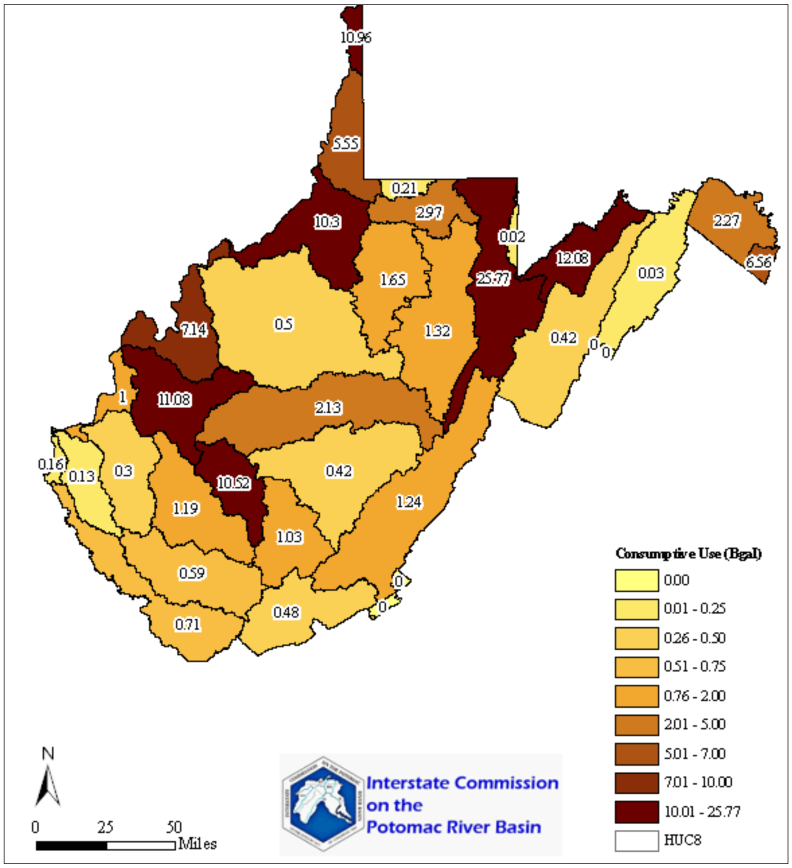
West Virginia Consumptive Use Projections for 2020, 2030, 2040



Prepared for
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Table of Contents

List of Figures

List of Tables

List of Appendices

Abbreviations

BBER	West Virginia University Bureau of Business and Economic Research
DEP	West Virginia Department of Environmental Protection
HUC8	8-Digit Hydrologic Unit
LQU	Large Quantity User
MPRWA	Middle Potomac River Watershed Assessment
NAICS	North American Industry Classification System
RW	Return flow and withdrawal
SIC	Standard Industrial Code
USGS	United States Geological Survey
WBR	Winter base-rate

Units of Measurement

Bgal	billion gallons
Mgal	million gallons

1 Introduction

Estimating the amount of water consumed is an essential component of a water resources plan for West Virginia. Water managers need to know how much is removed from the water system following a significant water withdrawal to evaluate the potential impact on downstream users and the environment.

> **BOX 1**
>
> **Consumptive Use** – "That part of water withdrawn that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment."
>
> *Source: USGS Water Science Glossary of Terms - http://ga.water.usgs.gov/edu/dictionary.html*

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 The first is to calculate the difference between how much water is withdrawn by a specific user and how much that user returns to the environment after use. For instance, the portion consumptively used by a public water provider is the total amount withdrawn from a source minus the amount that is discharged by the corresponding wastewater treatment plant.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 by the fact that the discharge information related to each withdrawal can be misleading because portions of the water go unaccounted for due to infiltration and losses. Additionally, water may be added due to inflow from stormwater before the discharge is measured.

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 and Runkle 2007)[1] 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 consumptive use coefficient method was selected for this study. The method also has the advantage of having previously been used in similar studies to estimate consumptive use for the state. 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 realm of 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 U.S. Geological Survey (USGS) eight-digit hydrologic unit code (HUC8) (**Figure 1**, **Table 1**) and by county. The methods used to develop the watershed and county projections do not allow the results to be compared. This report focuses on the watershed-level results. The methods and results by county are available in the appendices.

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[1] Shaffer and Runkle (2007) provide an easy to understand, in-depth explanation of methods for estimating consumptive use.

Figure 1. HUC8 watersheds of West Virginia.

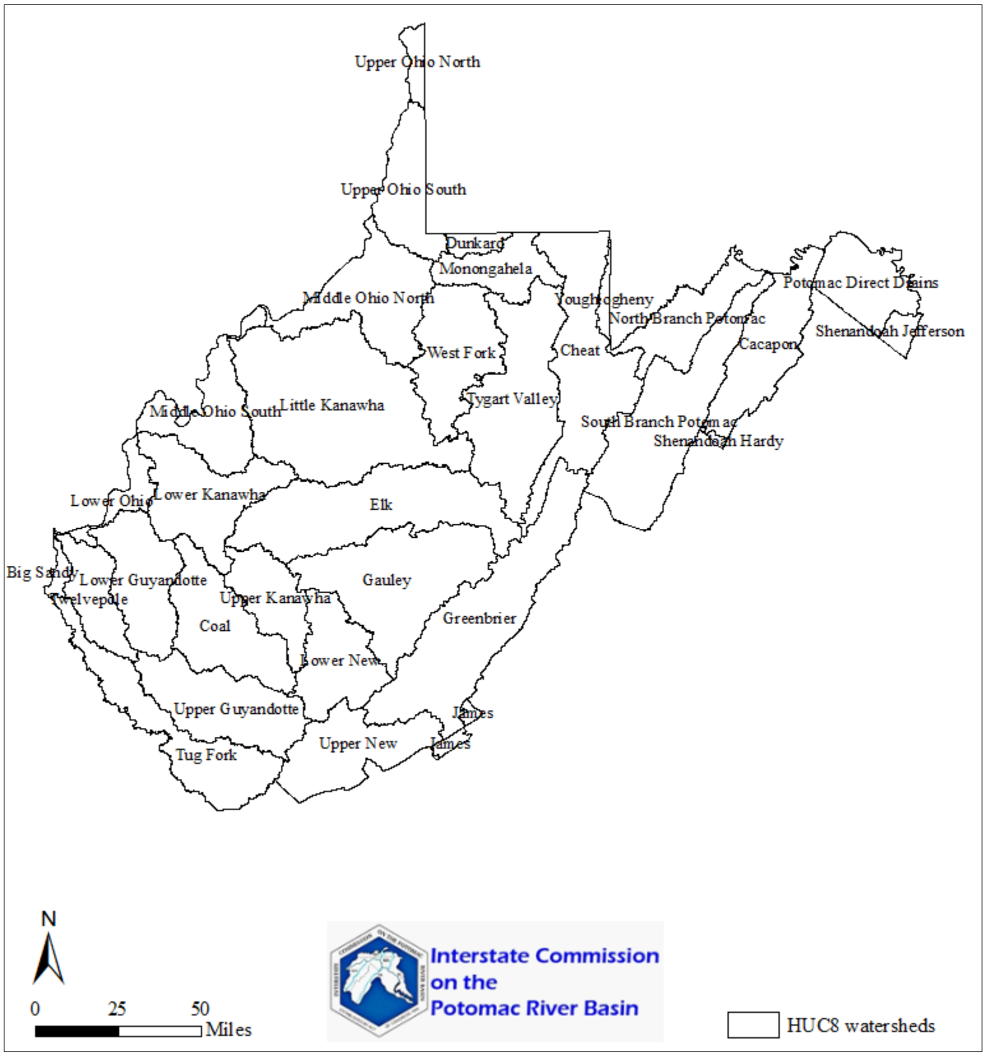


Table 1. USGS HUC8 codes and names for West Virginia.

HUC8 Code	HUC8 Name
2070001	South Branch Potomac
2070002	North Branch Potomac
2070003	Cacapon
2070004	Potomac Direct Drains
2070006	Shenandoah Hardy
2070007	Shenandoah Jefferson
2080201	James
5020001	Tygart Valley
5020002	West Fork
5020003	Monongahela
5020004	Cheat
5020005	Dunkard
5020006	Youghiogheny
5030101	Upper Ohio North
5030106	Upper Ohio South
5030201	Middle Ohio North
5030202	Middle Ohio South
5030203	Little Kanawha
5050002	Upper New
5050003	Greenbrier
5050004	Lower New
5050005	Gauley
5050006	Upper Kanawha
5050007	Elk
5050008	Lower Kanawha
5050009	Coal
5070101	Upper Guyandotte
5070102	Lower Guyandotte
5070201	Tug Fork
5070204	Big Sandy
5090101	Lower Ohio
5090102	Twelvepole

2 Current Water Use

2.1 Withdrawals

This project is based on water withdrawal data from West Virginia Department of Environmental Protection's (DEP) Large Quantity User (LQU) database. This database contains information on facilities that withdraw more than 750,000 gallons of water in any calendar month from either a surface- or ground-water source defined as waters of the state. The database includes information on who is withdrawing water, where it is occurring, the purpose for which it will be used, and how much is withdrawn monthly. The database has 11 water use categories (definitions provided by DEP):

- 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 hydrofracking a well.
- 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.
- 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 a separate DEP database.

Actual withdrawals by LQUs were required to be submitted in 2003, 2004, and 2005. No withdrawal information was collected for 2006 and 2007. Beginning in 2008, LQUs were required to report actual withdrawal volumes if their withdrawal was more or less than ten percent of the last reported value. For instance, if a withdrawal was reported as 10 million gallons in 2008 and the 2009 actual withdrawal amount was between 9 and 11 million gallons, the user was not required to submit a report. This reporting requirement leaves gaps in the LQU database. The most recent data were for 2011.

For the purposes of this study, annual withdrawal amounts were used. Reporting gaps in withdrawal data were filled in with the average of the previous three years of data. If only two previous years of data were 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). **Table 2** provides examples of these calculations.

Table 2. Illustration of assumptions made to fill in data gaps in the LQU database. Values in green represent reported values, purple represents averaged values, and blue values are set equal to a previously averaged or reported value. A dash (-) indicates that no withdrawal occurred.

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

Using these assumptions, estimates of past water use for the state were calculated. These are shown by water use type, watershed, and county in the tables in **Appendix A**. Additionally, while not in the LQU database (except for the water supply brokers represented in the Frac Water use category), DEP collects information on water used in the hydraulic fracturing process to extract natural gas from Marcellus Shale.

It is important to note that no estimates were made for water uses that did not meet the threshold of a LQU. Therefore, the water withdrawal estimates reported here do not include such uses as self-supplied water for domestic or agricultural use or those defined as a transient or non-community water supply by the West Virginia Department of Health and Human Resources.

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[2]. For both hydroelectric and aquaculture uses, water tends to run through a system instead for being used for a process or incorporated into a product. The Marcellus Shale projection was done using data not included in the LQU database.

In order to make withdrawal and consumptive use projections for this project, some of the DEP water use categories had to be combined. The reasons for this are explained in **Section 3**. The categories used in this project are:

- Mining and Petroleum (DEP categories - Mining and Petroleum)
- Manufacturing (DEP 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 **Appendix C** (**Table C-1** and **Table C-3**, respectively). The resulting withdrawals by use type are displayed in **Figure 2**. Marcellus Shale withdrawals are not shown here because data were not collected over the same time period. Refer to **Appendix B** for the Marcellus Shale data.

[2] There is an implied exemption for reporting agricultural water use in the Water Resources Protection Act §22-26-3: *Water withdrawals for self-supplied farm use and private households will be estimated*. [excerpt; emphasis added]

Figure 2. Annual withdrawals from the LQU database by (amended) use type.

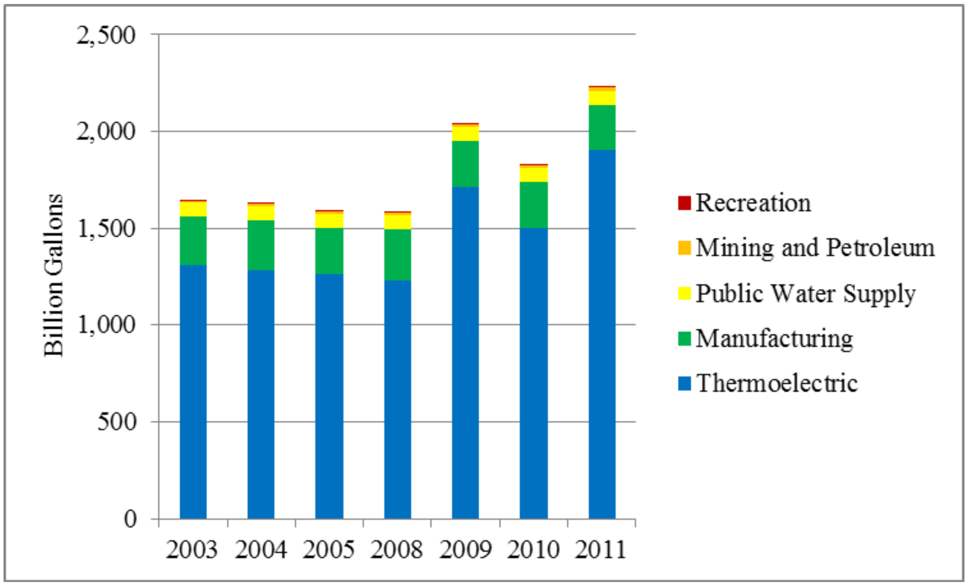


Figure 2 shows that the Thermoelectric sector is the largest user of water, followed by the Manufacturing sector. The majority of withdrawals occurred in three watersheds – North Branch Potomac, Cheat (after 2008), and Middle Ohio South (**Figure 3**). Though, by 2011, withdrawals in the Middle Ohio South had dropped by 65 percent from the 2003 level. This caused withdrawals in the watershed to be on par with withdrawals in Upper Ohio South and Upper Kanawha watersheds in 2011. The large withdrawal total in the Cheat and North Branch Potomac watersheds is driven by withdrawals in the Thermoelectric sector. The most recent withdrawal data (2011) is shown in **Figure 4** by watershed.

Figure 3. Total annual withdrawals by watershed. The inset graph focuses on those watersheds whose results are too small to see on the larger graph.

