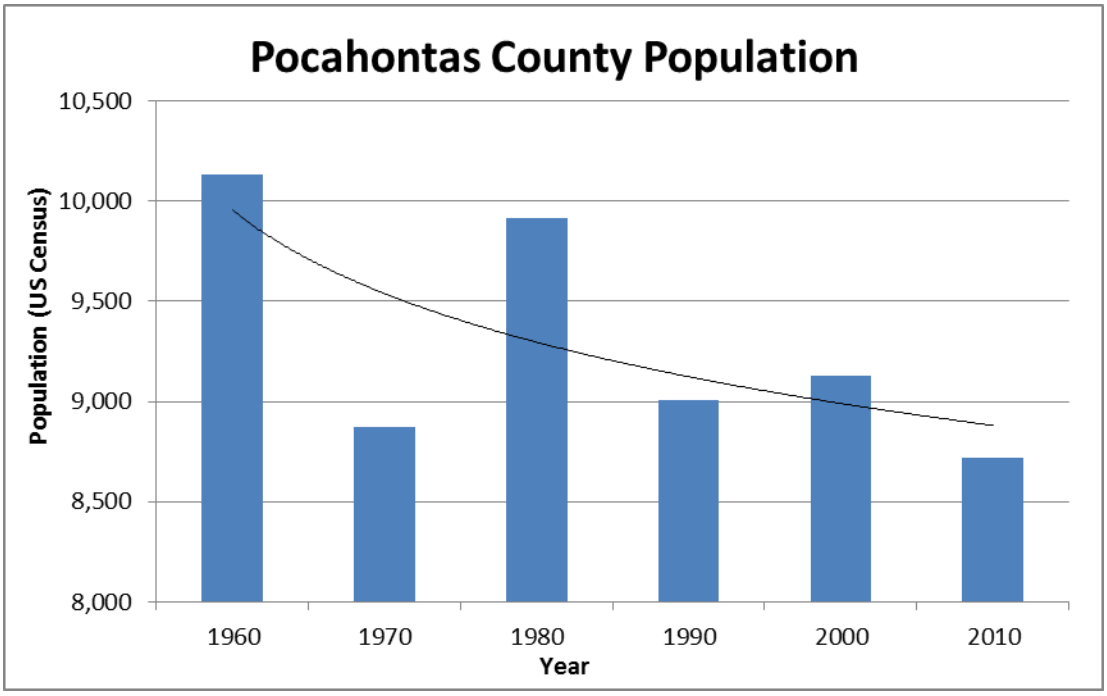
Groundwater demand projections were prepared for the county for the planning period between 2010-2035, based on historic estimated water data from the USGS (Table 9). While domestic populations are projected to decrease, domestic demand for groundwater is expected to increase slightly over the next 25 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)

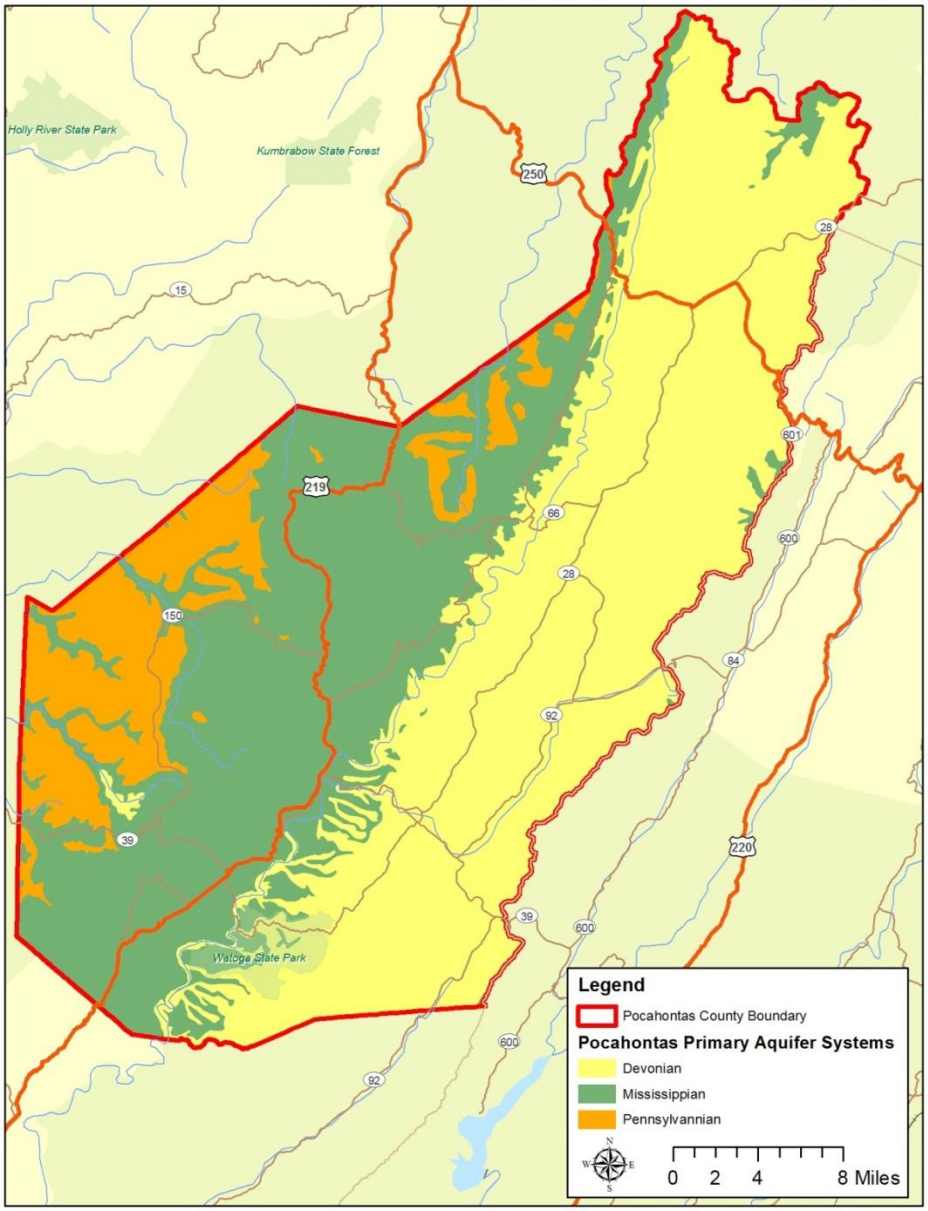


2.4 Identification of aquifer systems

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	Quatern-ary 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.