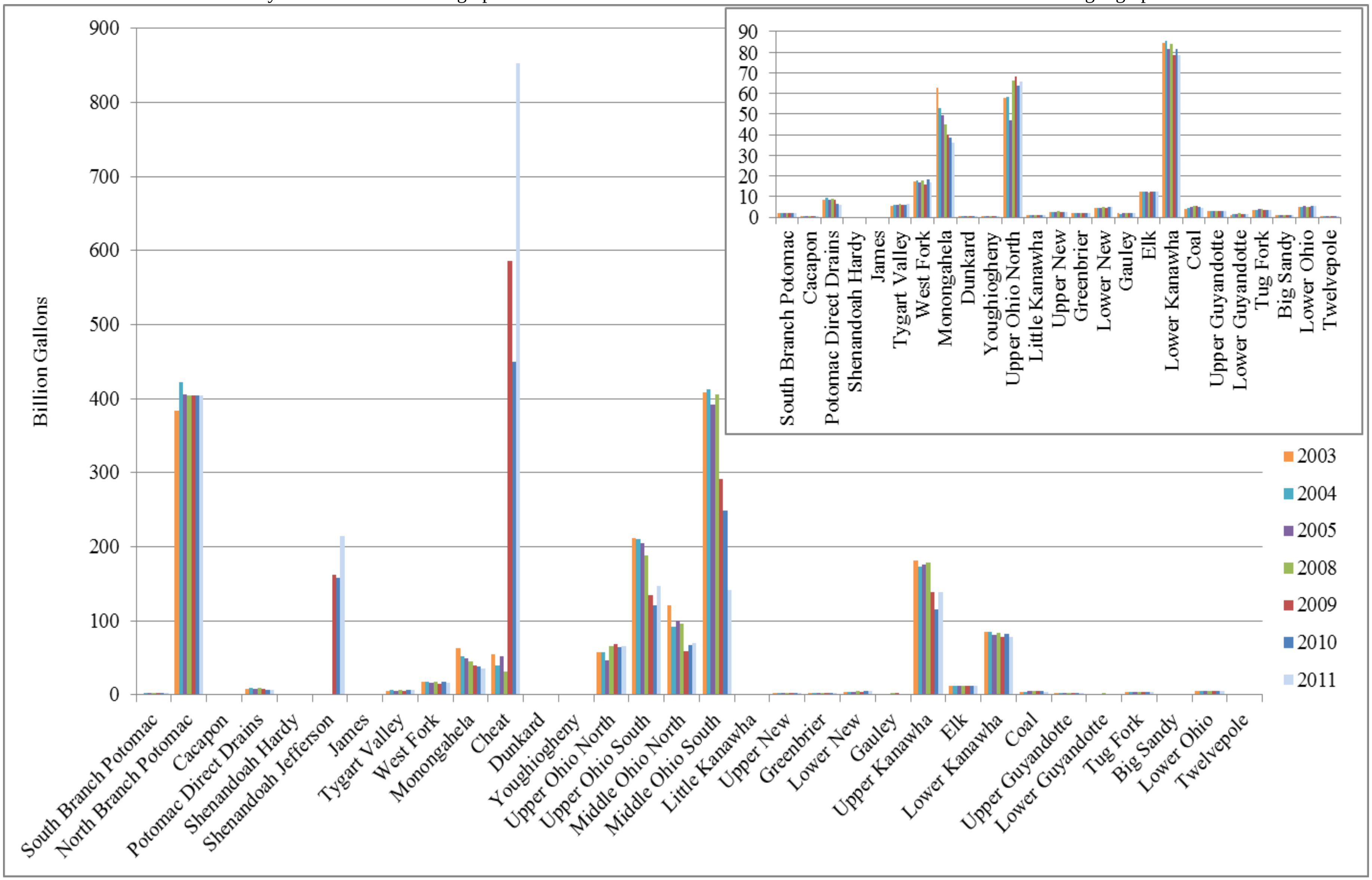
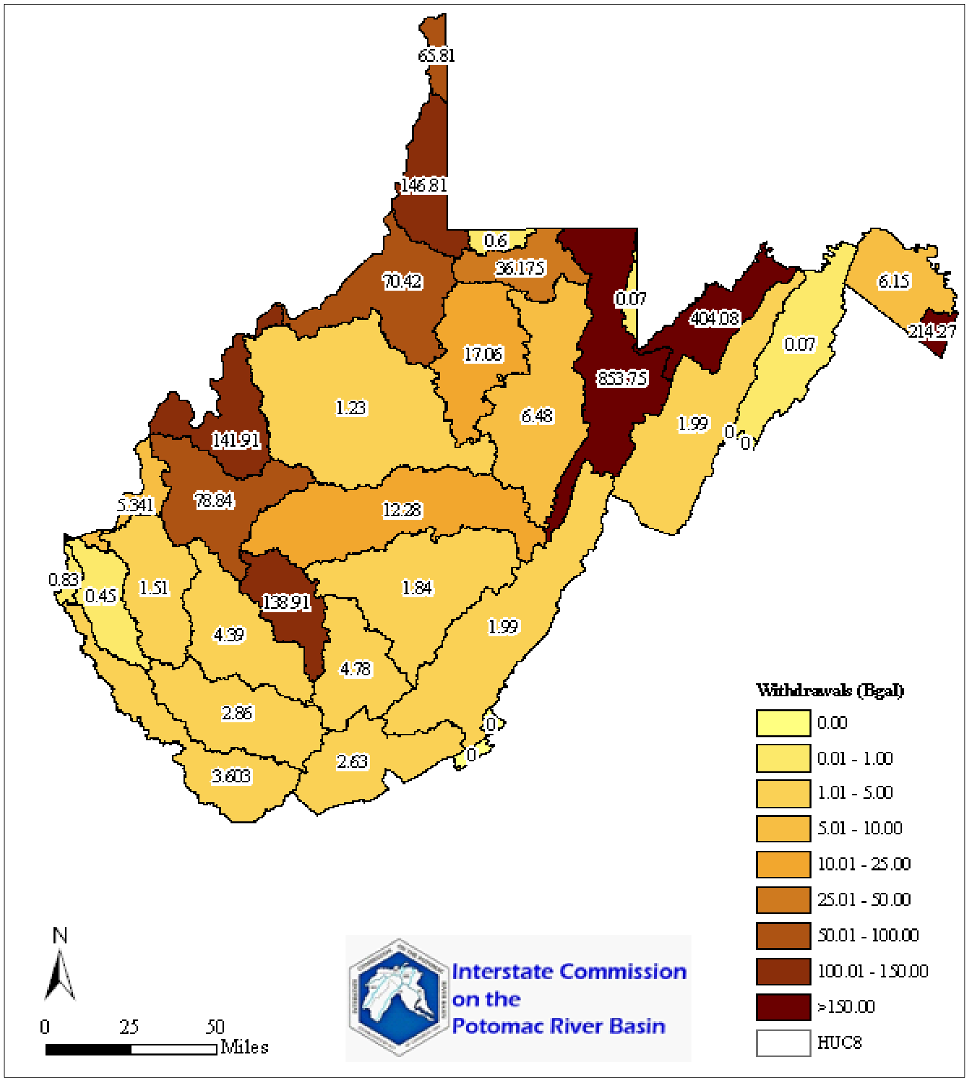


Figure 4. Withdrawals by watershed in 2011 from the LQU database (Marcellus Shale withdrawals not included).



2.2 Consumptive Use

2.2.1 Review of Consumptive Use Studies

Consumptive water use is defined by Solley et al. (1988) as that 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-, or ground-water source. Other sources of consumptive use information largely agree with this definition.

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 can be problematic due to the potential for over-generalization. In this section, several consumptive use estimation methods are described and the uncertainties inherent in each method are identified.

2.2.1.1 *West Virginia Water Resources Protection Act Water Use Survey Final Report*

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, the data were 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. A description of the method used to estimate the consumptive use in these cases is not available in the report. Additional information on the methods used would facilitate a complete evaluation of the potential error and uncertainty in the results. A breakdown of consumptive use by industry sector is not available in the tables of total consumptive use nor is consumptive use coefficients (DEP 2006, Appendices E and F). Industry-specific consumptive uses would be useful for application of the estimates for water resources planning and management.

Chapter 7 (Section 7.3) of the report contains estimates of future water use by industrial sector. These were calculated by Marshall University Center for Business and Economic Research using industry-specific water use coefficients (referred to as “net use”) (**Table 3**). The coefficients are based on water use per employee and are reported in gallons per employee per day (GED) (DEP 2006). Annual estimates for 2005 through 2010 by county and industry North American Industry Classification System (NAICS) code are given in Appendix L (DEP 2006). 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’s estimations of net use used several methods including calculation of net use rates from the DEP large user survey data, use of a fixed industry-specific estimated net use rate, and use of 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 were unavailable.

Table 3. 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.

2.2.1.2 *USGS Estimated Use of Water in the United States*

The USGS calculated consumptive use in *Estimated Use of Water in the United States* reports from 1985 through 1995 (Solley et al. 1998; Solley et al. 1993; Solley et al. 1988) but not in more recent water surveys. In these three studies, in-stream uses were compiled for eight use types: Public Supply, Commercial, Domestic, Irrigation, Livestock, Industrial, Mining, and Thermoelectric Power. Hydroelectric power generation (defined as an off-stream use) was not compiled even though it was reported by some states. Data were measured and reported by individual states. Each state produced its own water use data using their local methods and practices. Therefore, the values were calculated or measured by the states using different methodologies for different use types. Each state also has a different withdrawal reporting requirement threshold. This means the number and amounts estimated (non-reporting) withdrawals varies by state. As a result, the estimated fraction of the total water use, and the inherent uncertainty in the estimated values, varies by state. USGS compiled the state data into a consistent format. Details on the methods that were used by each state are not provided in the USGS reports. **Table 4** shows the consumptive use coefficients for West Virginia from the *Estimated Use of Water in the United States* report for 1995 (Solley et al. 1998). The advantage of the USGS data is that there are multiple years of reports from which general trends in use could be developed to guide or assist in evaluating use estimates from other sources.

Table 4. Estimates of consumptive use coefficients for West Virginia from Solley et al. 1998.

Use Type	Consumptive use coefficient (%)
Domestic	10
Commercial	15
Livestock	24
Industrial	15
Mining	23
Thermoelectric	4

2.2.1.3 *Middle Potomac River Watershed Assessment (MPRWA)*

The MPRWA (U.S. Army Corps of Engineers et al. 2012) analyses used the average of consumptive use factors by use sector as summarized in Shaffer and Runkle (2007) to project future consumptive uses in the Middle Potomac River Basin study area (**Table 5**). These consumptive use factors were developed from the USGS 1985, 1990, and 1995 *Estimated Use of Water in the United States* reports referred to above (Solley et al. 1998; Solley et al. 1993; Solley et al. 1988). The MPRWA study evaluated six water use sectors at the county-scale including domestic and public supply, industrial, irrigation, livestock, mining, and thermoelectric power. An average consumptive use coefficient was calculated from the coefficients in these three reports to project consumptive use beyond 1995. These consumptive use coefficients were used to project future consumptive use based on projected future withdrawals. The methods used to produce the coefficients and inherent uncertainties are described in the respective study reports (Solley et al. 1998; Solley et al. 1993; Solley et al. 1988). Averaging the consumptive use coefficients from three reports introduced additional uncertainty in the MPRWA through a potential over-generalization; but with the advantage of reducing the extremes in the previous estimates.

Table 5. Estimates of consumptive use coefficients from U.S. Army Corps of Engineers et al. 2012.

Use Type	Consumptive use coefficient (%)
Domestic and public supply	11
Industrial	9
Irrigation	82
Livestock	78
Mining	15
Power	3

2.2.1.4 *Consumptive Water-Use Coefficients for the Great Lakes Basin and Climatically Similar Areas*

Shaffer and Runkle (2007) compiled an extensive list of consumptive use coefficients by water use category applicable to the Great Lakes Basin and climatically similar areas. This study compiled and summarized consumptive use coefficients from about 100 sources by geographic area and water use category to provide an overview of coefficient ranges. West Virginia is among the states shown by the study to be "climatically similar." Consumptive use coefficients are provided for seven use categories; namely, Domestic and Public Supply, Industrial, Thermoelectric Power, Irrigation, Livestock, Commercial, and Mining (**Table 6**).

Three methods were used to compile consumptive use coefficients from the multiple sources: 1) listing the coefficient provided by the source, 2) calculating the coefficient from the amount of water consumed (reported) divided by the amount of water withdrawn (reported), and 3) calculating the coefficient from water used (water withdrawn minus water returned) divided by water withdrawn. The method used is indicated for each source and the uncertainties are discussed in the report. The sources are organized by use category and statistics are calculated on the consumptive use coefficients for each. Tables are provided that compare statistics of the consumptive use coefficients for each use category for the Great Lakes Basin and climatically similar areas. Uncertainties associated with averaging consumptive use coefficients apply to this study however the statistical treatment included provides insight into the distribution of the coefficients and the inherent uncertainties.

Table 6. Estimates of median consumptive use coefficients for Great Lakes Basin climatically similar areas from Shaffer and Runkle 2007.

Use Type	Consumptive use coefficient (%)
Domestic and Public Supply	15
Industrial	10
Thermoelectric Power	2
Irrigation	100
Livestock	100
Commercial	10
Mining	14

2.2.1.5 *Variations in Withdrawal, Return Flow, and Consumptive Use of Water*

Shaffer (2009) analyzed withdrawal data for Ohio, Indiana, and Wisconsin and return flow data for Ohio to compute consumptive use coefficients and monthly withdrawal and consumptive use for 1999 through 2004. Withdrawals were divided into nine different water use sectors, and some of these categories were further subdivided.

Consumptive use coefficients were calculated using three methods; namely, the return flow and withdrawal (RW) method, winter base-rate (WBR) method, and the Standard Industrial Code (SIC) method. The RW method is a water balance method where measured return flow is subtracted from measured withdrawals. This method was not used for the Public Supply category because the customers for water supply and wastewater treatment (return flow) systems are not always the same, the possibility of infiltration or stormwater inflows to sewer systems in addition to return flows, and there may be public uses and system losses that are not measured. The WBR method uses monthly withdrawal data to compute monthly consumptive use coefficients and found it is generally appropriate for the domestic and some other use categories. The WBR method assumes that for appropriate use categories the increase in summer withdrawals is due to outdoor use and is 100 percent consumptive. If the summer use percentage is greater than 0.5 percent greater than the winter use percentage in a particular use category, the WBR method could be used for the use category. A third method used for the industrial use category applies a fixed consumptive use coefficient calculated in a previous study (Shaffer and Runkle 2007) by SIC code for each facility. Due to the use of multiple methods for calculation of coefficients for different use types and states, summary consumptive use coefficients are not provided for this source.

Uncertainties inherent in these methods are similar to those in the studies previously described due primarily to the lack of data on withdrawals and return flows. For the WBR method, if monthly withdrawal and return flow data are not available then the monthly patterns described may be useful for estimation of a consumptive use coefficient but the level of uncertainty may be greater than for other estimation methods (Shaffer 2009).

2.2.1.6 *Marshall University Consumptive Use Estimations*

Marshall University calculated consumptive use totals for 2010 reported withdrawals for 8-, 10- and 12-digit HUCs and by facility but not by use category[3]. According to DEP, consumptive use was

[3] Excel workbook with Marshall University consumptive use calculations obtained from DEP, Copy of WatershedConsumptiveUse Without Hydroelectric Without Negative Consumptive Use 2010.xlsx.

calculated by subtracting reported discharges from reported withdrawals, similar to the RW method described above. Uncertainties inherent in this method include the following. First, the amount of withdrawals may not equal the amount of discharges plus the amount of water consumed because the systems are not closed. Stormwater can add water to the flow in combined systems. Leaking pipes can cause infiltration into or loss from the system. Second, there are often uncertainties associated with withdrawal and discharge data collection and reporting. Some facilities get part of their water from self-supplied sources and some from public supplies. Further, some facilities may discharge part of their wastewater to their own discharge point and some to public wastewater systems.

2.2.1.7 *Discussion*

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 loses. 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 on the equipment and practices at each reporting facility. There is typically no reporting or assessment of these inaccuracies. Another possible source of uncertainty relates to the reporting scale. In a study using a county-based reporting scale, for instance, a withdrawal made in one county with an associated discharge in 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. This threshold leaves a possibly significant percentage of total use unaccounted or estimated.

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.

2.2.2 Consumptive Use Scenarios

As mentioned above, this project 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 7 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 7**). 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.

These factors were applied to the withdrawal totals by watershed and county for each water use type. This is simply done as shown in **Eq. 1**:

Withdrawal * consumptive use coefficient = consumptive use estimate (**Eq.1**)

Table 7. 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
Great Lakes Basin						
Domestic and Public Supply	0	10	12	15	74	161
Industrial	0	7	10	14	35	122
Thermoelectric Power	0	1	2	2	21	141
Irrigation	70	90	90	96	100	95
Livestock	0	80	83	90	100	85
Commercial	4	8	10	15	26	29
Mining	0	7	10	25	58	58
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
Great Lakes Basin and climatically similar areas						
Domestic and Public Supply	0	10	13	15	74	299
Industrial	0	6	10	13	35	219
Thermoelectric Power	0	1	2	3	75	216
Irrigation	37	90	91	100	100	170
Livestock	0	80	90	100	100	158
Commercial	3	8	10	13	33	90
Mining	0	8	13	22	86	141
World						
Domestic and Public Supply	14	16	16	18	19	4
Industrial	9	10	10	11	11	4
Agriculture	65	65	68	72	78	4

Appendix C 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 5** and **Figure 6** 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 7**). The Manufacturing sector has a high consumptive use rate that leads to high consumptive use totals even with the lower withdrawal totals. The Cheat watershed consumed the most water in 2011 (**Figure 8** and **Figure 9**). Total consumptive use by watershed is shown on a map in **Figure 10** and **Figure 11**.

Figure 5. High scenario consumptive use estimates by (amended) use type.

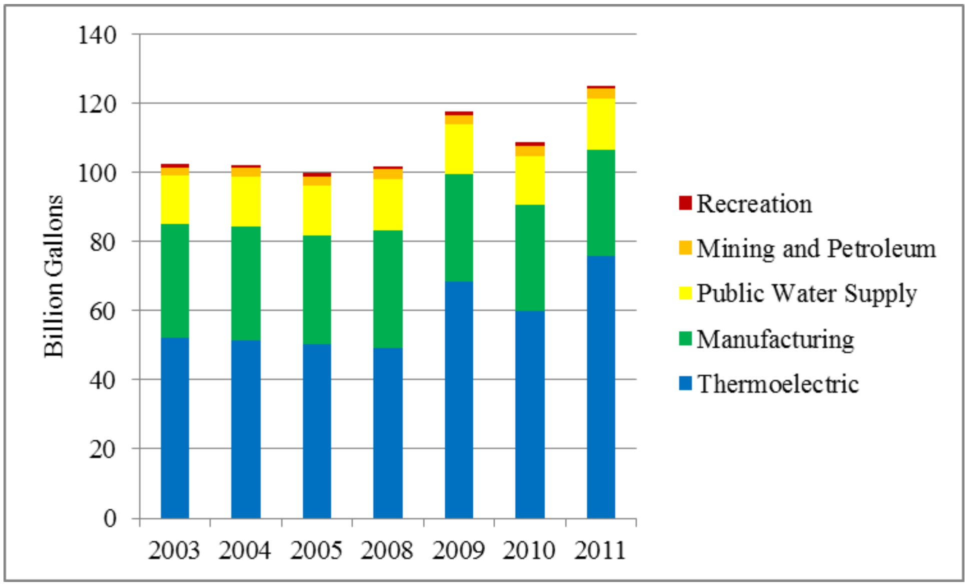


Figure 6. Low scenario consumptive use estimates by (amended) use type.

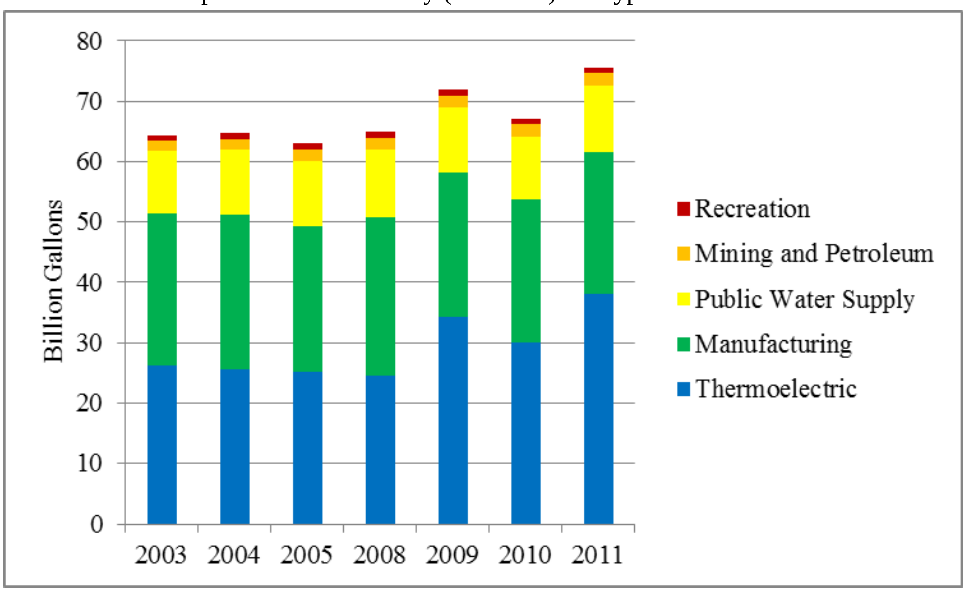


Figure 7. Withdrawals and high consumptive use estimates by use type (2011).

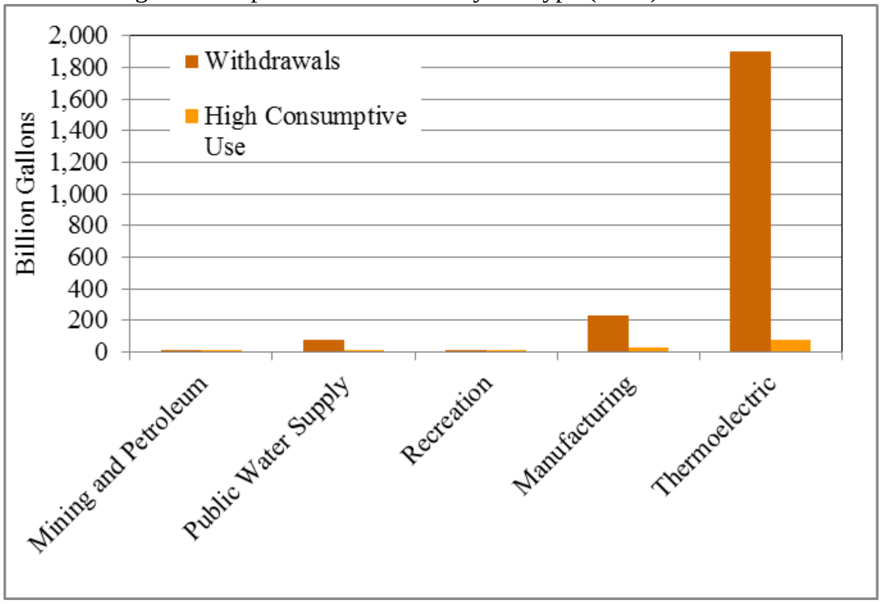


Figure 8. High scenario consumptive use estimates by watershed (not including Marcellus Shale). The inset graph focuses on those watersheds whose results are too small to see on the larger graph.

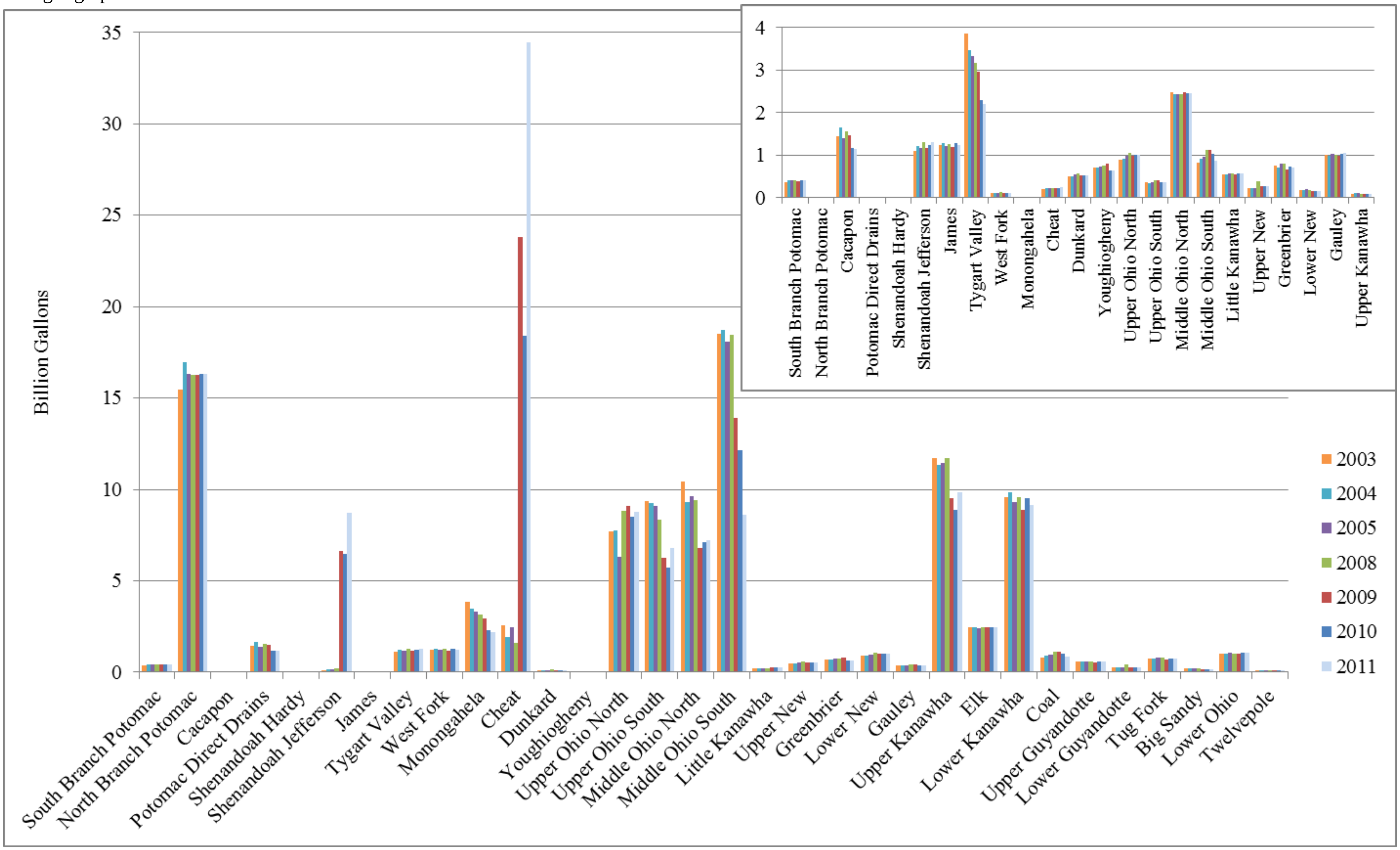


Figure 9. Low scenario consumptive use estimates by watershed (not including Marcellus Shale). The inset graph focuses on those watersheds whose results are too small to see on the larger graph.