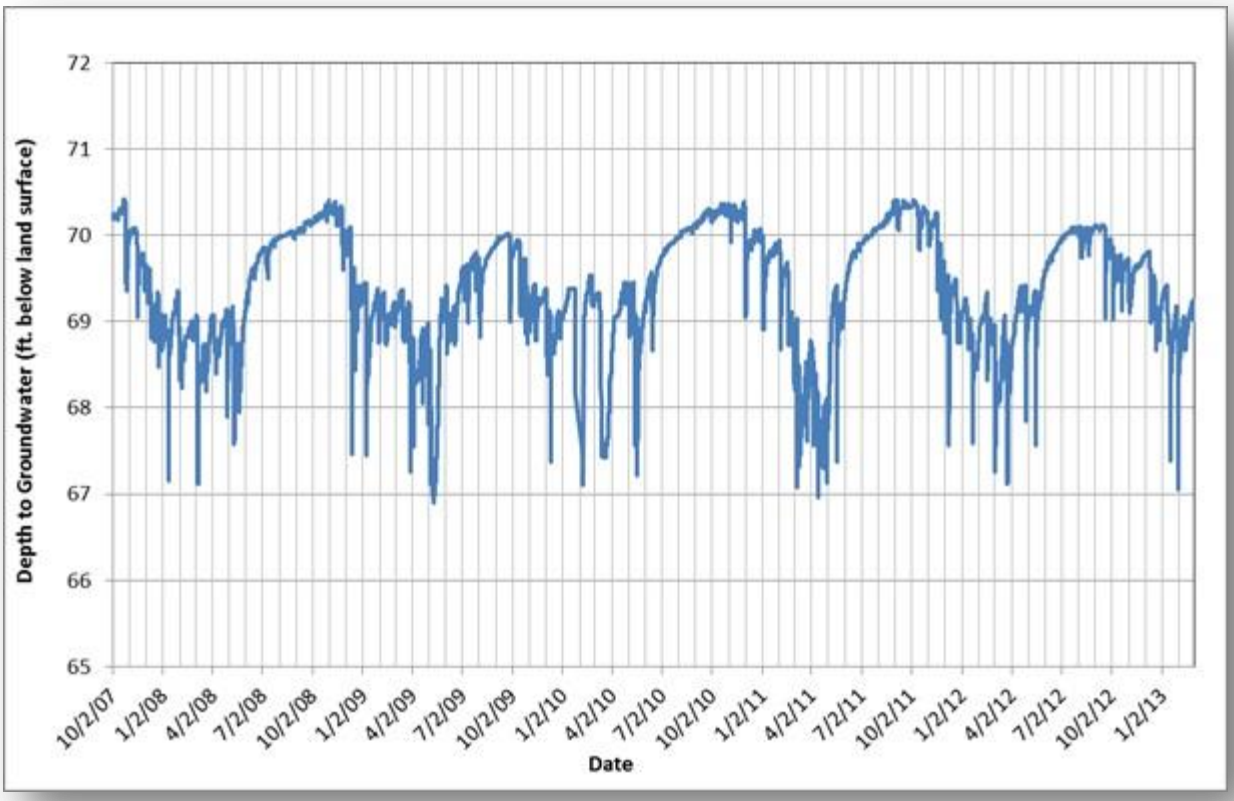
Although there are no active groundwater level monitoring wells completed within the Pennsylvannian System, well completion records and other publications (8) indicate that groundwater levels are highly variable depending on local topography. Depths to groundwater vary from approximately 15 feet (in 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.

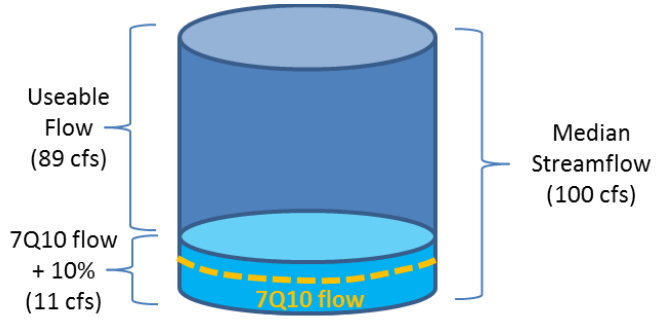
It is also important to note that some of the HUC-12 watersheds contribute flow to downstream HUC-12 watersheds. Additional calculations were required to avoid duplicity in the surface water safe yield calculations (see Section 1.2.5), but were not applied to the groundwater calculations. Travel times 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				
HUC-12 number	HUC-12 name	Watershed area (AC)	Median annual baseflow (MG)	60% median annual baseflow (MG)	Estimated groundwater safe yield			Median summer baseflow (annualized, MG)	60% median summer baseflow (annualized, MG)	Estimated groundwater safe yield		
					MGY	MGD	GPD/ AC			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					
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)	Estimated groundwater safe yield			(7q10 summer + 10%)/ median summer flow	Median summer baseflow available for use	Median summer baseflow (mG)	Estimated groundwater safe yield		
						MGY	MGD	GPD/ AC				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