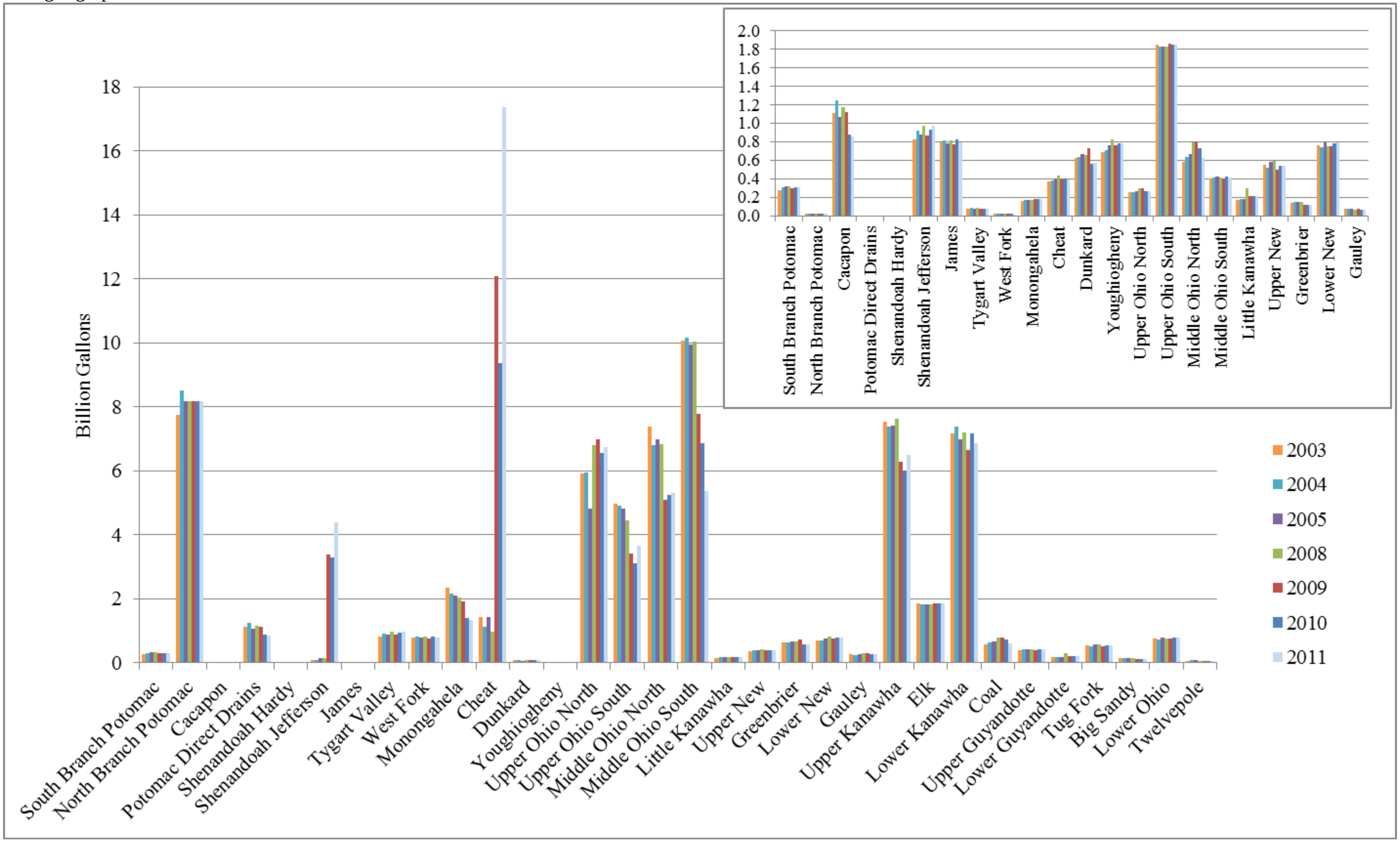


Figure 10. High scenario consumptive use estimate for 2011 (not including Marcellus Shale).

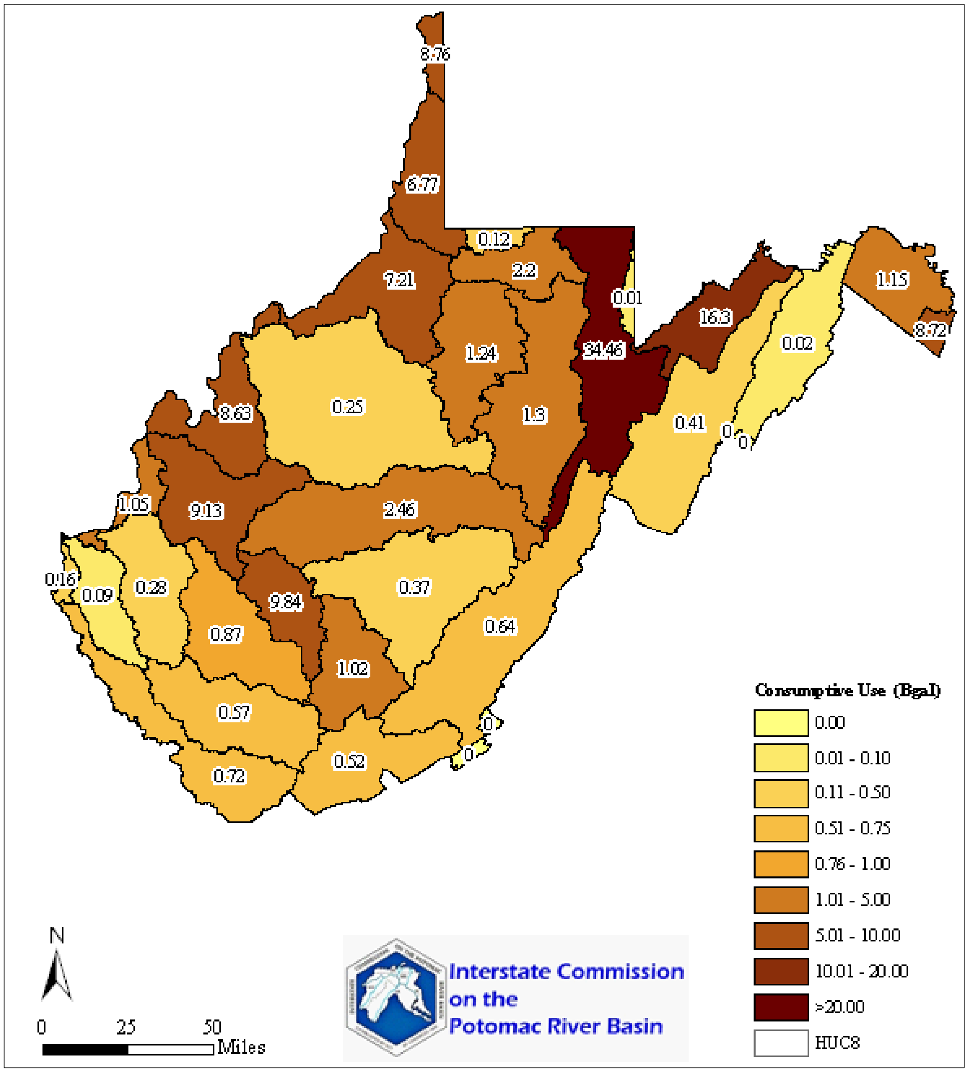
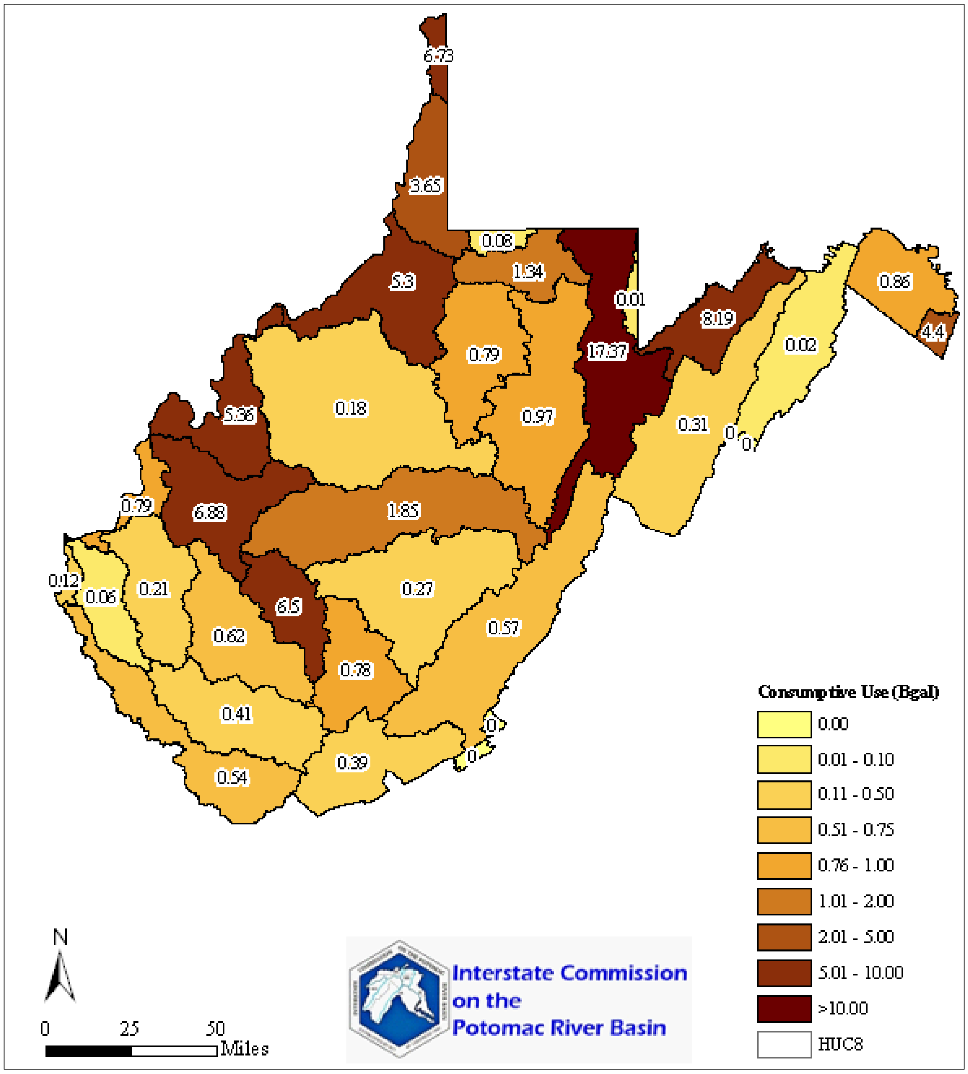


Figure 11. Low scenario consumptive use estimate for 2011 (not including Marcellus Shale).



For the Marcellus Shale use category, a low scenario consumptive use rate of 91 percent was calculated from the DEP data (**Table 8**). 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.

Table 8. Marcellus Shale withdrawals and consumptive use estimates by HUC. Data were provided by DEP outside of the LQU database.

HUC8	Sum of Past and Planned Wells (2009-2015) (Bgal)		
	Withdrawal	HIGH Consumptive Use	LOW Consumptive Use
North Branch Potomac	0.05	0.05	0.05
Tygart Valley	0.95	0.95	0.86
West Fork	13.13	13.13	11.94
Monongahela	0.51	0.51	0.47
Cheat	0.11	0.11	0.10
Dunkard	0.02	0.02	0.02
Youghiogheny	0.02	0.02	0.02
Upper Ohio North	0.77	0.77	0.70
Upper Ohio South	7.61	7.61	6.93
Middle Ohio North	15.94	15.94	14.50
Little Kanawha	6.83	6.83	6.21
Gauley	0.08	0.08	0.08
Elk	0.01	0.01	0.01
TOTAL	46.03	46.03	41.88

3 Water 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 2.2** were then applied to these projected withdrawals to estimate consumptive use by watershed and county as explained in **Section 4**.

3.1 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 readily be applied statewide.

Withdrawals were projected at the watershed and county levels – not for individual withdrawal points (**Box 2**). While similar methods were used for the two sets of projections, the 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.

BOX 2

General Withdrawal Projection Steps:

1. Sum withdrawals by watershed (or county) for the years of data in the LQU database.
2. Sum 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.

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). These data were 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 mainly from the U.S. Bureau of Labor Statistics' 2012 *Industry employment and output projections to 2020* (BLS 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 rest of this section details 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.

3.1.1 Mining and Petroleum

In order to implement the withdrawal projection method described above, the relevant employment data was collected[4]. To make the best use of the available employment data, the DEP water use categories of Mining and Petroleum were combined into one category (**Table C-1**). DEP defined these uses 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 hydrofracking a well.

There are a couple of NAICS codes that 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."

The Petroleum water use category was not considered independently because most of the relevant county employment data were 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 DEP had no reported withdrawals for the hydraulic fracturing of Marcellus Shale, code 21

[4] Refer to **Appendix D** for a step-by-step explanation of the methods used.

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 (WVU 2012). The same employment NAICS code for each county was used over the period of record in the LQU database to get consistent employee use rates regardless of when development of the Marcellus Shale began in a certain area.

Table D-1 shows the employment numbers used for each county and includes notes on any additional assumptions. These employment numbers were used to develop per employee use rates by county (**Table D-3**).

To estimate employment numbers by watershed, county employment was apportioned to the watershed-level using the method explained in **Box 3**. The employment numbers for each watershed are shown in **Table D-2**. High and low employment projections were based off of 2011 employment data. The high scenario increased employment annually by 0.4 percent (**Eq. 2**). 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* (WVU 2012) through 2017. This rate was applied for the 2020, 2030, and 2040 scenarios.

BOX 3

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. Sum employees in each watershed.

$$E_{t_2} = E_{t_1} \times (1 \pm r)^{(t_2 - t_1)} \qquad \textbf{(Eq. 2)}$$

Where, E = employees at time t

t = year

r = 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 **Eq. 3**. The average per employee water use rates for the Mining and Petroleum sector by watershed and county are in **Table D-3** and **Table D-5**, respectively.

$$W_2 = E_{t_2} \times U_a \qquad \textbf{(Eq. 3)}$$

Where, W_2 = forecasted withdrawal

U_a = 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 projections are in **Table D-4** and the county-level projections are in **Table D-7**.

3.1.2 Manufacturing

In order to project the Industrial, Chemical, and Timber DEP use categories using employment and industry data, the withdrawals were combined into a single Manufacturing category (**Table C-3**)[5]. The description of each category provided by DEP 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 E-1**). 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” (BLS 2013).

Using the same method described in **Box 3** in the previous section, the county-level employment data were transformed to the watershed level (**Table E-2**). Per employee water use rates for the

[5] Refer to **Appendix E** for a step-by-step explanation of the methods used.

Manufacturing sector were calculated for each watershed and county (**Table E-3** and **Table E-5**, 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 (**Eq. 2)**. 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 (WVU 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 (BLS 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 totals withdrawals by watershed and county using **Eq. 3**. **Table E-4** and **Table E-7** show the results of the high and low scenario projections by watershed and county, respectively.

3.1.3 Recreation

The Recreation water use projection used the same method as the Mining and Petroleum and Manufacturing sectors[6]. 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)[7]. 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 F-1** details the assumptions used to estimate the number of employees in each county with a Recreation water use withdrawal. Employment at the watershed level was derived using the steps detailed in **Box 3** (**Table F-2**).

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

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[6] Refer to **Appendix F** for a step-by-step explanation of the methods used.

[7] Leisure and hospitality category (BLS 2013):

Arts, Entertainment, and Recreation (71): "The Arts, Entertainment, and Recreation sector includes a wide range of establishments that operate facilities or provide services to meet varied cultural, entertainment, and recreational interests of their patrons. This sector comprises (1) establishments that are involved in producing, promoting, or participating in live performances, events, or exhibits intended for public viewing; (2) establishments that preserve and exhibit objects and sites of historical, cultural, or educational interest; and (3) establishments that operate facilities or provide services that enable patrons to participate in recreational activities or pursue amusement, hobby, and leisure-time interests. Some establishments that provide cultural, entertainment, or recreational facilities and services are classified in other sectors."

Accommodation and Food Services (72)

Accommodation (721): "Industries in the Accommodation subsector provide lodging or short-term accommodations for travelers, vacationers, and others. There is a wide range of establishments in these industries. Some provide lodging only; while others provide meals, laundry services, and recreational facilities, as well as lodging. Lodging establishments are classified in this subsector even if the provision of complementary services generates more revenue. The types of complementary services provided vary from establishment to establishment."

employment for 2020, 2030, and 2040 (WVU 2012). The projected numbers of employees by watershed and county are in **Table F-2** and **Table F-6** (**Eq. 2**). Dividing the water withdrawals in each watershed or county by the number of employees yielded the per employee use rates (**Table F-3** and **Table F-5**, 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 F-4**) and by county (**Table F-7**) (**Eq. 3**).

3.1.4 Public Water Supply

Projections for the Public Water Supply sector used a slightly different method from that used for the sectors described above[8]. 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 were provided by DEP from the U.S. Census. The population data were at the Census block level making it possible to assign each block to a watershed. The process was completed for the 2010 data by DEP. For the blocks that crossed more than one watershed, DEP used satellite imagery to determine the number of households, and therefore population, that should be assigned to each watershed. This level of detail was not available for the 2000 block data. To assign the population in each block to a watershed, 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 (**Table G-1**). Using these annual population estimates, a per capita use rate was calculated for each watershed by dividing the withdrawal in a given year by the estimated number of people in the watershed that year (**Table G-3**).

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 G-4**). 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 G-6**).

3.1.5 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[9]. The *2013 West Virginia Economic Outlook* predicts an annual decrease of 2.3 percent in coal-fired power capacity through 2017 (WVU 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" (EIA 2012). This is an annual decrease of 0.46 percent. This rate was used for the high and low

[8] Refer to **Appendix G** for a step-by-step explanation of the methods used.
[9] Refer to **Appendix H** for a step-by-step explanation of the methods used.

scenario's 2030 and 2040 projections. It is expected that there will be a significant 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 power production will 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 were:

- First Energy: Albright, Willow Island, and Rivesville (First Energy Corp. 2012)
- AEP: Kammer, Kanawha River, and Phillip Sporn (AEP 2013)

The high and low withdrawal projections are shown by watershed and county respectively in **Table H-1** and **Table H-2**.

3.1.6 Marcellus Shale/Hydraulic Fracturing

Water used for hydraulic fracturing of Marcellus Shale is tracked in a separate water use database by DEP. In this database, water use is tracked by the water source and the withdrawal rates are for a well pad, not for individual wells. To get an average water withdrawal per well, the reported withdrawal for each pad was divided by the number of wells registered to that pad. The database also has information on planned withdrawals for future wells through 2015. These planned withdrawals were combined with the past withdrawals (beginning in 2009) to get the average per well withdrawal rate. The resulting average withdrawal per well was approximately five million gallons.

To forecast the future withdrawals for hydraulic fracturing, an estimation of the future number of wells was needed[10]. 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). This translated to a predicted number of wells in each state in 2020. 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 the average water withdrawal per well described above, a total water withdrawal was calculated for the state (**Table 9**).

Table 9. High and low scenario Marcellus Shale withdrawals for 2020.

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 10**). 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.

[10] Refer to **Appendix B** for a step-by-step explanation of the methods used.

Table 10. Withdrawal totals for past and planned (2009-2015) and future (2020) Marcellus Shale development by watershed.

HUC8	Withdrawals from DEP (Bgal)	Percent of Total Withdrawal	Estimated 2020 Withdrawals (Bgal)	
			HIGH Scenario	LOW Scenario
North Branch Potomac	0.05	0.11	0.004	0.001
Tygart Valley	0.95	2.06	0.08	0.03
West Fork	13.13	28.52	1.10	0.40
Monongahela	0.51	1.11	0.04	0.02
Cheat	0.11	0.23	0.01	0.003
Dunkard	0.02	0.05	0.002	0.001
Youghiogheny	0.02	0.04	0.002	0.001
Upper Ohio North	0.77	1.68	0.06	0.02
Upper Ohio South	7.61	16.53	0.64	0.23
Middle Ohio North	15.94	34.63	1.34	0.49
Little Kanawha	6.83	14.84	0.57	0.21
Gauley	0.08	0.18	0.01	0.003
Elk	0.01	0.02	0.001	0.0003
TOTAL	46.03	100.00	3.86	1.41

The 2030 and 2040 projections assumed that new wells were not being drilled, but that existing wells were being refractured to increase gas production. The refracturing of wells is highly variable and difficult to predict. For the 2030 high scenario, it was assumed that one-fifth of the wells would be refractured since the DEP data covers approximately five years of activity. The 2030 low scenario assumed that half of those wells (one-tenth of the DEP wells) would be refractured. The 2040 scenario assumed that half of the wells would be refractured in both the high and low 2020 development scenarios. **Table 11** shows the results for the 2030 and 2040 projections.

Table 11. High and low scenario Marcellus Shale withdrawal estimates for 2030 and 2040 by watershed.

HUC8	2030 Withdrawal (Bgal)		2040 Withdrawal (Bgal)	
	HIGH	LOW	HIGH	LOW
North Branch Potomac	0.01	0.005	0.002	0.001
Tygart Valley	0.19	0.09	0.04	0.01
West Fork	2.63	1.31	0.55	0.20
Monongahela	0.10	0.05	0.02	0.01
Cheat	0.02	0.01	0.005	0.002
Dunkard	0.005	0.002	0.001	0.0003
Youghiogheny	0.004	0.002	0.001	0.0003
Upper Ohio North	0.15	0.08	0.03	0.01
Upper Ohio South	1.52	0.76	0.32	0.12
Middle Ohio North	3.19	1.59	0.67	0.24
Little Kanawha	1.37	0.68	0.29	0.10
Gauley	0.02	0.01	0.003	0.001
Elk	0.002	0.001	0.0005	0.0002
TOTAL	9.20	4.60	1.93	0.70

The corresponding county-level tables are in **Appendix B**.

3.2 Withdrawal Projection Results

The projected withdrawals for the high and low scenarios in 2020, 2030, and 2040 are shown by watershed in **Figure 12**, **Figure 13**, and **Table 12** and by water use category in **Table 13**. The Thermoelectric sector continues to withdraw the greatest amount of water in the state. The watersheds with the greatest withdrawals – Cheat, North Branch Potomac, and Shenandoah Jefferson – 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.

Figure 12. High scenario withdrawals by watershed. The inset graph focuses on those watersheds whose results are too small to see on the larger graph.

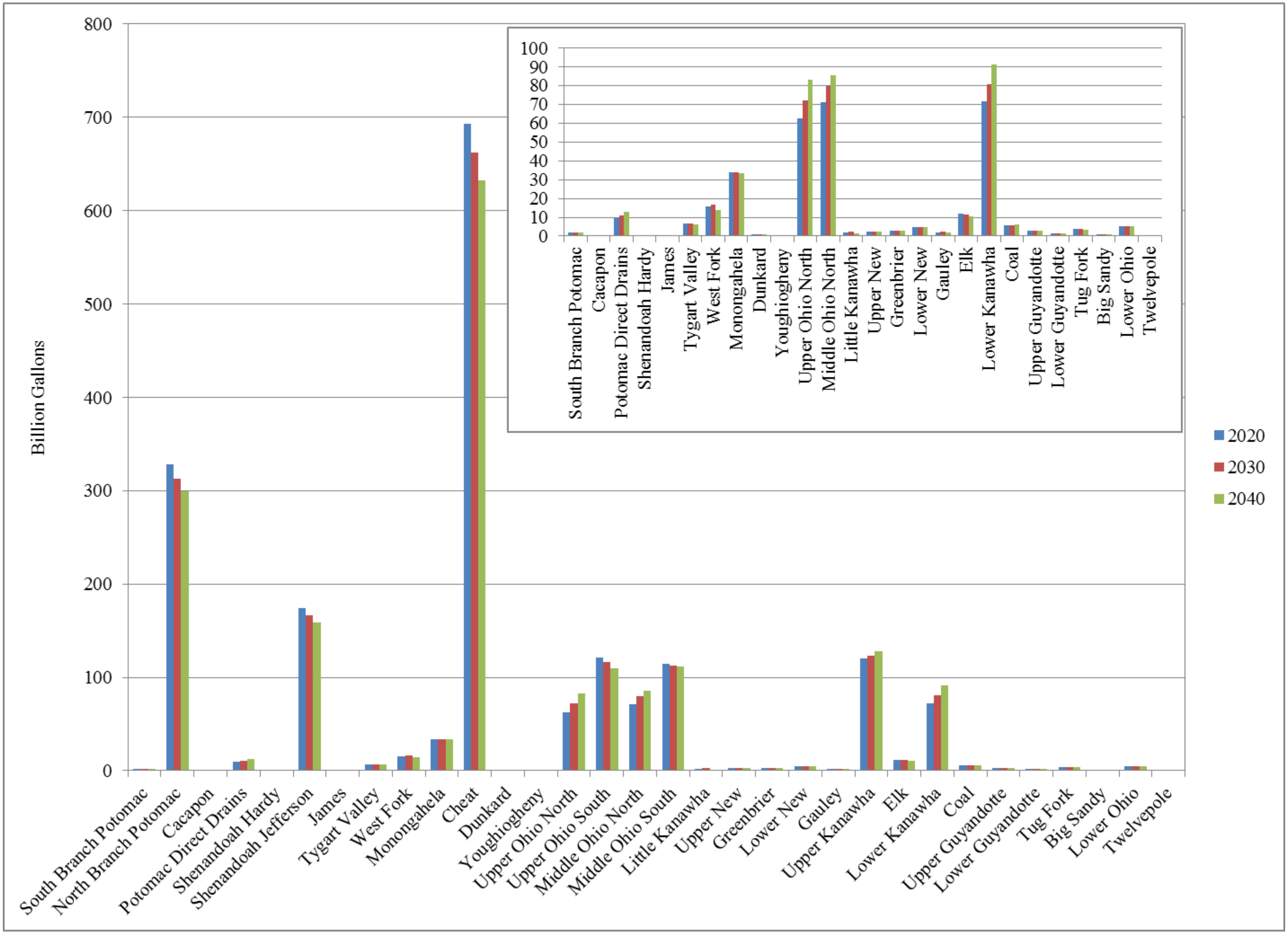


Figure 13. Low scenario withdrawals by watershed. The inset graph focuses on those watersheds whose results are too small to see on the larger graph.

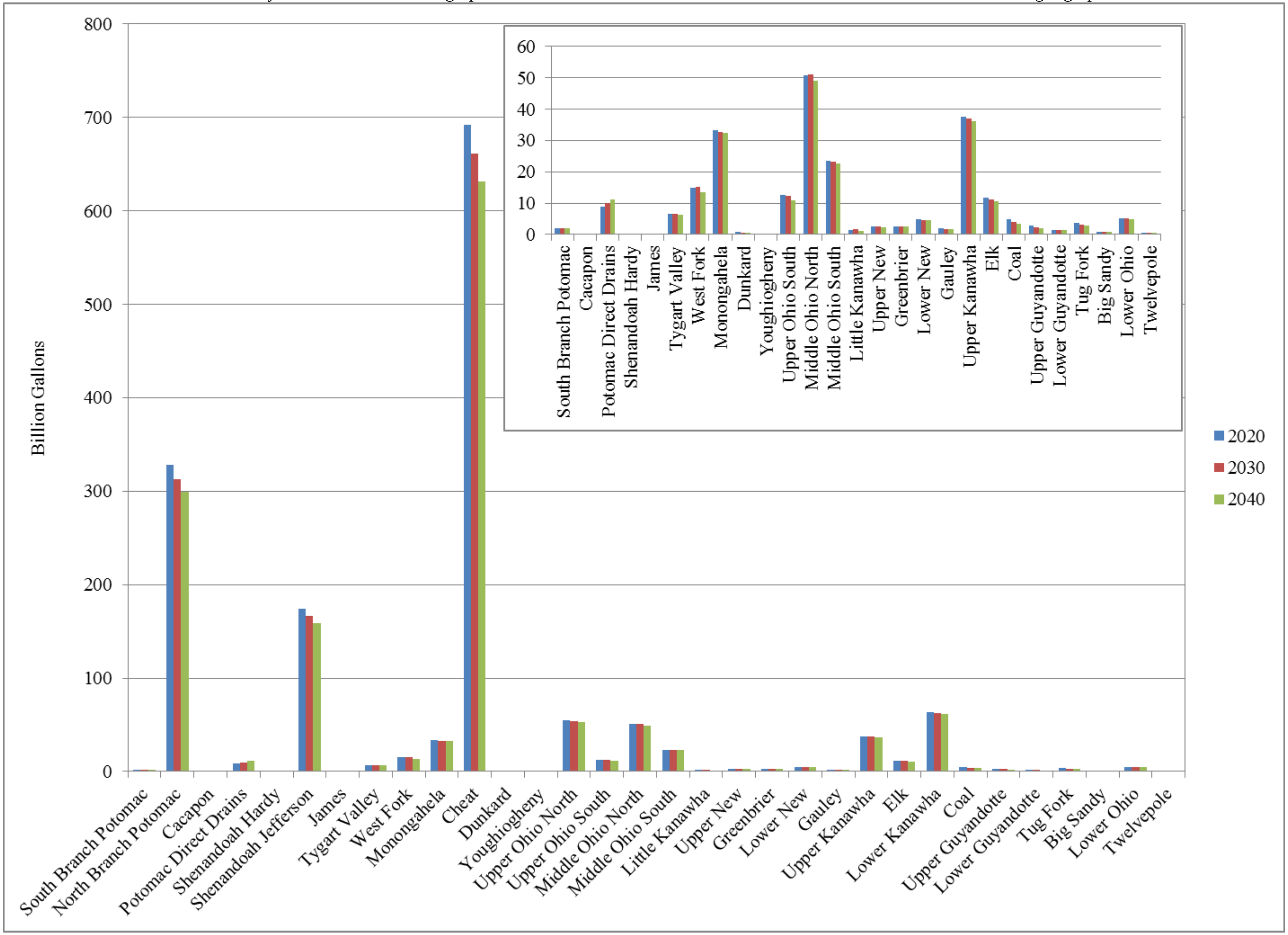


Table 12. High and low scenario withdrawal estimates by watershed.