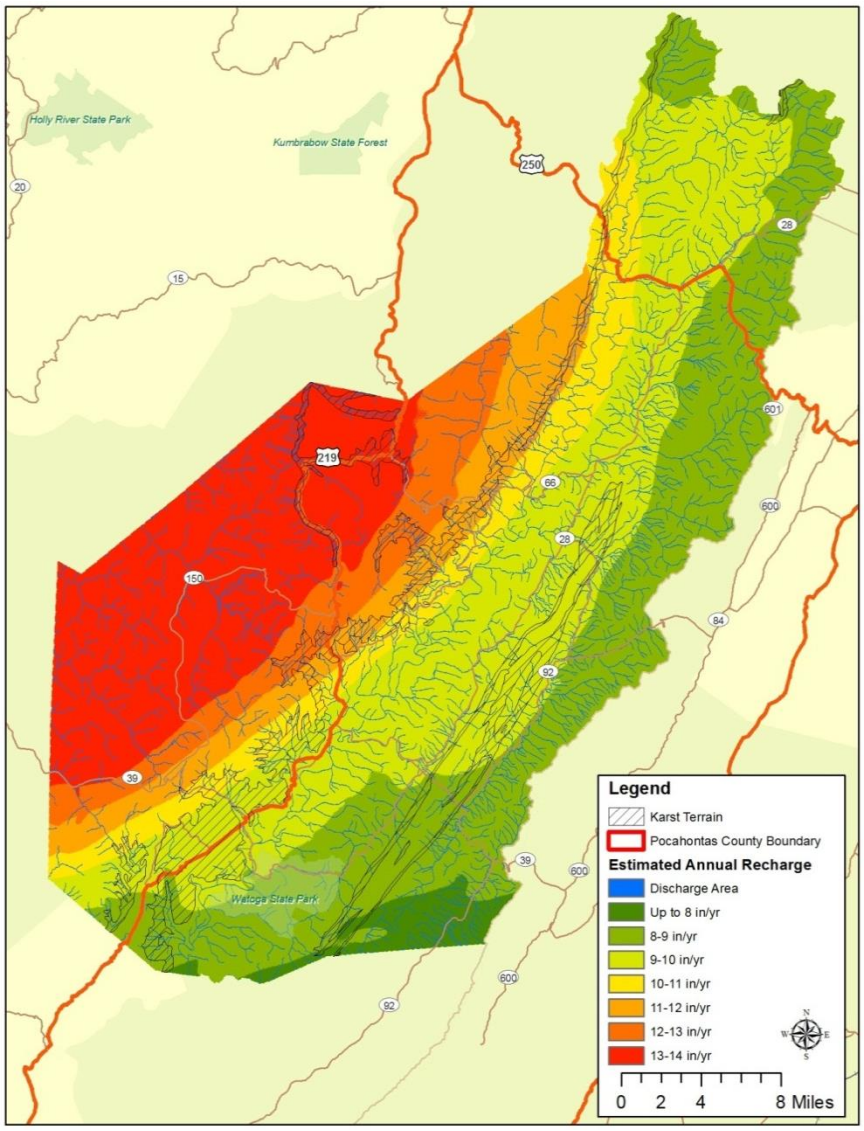
The primary nonconsumptive groundwater function in the county is baseflow to streams, rivers, and springs. Across the county, it is estimated that up to 43 percent of the total annual streamflow volume is attributable to baseflow. Declines in the groundwater table associated with groundwater pumpage 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

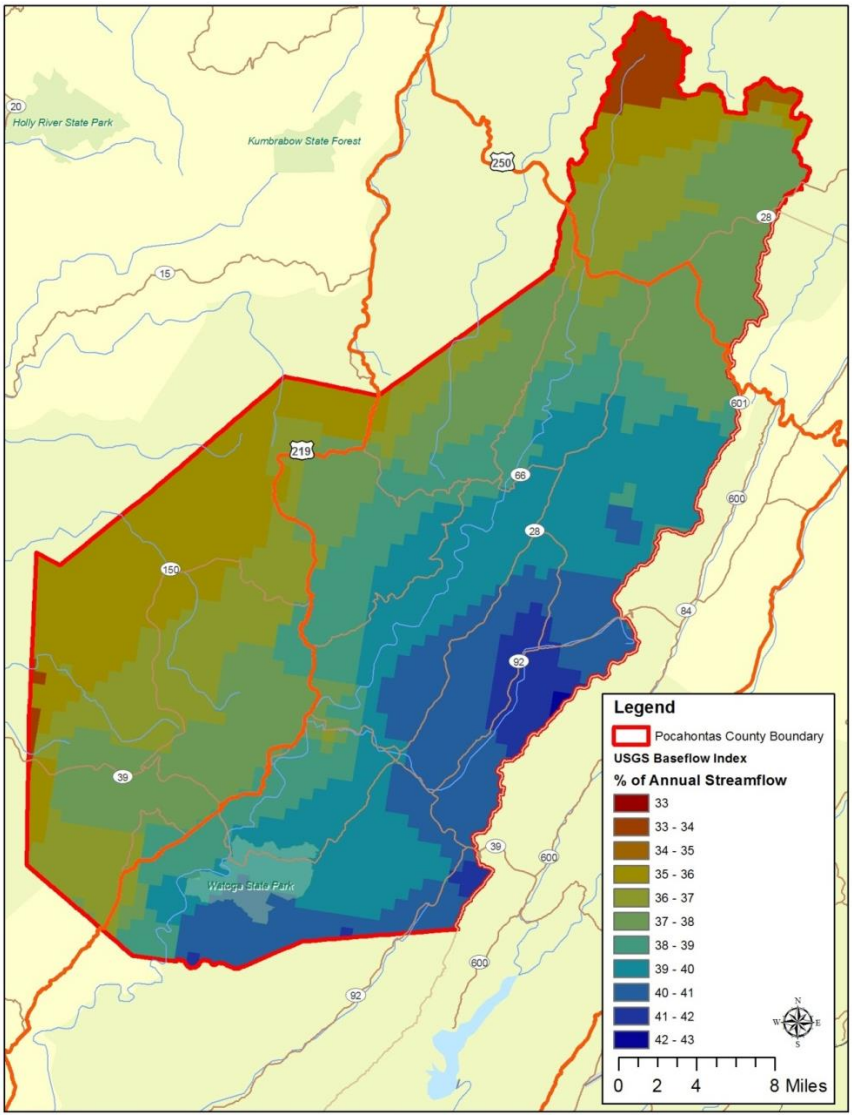


The results of the analysis (shown in Figure 77) indicate that recharge ranges from approximately 7 to 14 inches per year across the county. The western half of the county (the region west of and adjacent to Hwy. 219) constitutes a prime recharge area (shown in red and orange hues on Figure 7), with 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.

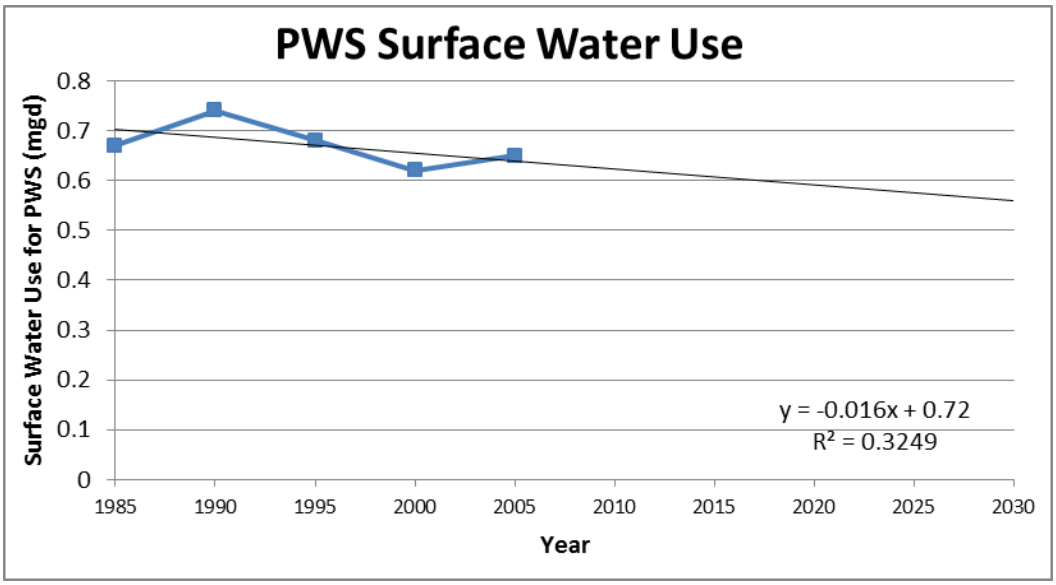
3. CONSUMPTIVE AND NON-CONSUMPTIVE USE DEMANDS - §22-26-8 (C)(5)