HUC8	HIGH Scenario Withdrawals (Bgal)			LOW Scenario Withdrawals (Bgal)		
	2020	2030	2040	2020	2030	2040
South Branch Potomac	2.11	2.13	2.05	2.10	2.10	2.02
North Branch Potomac	327.82	313.09	299.01	327.80	313.05	298.96
Cacapon	0.08	0.09	0.09	0.08	0.09	0.09
Potomac Direct Drains	9.38	10.97	12.68	8.92	9.97	11.05
Shenandoah Hardy	0.00	0.00	0.00	0.00	0.00	0.00
Shenandoah Jefferson	174.08	166.41	159.09	174.07	166.39	159.04
James	0.00	0.00	0.00	0.00	0.00	0.00
Tygart Valley	6.61	6.74	6.42	6.52	6.55	6.27
West Fork	15.64	16.69	14.08	14.89	15.27	13.59
Monongahela	34.02	33.78	33.60	33.28	32.75	32.33
Cheat	692.91	661.84	632.14	692.26	661.15	631.42
Dunkard	1.00	1.03	1.07	0.82	0.69	0.58
Youghiogheny	0.11	0.11	0.10	0.11	0.11	0.10
Upper Ohio North	62.48	72.14	83.08	54.33	53.65	52.81
Upper Ohio South	120.80	116.37	110.09	12.68	12.41	10.99
Middle Ohio North	71.10	79.98	85.75	50.82	51.13	48.98
Middle Ohio South	114.57	112.97	111.87	23.50	23.13	22.66
Little Kanawha	1.73	2.50	1.35	1.37	1.81	1.16
Upper New	2.61	2.54	2.41	2.61	2.53	2.40
Greenbrier	2.72	2.84	2.93	2.59	2.56	2.48
Lower New	4.98	4.90	4.72	4.89	4.72	4.46
Gauley	2.13	2.15	2.11	1.96	1.82	1.65
Upper Kanawha	120.39	123.45	127.69	37.71	36.99	36.29
Elk	11.74	11.25	10.61	11.71	11.18	10.51
Lower Kanawha	71.70	80.82	91.54	63.72	62.72	61.72
Coal	5.59	5.78	5.96	4.73	4.06	3.48
Upper Guyandotte	3.06	3.02	2.97	2.75	2.41	2.09
Lower Guyandotte	1.56	1.59	1.61	1.48	1.43	1.36
Tug Fork	3.89	3.74	3.56	3.62	3.21	2.81
Big Sandy	0.92	0.88	0.84	0.91	0.86	0.79
Lower Ohio	5.19	5.21	5.21	5.14	5.08	5.01
Twelvepole	0.61	0.62	0.63	0.54	0.48	0.42
TOTAL	1,871.53	1,845.63	1,815.26	1,547.91	1,490.30	1,427.52

Table 13. High and low scenario withdrawal estimates by water use category.

Water Use Category	HIGH Withdrawals (Bgal)			LOW Withdrawals (Bgal)		
	2020	2030	2040	2020	2030	2040
Manufacturing	232.13	269.40	312.68	201.23	199.18	197.15
Mining and Petroleum	17.10	17.82	18.53	14.14	11.93	10.07
Recreation	2.37	2.61	2.88	2.14	2.14	2.14
Thermoelectric	1,542.30	1,472.79	1,406.43	1,255.22	1,198.66	1,144.65
Public Water Supply	73.78	73.81	72.82	73.78	73.81	72.82
Marsellus Shale	3.85	9.20	1.92	1.40	4.58	0.69
TOTAL	1,871.53	1,845.63	1,815.26	1,547.91	1,490.30	1,427.52

4 Consumptive Use Projections

Projecting consumptive use by watershed for 2020, 2030, and 2040 was done using the high and low withdrawal scenarios described above and the consumptive use rates detailed in **Section 2.2** (**Table 14**). 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 14. 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	91

Results are shown by watershed in **Figure 15**, **Figure 15**, and **Table 15** and by water use category in **Table 16**. They are also displayed on a map of watersheds in **Figure 16** and **Figure 17**.

Consumptive uses in some watersheds are higher in 2030 than either in 2020 or 2040. This is due to the refracturing assumption that was made in the Marcellus Shale development sector. It was assumed that either a fifth or a tenth of the wells fractured between 2009 and 2015 would be refractured in 2030. Combined with the extremely high consumptive use rate (91 or 100 percent) this caused consumptive use to peak in that year.

The Cheat 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 (two to four percent) (**Figure 14**). The North Branch Potomac also has a large Thermoelectric withdrawal and, therefore, consumptive use total. Other watersheds with comparatively high consumptive use totals are the Middle Ohio North, Upper Kanawha, 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 a Manufacturing withdrawal.

Figure 14. High scenario consumptive use by watershed. The inset graph focuses on those watersheds whose results are too small to see on the larger graph.

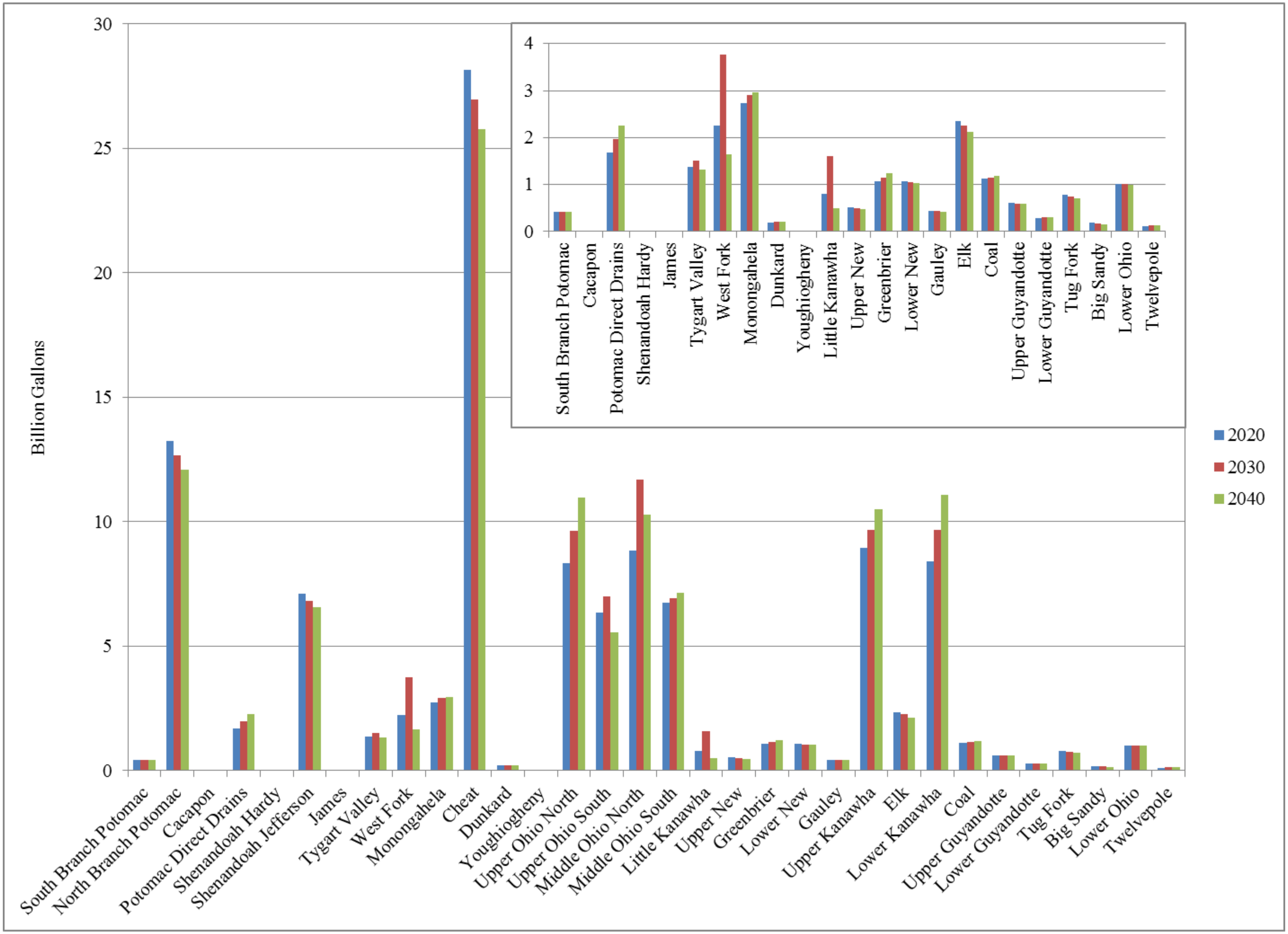


Figure 15. Low scenario consumptive use by watershed. The inset graph focuses on those watersheds whose results are too small to see on the larger graph.

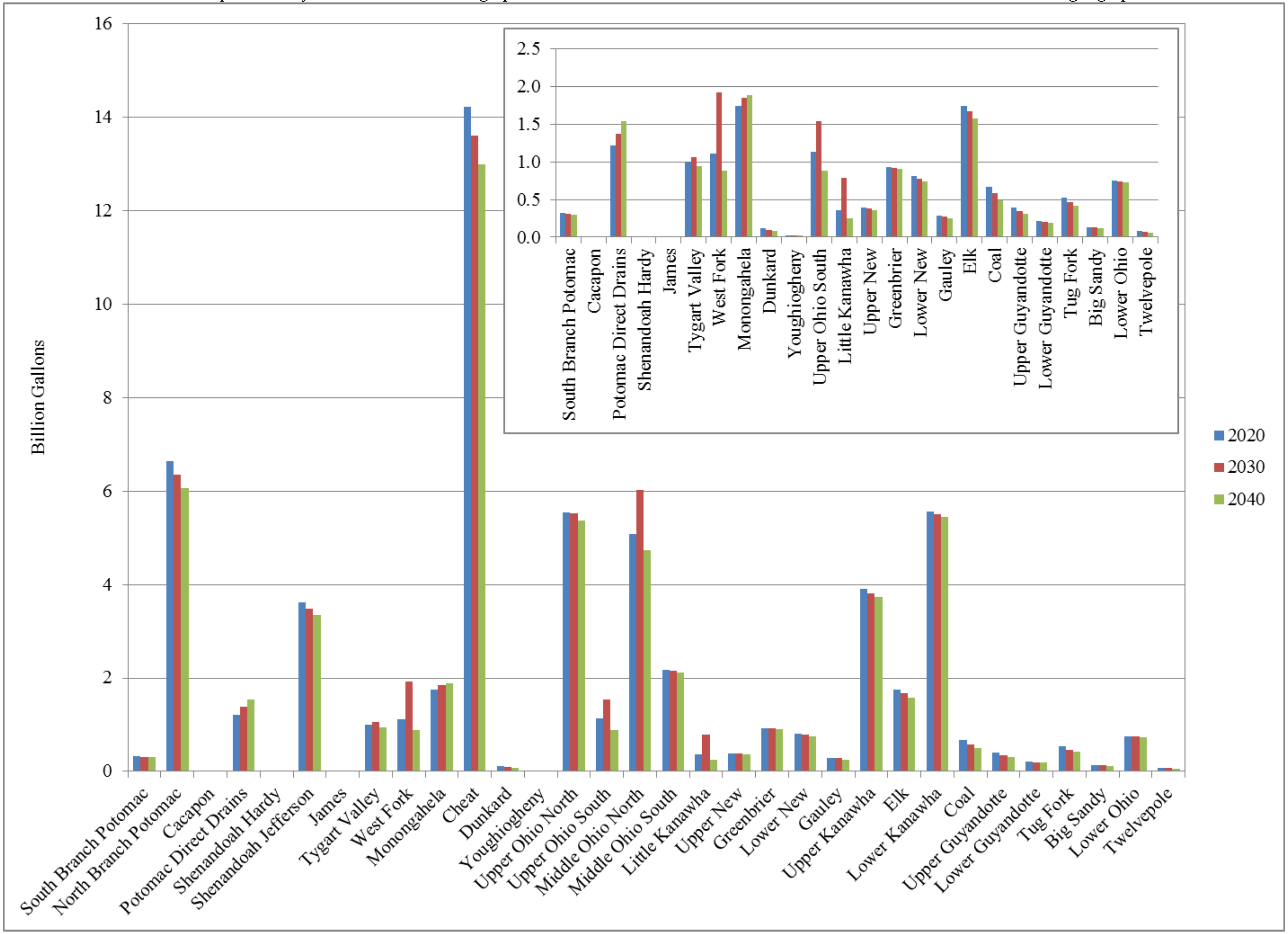


Table 15. High and low scenario consumptive use estimates by watershed.

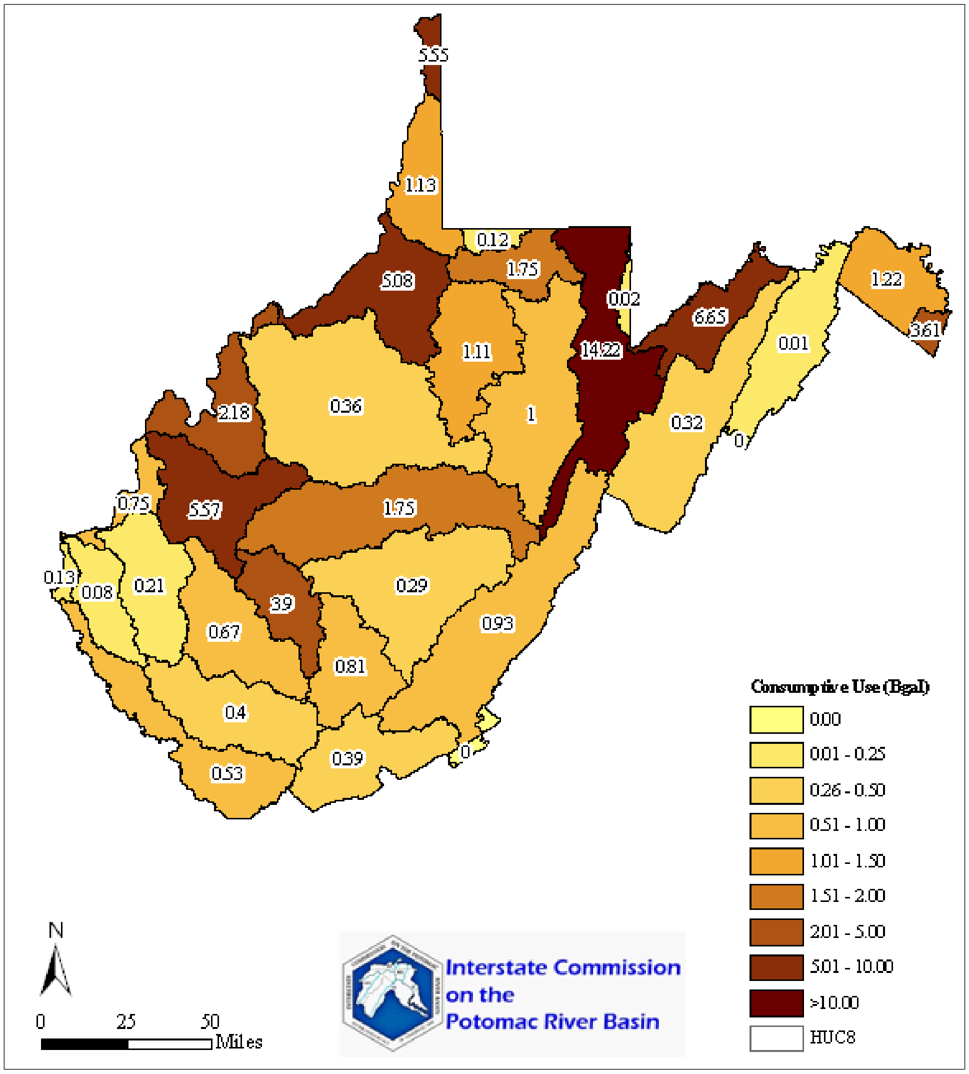
HUC8	HIGH Scenario Consumptive Use (Bgal)			LOW Scenario Consumptive Use (Bgal)		
	2020	2030	2040	2020	2030	2040
South Branch Potomac	0.42	0.42	0.42	0.32	0.31	0.30
North Branch Potomac	13.23	12.66	12.08	6.65	6.36	6.07
Cacapon	0.02	0.03	0.03	0.01	0.01	0.01
Potomac Direct Drains	1.68	1.97	2.27	1.22	1.38	1.54
Shenandoah Hardy	0.00	0.00	0.00	0.00	0.00	0.00
Shenandoah Jefferson	7.13	6.84	6.56	3.61	3.48	3.35
James	0.00	0.00	0.00	0.00	0.00	0.00
Tygart Valley	1.38	1.50	1.32	1.00	1.06	0.95
West Fork	2.25	3.77	1.65	1.11	1.92	0.89
Monongahela	2.74	2.90	2.97	1.75	1.85	1.89
Cheat	28.14	26.95	25.77	14.22	13.61	13.00
Dunkard	0.20	0.21	0.21	0.12	0.10	0.08
Youghiogheny	0.02	0.02	0.02	0.02	0.02	0.02
Upper Ohio North	8.33	9.65	10.96	5.55	5.52	5.37
Upper Ohio South	6.34	6.99	5.55	1.13	1.54	0.88
Middle Ohio North	8.85	11.68	10.30	5.08	6.03	4.73
Middle Ohio South	6.76	6.94	7.14	2.18	2.15	2.12
Little Kanawha	0.80	1.60	0.50	0.36	0.79	0.25
Upper New	0.52	0.50	0.48	0.39	0.38	0.36
Greenbrier	1.08	1.16	1.24	0.93	0.92	0.91
Lower New	1.07	1.05	1.03	0.81	0.78	0.74
Gauley	0.43	0.44	0.42	0.29	0.28	0.25
Upper Kanawha	8.96	9.67	10.52	3.90	3.81	3.73
Elk	2.35	2.26	2.13	1.75	1.67	1.58
Lower Kanawha	8.42	9.65	11.08	5.57	5.51	5.44
Coal	1.12	1.15	1.19	0.67	0.58	0.49
Upper Guyandotte	0.62	0.60	0.59	0.40	0.35	0.31
Lower Guyandotte	0.29	0.30	0.30	0.21	0.20	0.19
Tug Fork	0.78	0.75	0.71	0.53	0.47	0.42
Big Sandy	0.18	0.17	0.16	0.13	0.13	0.12
Lower Ohio	1.01	1.01	1.00	0.75	0.74	0.73
Twelvepole	0.12	0.13	0.13	0.08	0.07	0.06
TOTAL	115.24	122.95	118.73	60.74	62.02	56.78

Table 16. High and low scenario consumptive use estimates by water use category.

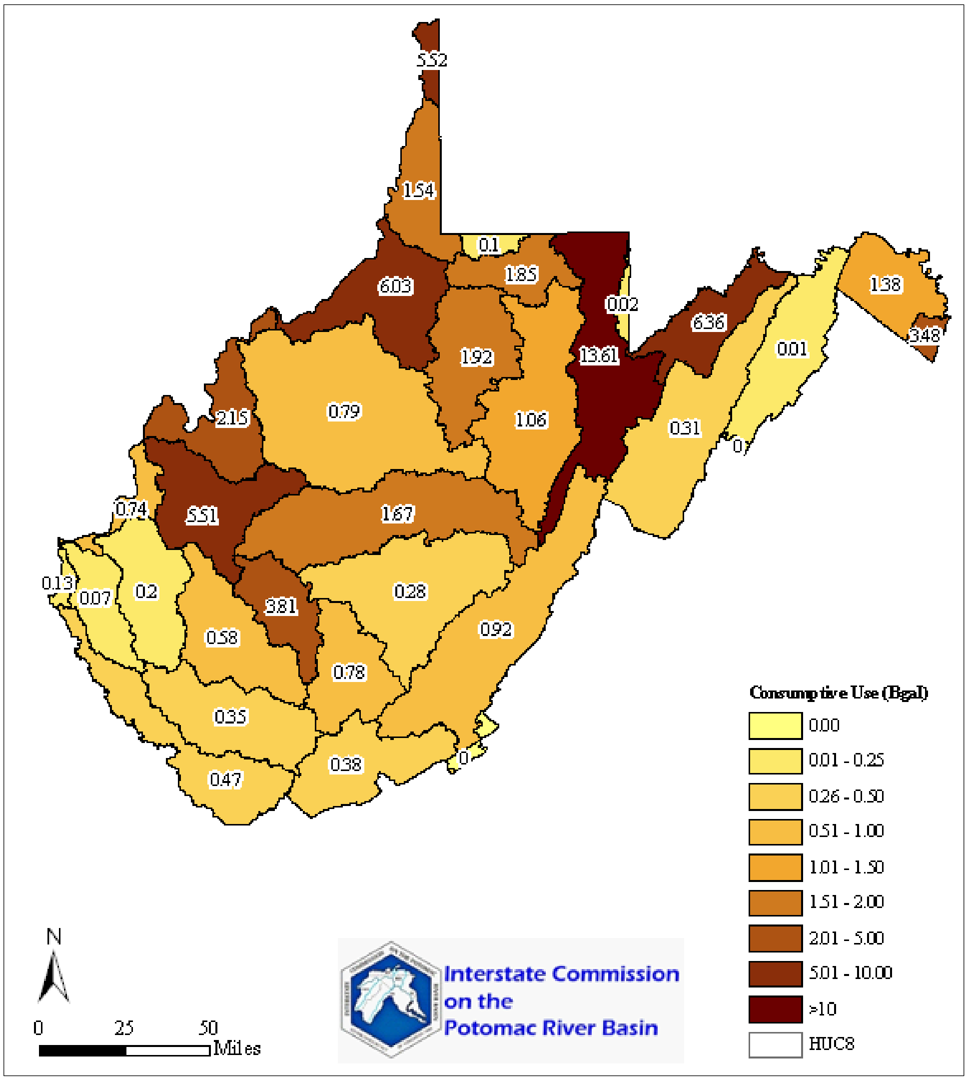
Water Use Category	HIGH Consumptive Use (Bgal)			LOW Consumptive Use (Bgal)		
	2020	2030	2040	2020	2030	2040
Manufacturing	30.18	35.02	40.65	20.15	19.93	19.72
Mining and Petroleum	3.42	3.56	3.71	2.00	1.67	1.40
Recreation	1.34	1.48	1.63	1.18	1.18	1.18
Thermoelectric	61.69	58.91	56.26	25.10	23.99	22.89
Public Water Supply	14.76	14.78	14.57	11.05	11.07	10.96
Marcellus Shale	3.85	9.20	1.92	1.26	4.18	0.63
TOTAL	115.24	122.95	118.73	60.74	62.02	56.78

Figure 16. Low scenario consumptive use projections for 2020 (a), 2030 (b), and 2040 (c).

(a) 2020



(b) 2030


5.52
1.54
0.1
1.85
6.03
0.02
6.36
1.38
3.48
0.01
1.92
13.61
0.79
2.15
1.06
0.31
0.74
5.51
1.67
0.13
0.07
0.2
0.28
3.81
0.58
0.92
0.78
0.35
0.38
0
0.47
Consumptive Use (Bgal)
0.00
0.01 - 0.25
0.26 - 0.50
0.51 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 5.00
5.01 - 10.00
>10
HUC8
N
0
25
50
Miles
Interstate Commission
on the
Potomac River Basin