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:

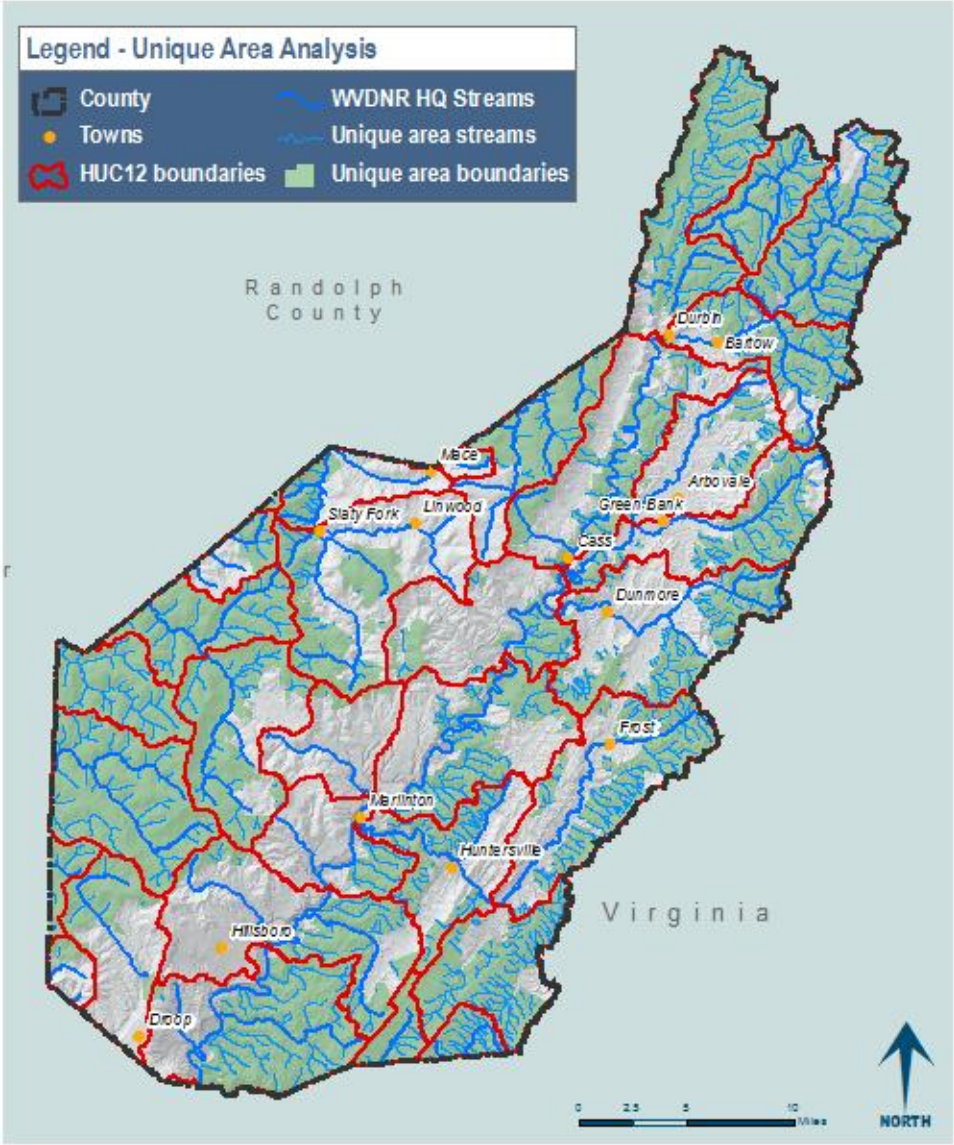
> "natural, scenic, environmental or recreational values of national, regional, local or statewide significance, including national and state parks; designated wild, scenic and recreational rivers; national and state wildlife refuges; and the habitats of federal and state endangered or threatened species."

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

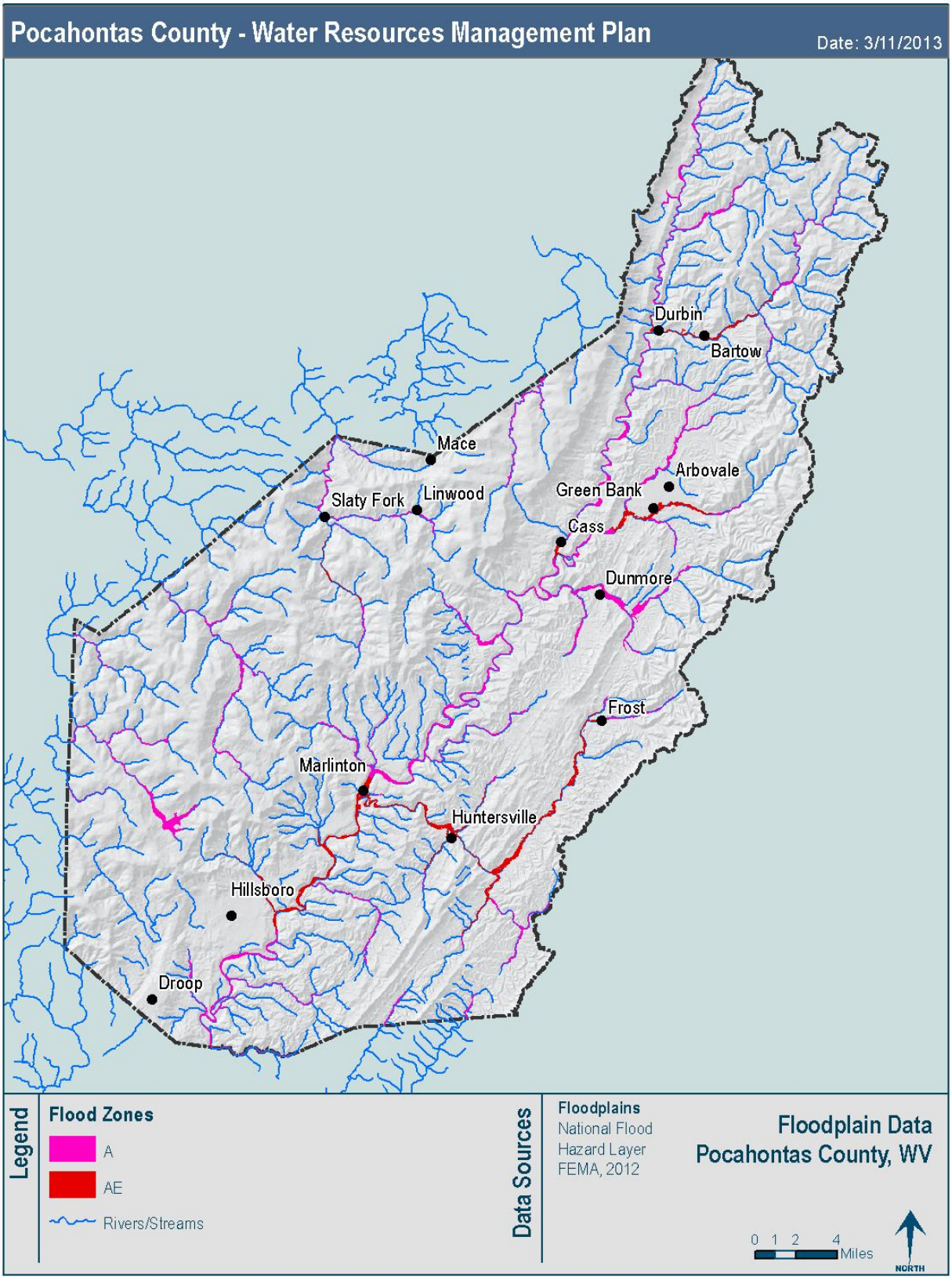
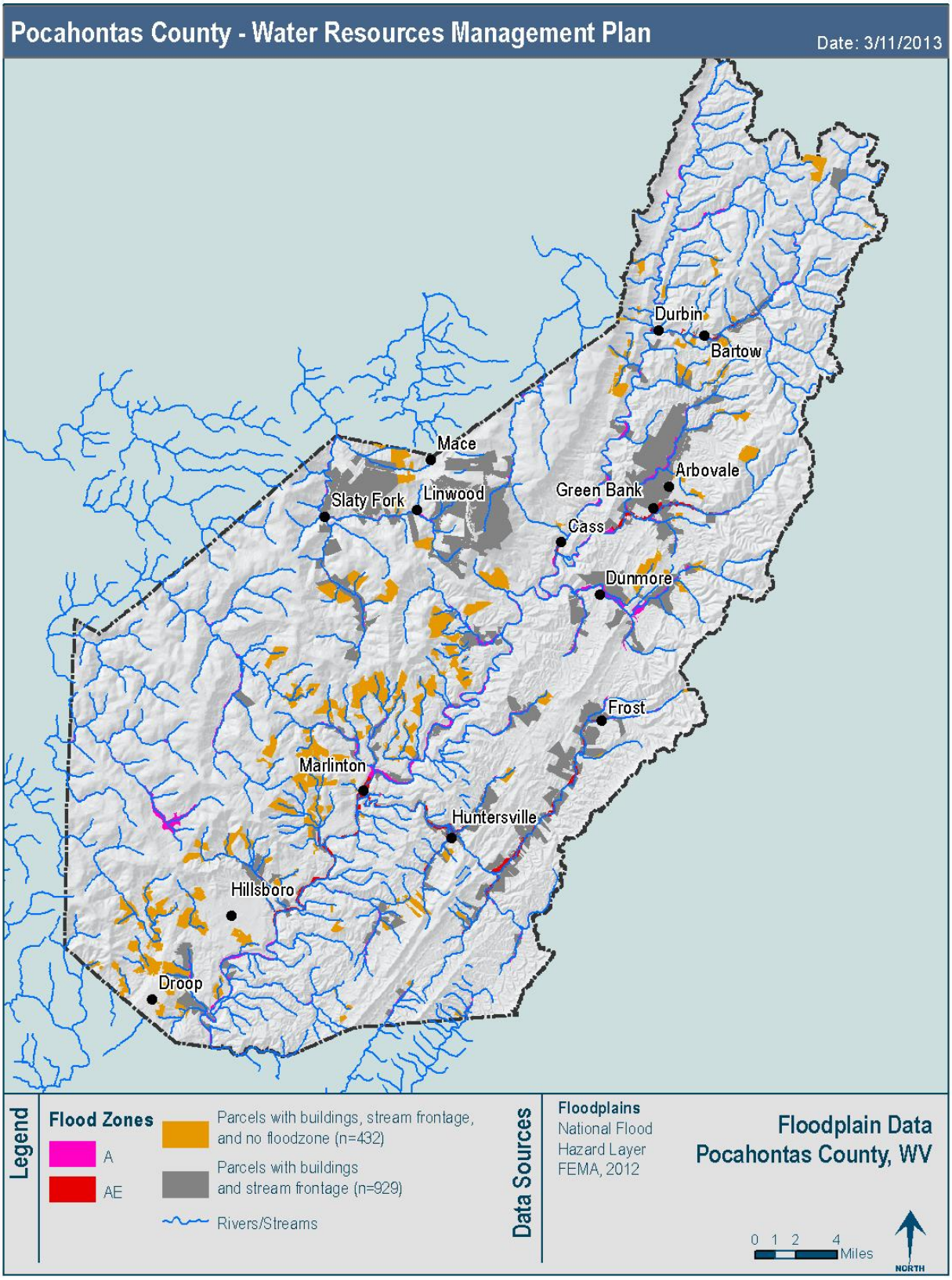


Figure 12: Flood zones and parcels with buildings and stream frontage



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

	2009		2010		2011		2012		2013*	
NRCS field performance measure	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.

REFERENCES

1. **Sophocleous, M.** *On the Elusive Concept of Safe Yield and the Response of Interconnected Stream-aquifer Systems to Development.* Lawrence, Kansas : Kansas Geological Survey, The University of Kansas, 1998.

2. **Wiley, Jeffrey B and Atkins, John T.** *Estimation of Selected Seasonal Streamflow Statistics Representative of 1930-2002 in West Virginia: Scientific Investigations Report 2010-5185.* s.l. : USGS, 2010.

3. **Wiley, Jeffrey B.** *Low-Flow Analysis and Selected Flow Statistics Representative of 1930–2002 for Streamflow-Gaging Stations in or Near West Virginia: Scientific Investigations Report 2006-5002.* s.l. : USGS, 2006.

4. —. *Estimating selected streamflow statistics representative of 1930–2002 in West Virginia: Scientific Investigations Report 2008-5105.* s.l. : USGS, 2008.

5. —. *Comparison of Base Flows to Selected Streamflow Statistics Representative of 1930-2002 in West Virginia: Scientific Investigation Report 2012-5121.* s.l. : USGS, 2012.

6. **West Virginia Legislature.** *WV Code of State Rules Chapter 22, Article 26: Water Resources Protection and Management Act.* Charleston, WV : s.n., 2012.

7. **USGS.** Water Data for the Nation. *Water Use in the United States.* [Online] Jan 16, 2013. http://water.usgs.gov/watuse/.

8. **West Virginia Geological and Economic Survey.** *Hydrologic Ground-water Atlas: Gauley River Basin.* 1985. Spatial data.

9. **WVDEP.** Program Manager, WVDEP. *In-person meeting at WVDEP office with Brandon Ashby, Evan Hansen, Fritz Boettner.* June 2012.

10. **Alley, William M, Reilly, Thomas E and Franke, O Lehn.** *Sustainability of Groundwater Resources - Circular 1186.* Denver : USGS, 1999.

11. **Woolock, David M.** *Base-flow index grid for the conterminous United States.* [Spatial data downloaded February 15, 2013] s.l. : USGS, 2003.

12. **USGS.** *National Hydrography Dataset.* [Spatial data downloaded February 27, 2013] 2011.

13. **Shaffer, Kimberly H.** *Variations in Withdrawal, Return Flow, and Consumptive Use of Water in Ohio and Indiana, with selected Data from Wisonsin, 1999-2004: Scientific Investigations Report 2009-5096.* s.l. : USGS, 2009.

14. **WVDEP.** Program Manager, WVDEP. *Email to author Boettner.* March 08, 2013.

15. **Pocahontas County Commission.** *Pocahontas County Floodplain Ordinance.* [PDF] 2010.

16. **Fischer, Rondi.** Marlinton-White Sulfur Springs District Ranger, USFS. *Emails to author Knight.* March 8-11, 2013.

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
		• TMDL subwatersheds with load allocations calculated
		• Catchments with all many statistics calculated per catchment, which include:
		  ○ Land-use
		  ○ Calculated groundwater consumption
		  ○ Wells per catchment
		  ○ Recharge rate, both surface and groundwater
		  ○ Baseflow information
		  ○ Climatic conditions
		• Water quality sample locations for the study area
		• Digitized well yield estimates for parts of Pocahontas County

Basemap	Cartographic representations of relevant Pocahontas County features	• county boundary • Roads • HUC 12 watersheds • Populated places with annotation • 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 • Source water protection areas • Impaired subwatersheds
Geology/karst	Geologic features of Pocahontas County, including karst and cave data provided by various institutions	• Geology of the county • Groundwater vulnerability • Groundwater risk • Karst formations • West Virginia Speological Survey (WVASS) Cave locations (CONFIDENTIAL) • 8-Rivers dye trace locations • Interpreted groundwater basins (part of this study and mapped in the report) • Pocahontas County oil and gas wells • WVDEP Sinking streams • WVDEP dye trace locations
Hydrology	Surface water data used for both cartography and analysis	• WVDEP high resolution stream datasets, reaches • WVDEP 2010 303(d)-listed stream • NHD 1-100k catchments • NHD 1-100k flowlines (streams) • NRCS HUC-12 watershed boundaries • Watershed annotation • Stream gauge locations
Recreation	Public lands	• Monongahela National Forest boundary • State forest boundaries • State park boundaries • 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 • HUC-12 surface water withdrawal guidelines, calculated for fall, winter, spring, and summer • Groundwater safe yield, calculated for fall, winter, spring, and summer • Groundwater withdrawal guidelines, calculated for fall, winter, spring, and summer • HUC 12 critical planning areas based on safe yield guidelines
Social	Demographic and economic datasets	• Block population (point locations) • Block population (polygons) • Business and public administrative water users • county parcels (2010) • 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 • Priority parcels for septic inventory and evaluation • WVDEP water service areas (polygons)
Other	Tables and other datasets without a specific category	• TMDL wasteload allocations • Impaired streams by mile summary • Land-use dataset – raster 2001 • Elevation dataset – raster 2001 • Hillshade dataset – raster 2001 • 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
900 Tenth Avenue
Marlinton, WV 24954

Prepared by:

Downstream Strategies, LLC
295 High Street, Suite 3
Morgantown, WV 26505

Brandon Ashby

Downstream Strategies

TABLE OF CONTENTS

1. INTRODUCTION 4
1.1 MONITORING PLAN OBJECTIVES 4
1.2 PRELIMINARY CONSIDERATIONS 5
2. MONITORING NETWORK DESIGN 7
2.1 INSTALLATION OF NEW WELLS 9
2.2 SELECTION OF EXISTING WELLS 11
MONITORING OF SPRINGS (OPTIONAL) 11
3. MONITORING PROTOCOLS 12
3.1 WATER QUALITY SAMPLING 12
3.2 WATER LEVEL MONITORING 13
4. DATA STORAGE AND MANAGEMENT 14
5. INTER-AGENCY COOPERATION 15
6. COST ESTIMATES 18

TABLE OF FIGURES

Figure 1: County-wide monitoring well placement grid map 8
Figure 2: Example well schematic-construction details are approximate and subject to change based on local conditions 10
Figure 3: Example groundwater hydrograph 15

TABLE OF TABLES

Table 1: Important monitoring plan considerations 6
Table 2: Number of proposed monitoring wells by HUC watershed 7
Table 3: Three tiers of the groundwater monitoring plan 9
Table 4: Favorable criteria for the selection of existing wells for use in monitoring plan tiers 2 and 3 11
Table 5: Proposed groundwater monitoring parameters 13
Table 6: Potential groundwater monitoring plan teaming partners 16
Table 7: Tier 1 estimated costs 19
Table 8: Tier 2 estimated costs 21
Table 9: Tier 3 estimated costs 23

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? 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. 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? What type of outreach to landowners can the county conduct to interest land owners in allowing access to their private wells for groundwater monitoring? 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. 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. 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? What other agencies or non-profits have a vested interest in, or a stated goal of monitoring the county's water resources? What technical, financial, or other cooperation will the county seek from potential partnering agencies? 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. 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. 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? 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? What agencies or partners would be likely to contribute funding to the project?	Examine current and potential funding sources. Begin searching for grant opportunities. 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)? 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. 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).

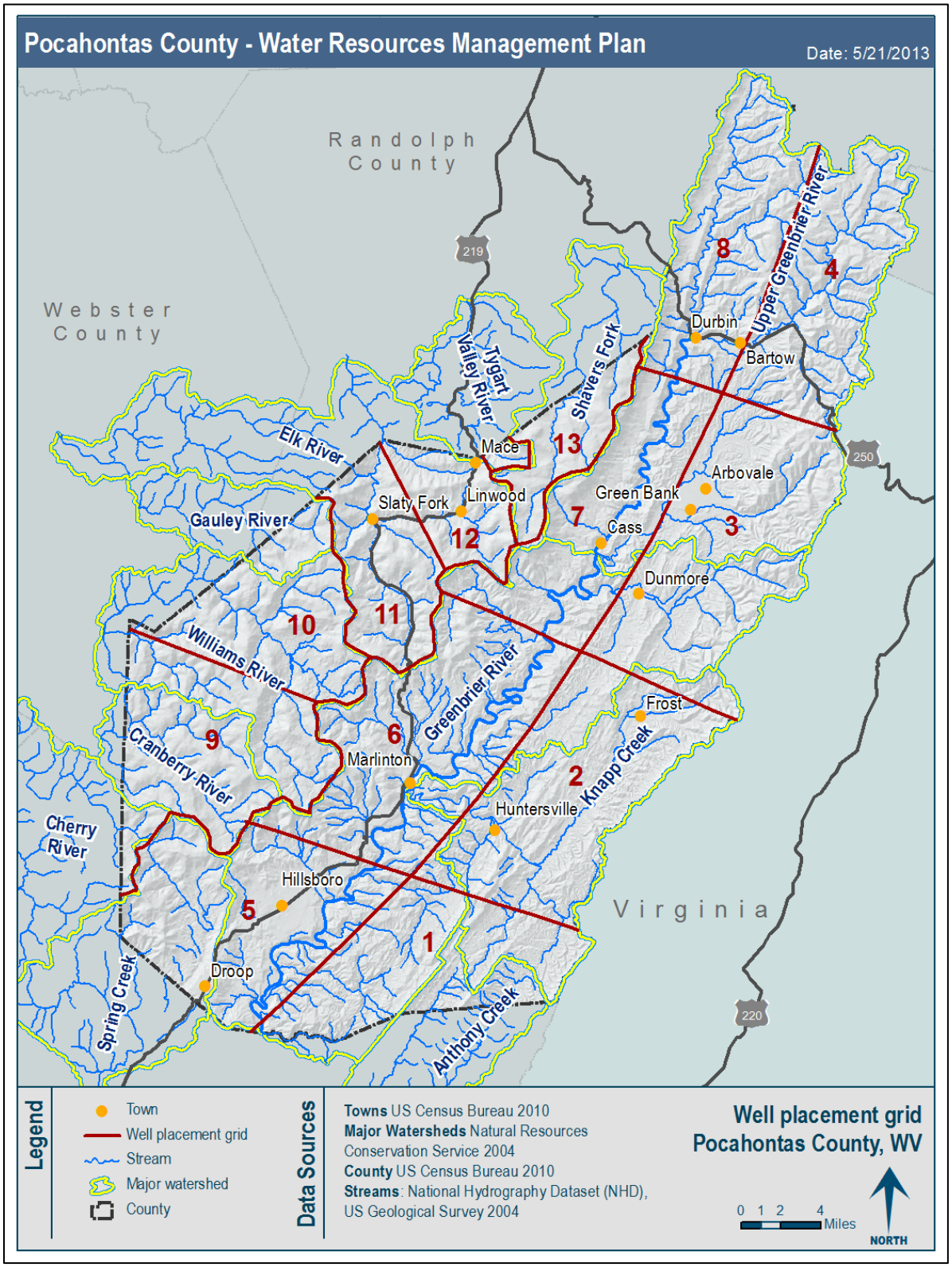
Table 2: Number of proposed monitoring wells by HUC watershed

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

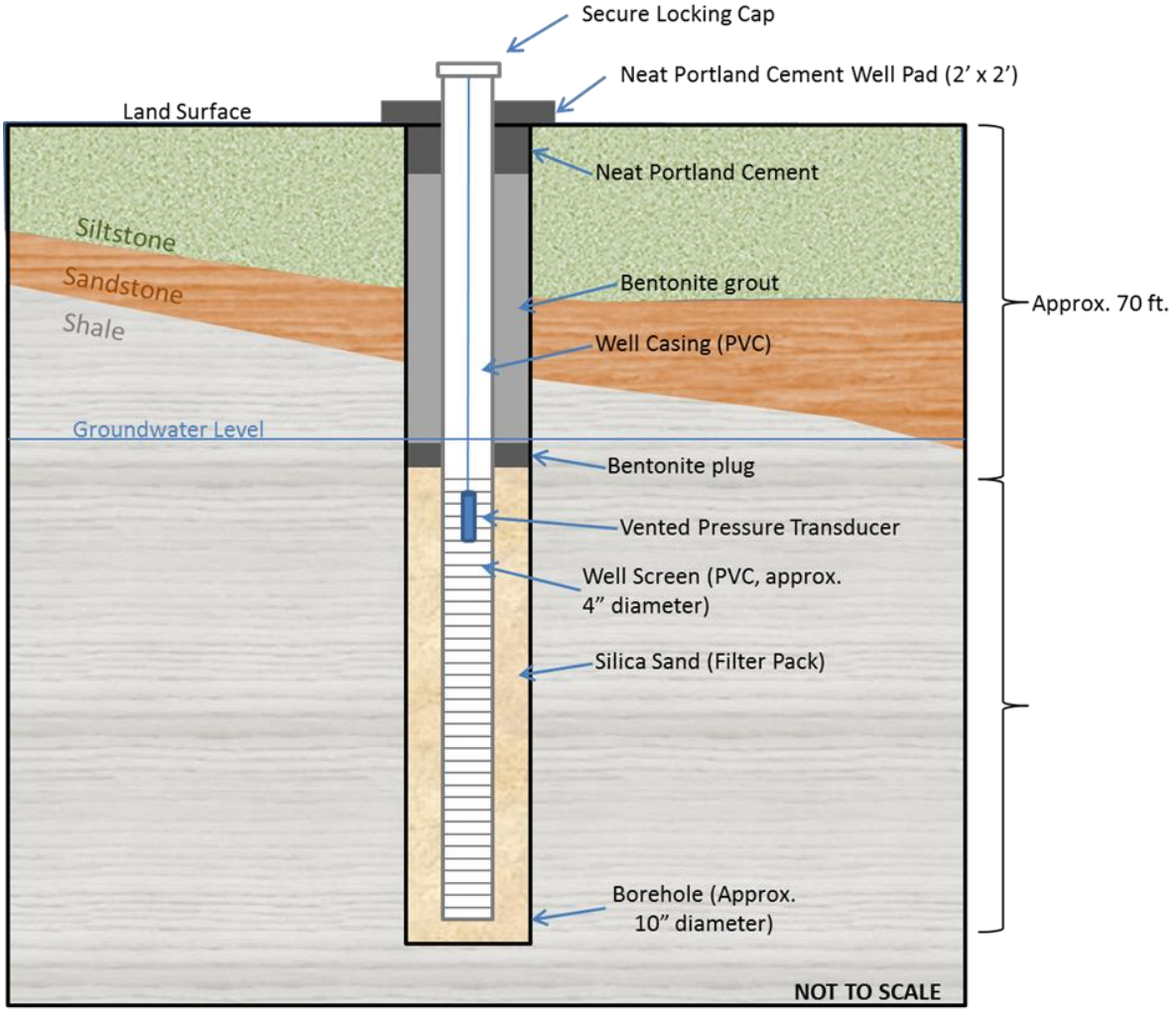
Monitoring Plan	Proposed New Infrastructure	Number of Monitoring Stations	Water Level Monitoring Frequency	Water Quality Monitoring Frequency
Tier 1	12 dedicated monitoring wells	12 new wells Any available existing wells +1 existing USGS well **13+ wells**	Continuous	Bi-annually for first 3 years; Annually thereafter
Tier 2	6 dedicated monitoring wells	6 new wells 6 existing wells (minimum) +1 existing USGS well **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) +1 existing USGS well **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

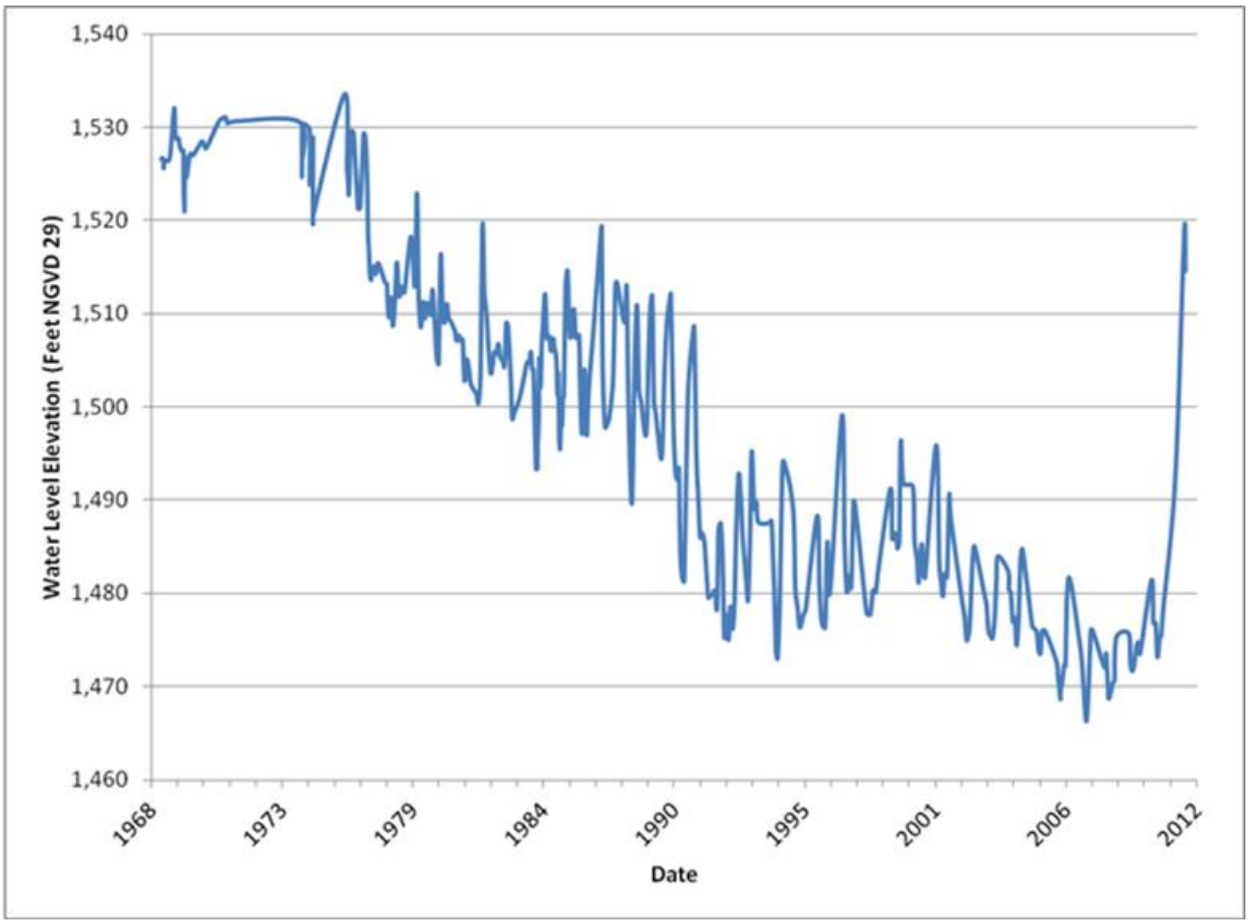
As data is collected over the duration of the plan, the county should store the data in Microsoft Excel or Access databases. The data could be integrated into the existing water quality database provided to the county as part of Phases I of the WRMP. Appending new data into the existing database would 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 Partnerning 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** Hydrologist USGS Northeast Area 215 Limekiln Road New Cumberland, PA 17070 Phone: 717-730-6947 Fax: 717-730-6997 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 Hydrologist USGS Northwest Area 934 Broadway, Ste. 300 Tacoma, WA 98402 Phone: 253-552-1683 Fax: 253-552-1581 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. Engineering Hydrologist Hydrologic Investigations and Surveillance Section **Melvin V. Mathes, Jr.** Hydrogeologist Hydrologic Investigations and Surveillance Section **Gary R. Crosby** Lead Hydrologic Technician Hydrologic Networks Unit USGS West Virginia Water Science Center Office 11 Dunbar Street Charleston, West Virginia, 25301 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 Partnerning 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.** WV DEP Program Manager, Water Use Section 601 57th Street SE Charleston, WV 25304 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** USDA Forest Service, Monongahela Forest Supervisor 200 Sycamore Street Elkins, WV 26241 (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.