(c) 2040

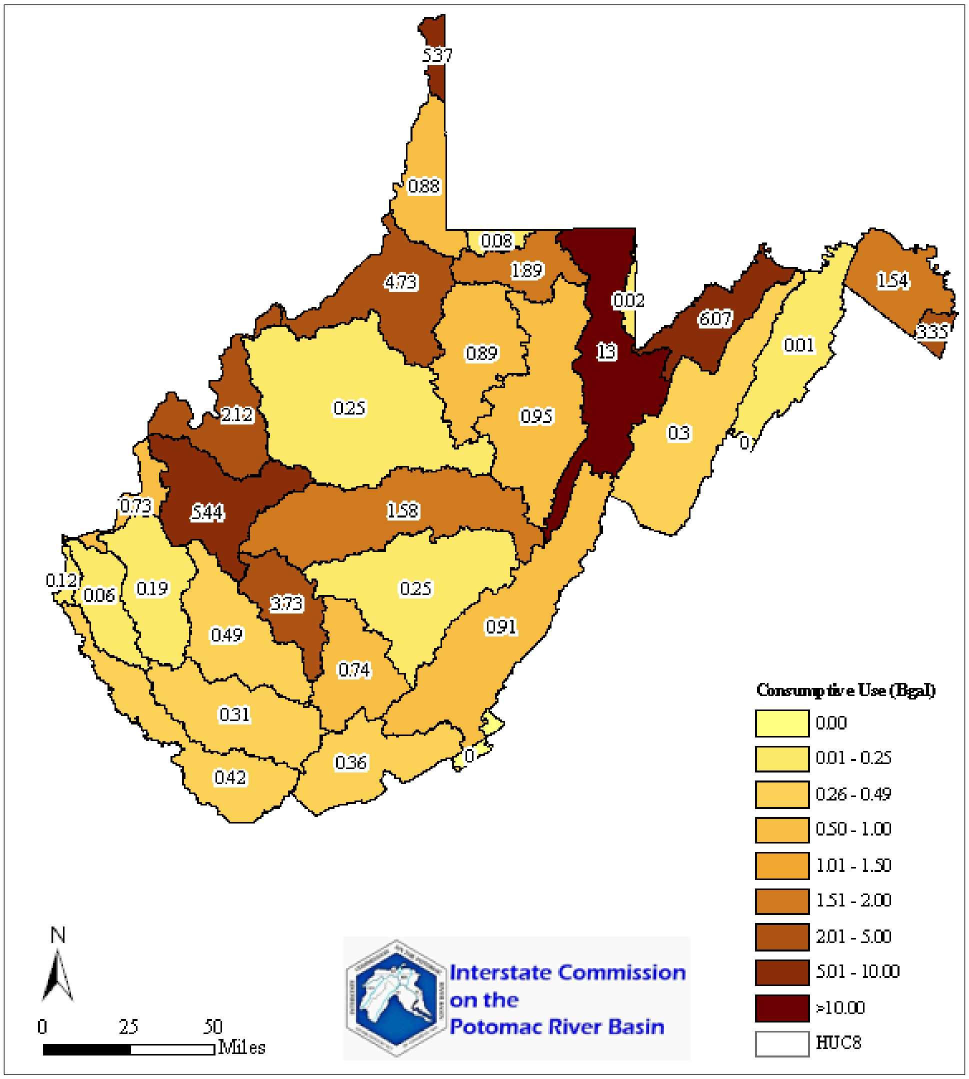
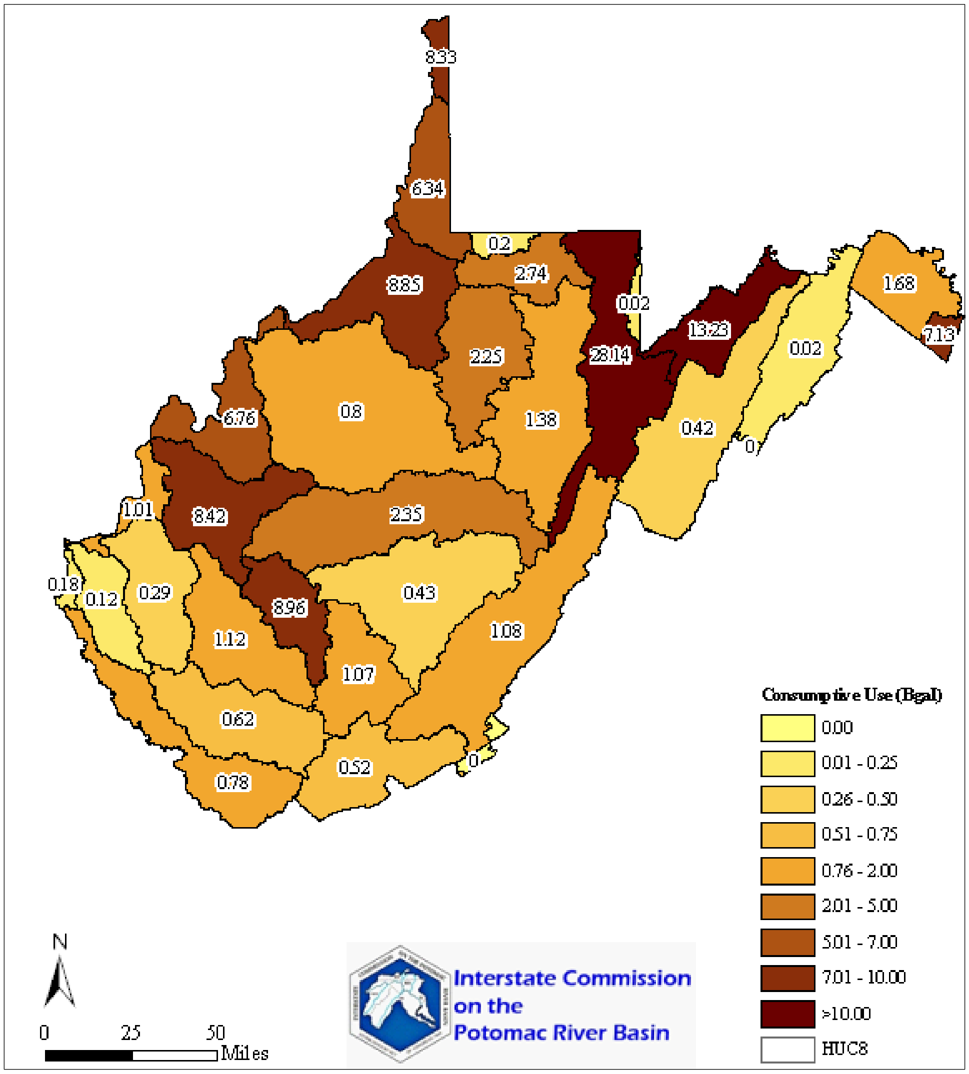
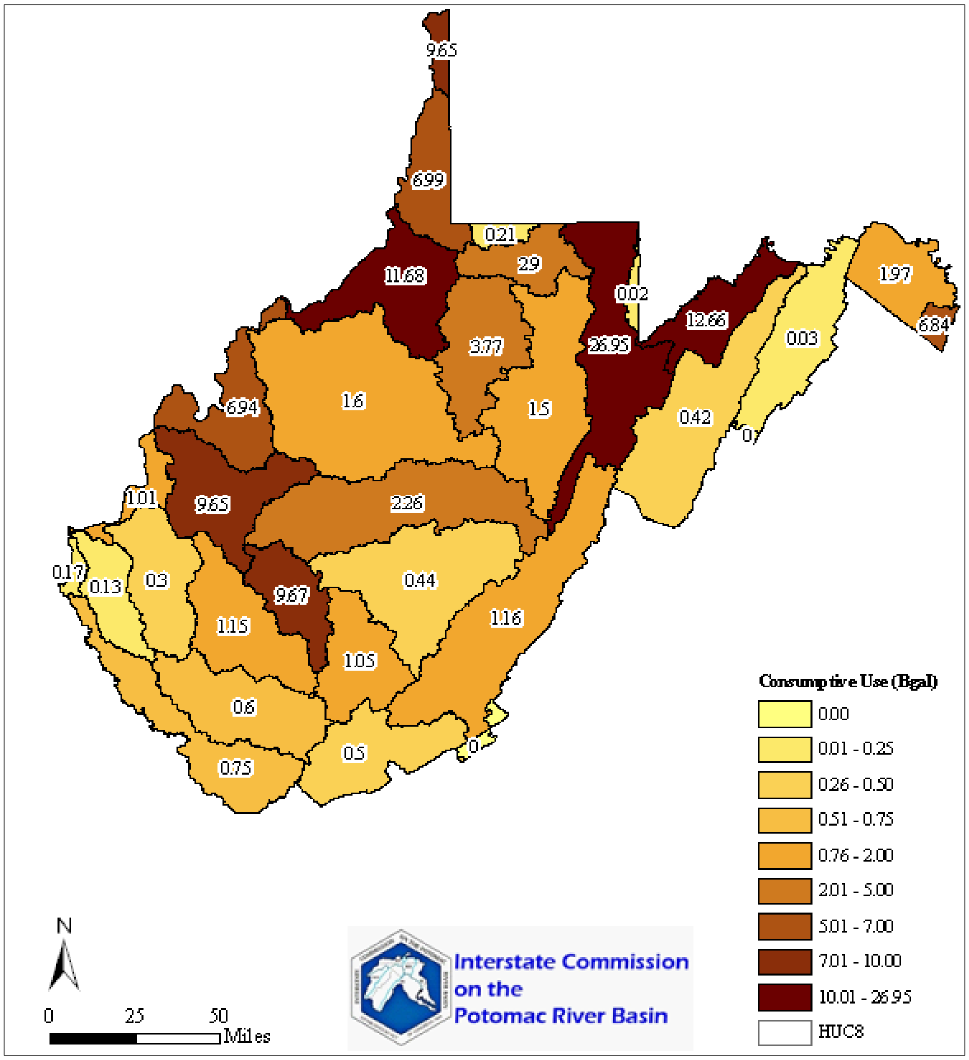

5.37
0.88
0.08
1.89
4.73
0.02
6.07
1.54
3.35
0.01
0.89
13
2.12
0.25
0.95
0.3
0
0.73
5.44
1.58
0.12
0.06
0.19
3.73
0.25
0.91
0.49
0.74
0.31
0.36
0
0.42
Consumptive Use (Bgal)
0.00
0.01 - 0.25
0.26 - 0.49
0.50 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 5.00
5.01 - 10.00
>10.00
HUC8
N
0
25
50
Miles
Interstate Commission
on the
Potomac River Basin

Figure 17. High consumptive use scenario projections for 2020 (a), 2030 (b), and 2040 (c).

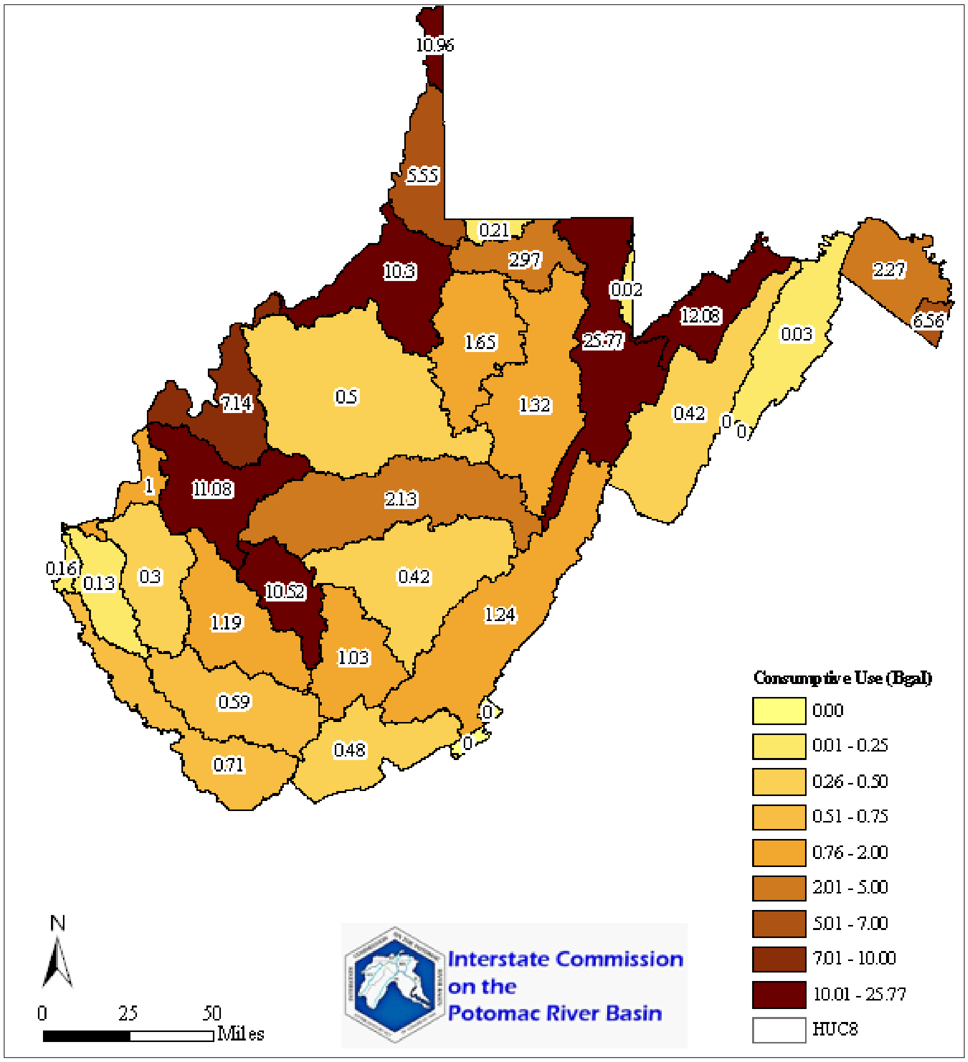
(a) 2020



(b) 2030

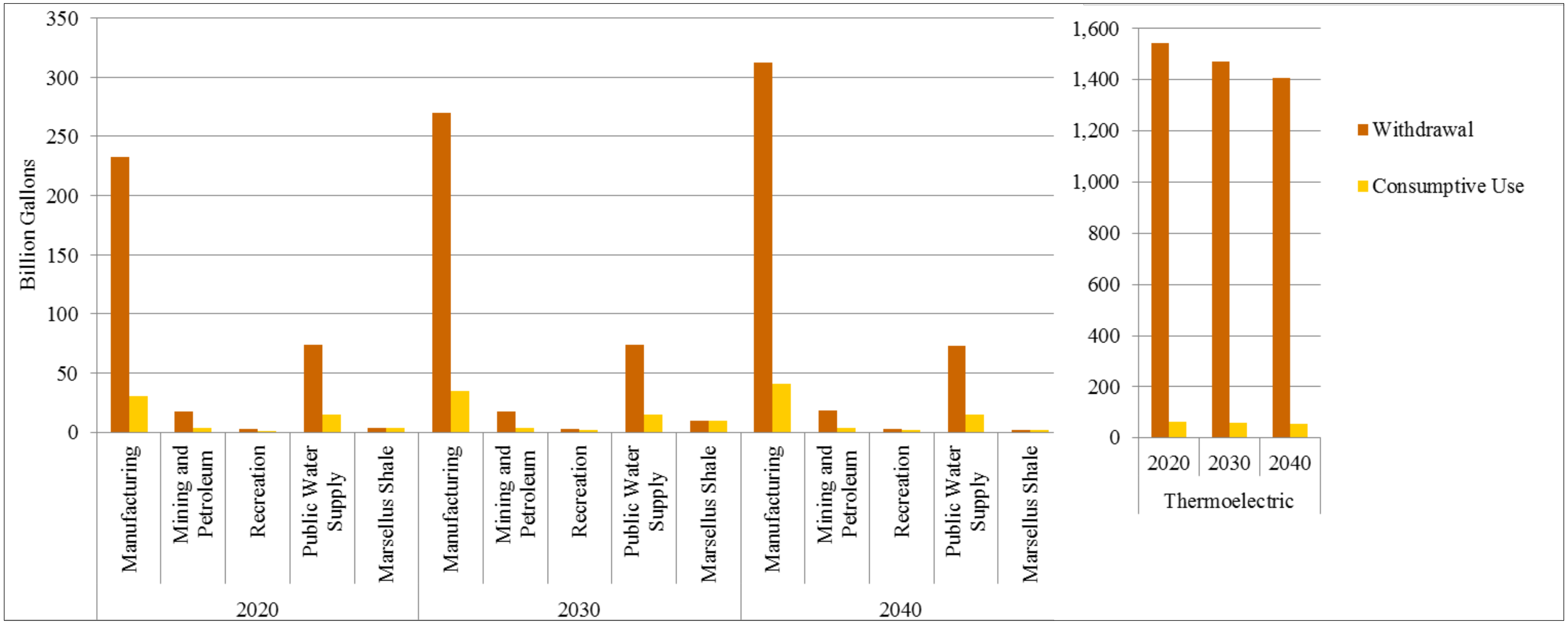

9.65
6.99
0.21
11.68
2.9
0.02
12.66
1.97
6.84
0.03
3.77
26.95
1.6
1.5
6.94
0.42
1.01
9.65
2.26
0.17
0.13
0.3
9.67
0.44
1.15
1.16
1.05
0.6
0.5
0.75
0
Consumptive Use (Bgal)
0.00
0.01 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 2.00
2.01 - 5.00
5.01 - 7.00
7.01 - 10.00
10.01 - 26.95
HUC8
N
0
25
50
Miles
Interstate Commission
on the
Potomac River Basin

(c) 2040



10.96
5.55
0.21
2.97
10.3
0.02
12.08
2.27
6.56
0.03
1.65
25.77
7.14
0.5
1.32
0.42
0
0
1
11.08
2.13
0.16
0.13
0.3
10.52
0.42
1.19
1.24
1.03
0.59
0
0
0.48
0.71
N
0
25
50
Miles
Interstate Commission
on the
Potomac River Basin
Consumptive Use (Bgal)
0.00
0.01 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 2.00
2.01 - 5.00
5.01 - 7.00
7.01 - 10.00
10.01 - 25.77
HUC8

Figure 18. Withdrawal and high consumptive use estimates for 2020, 2030, and 2040 by use type.



5 Effect of Drought and Climate Change on Consumptive Use

Forecasting withdrawals and consumptive use under normal or average conditions is difficult. Forecasts become even more complicated under drought and climate change conditions. The simplest way to think about these complications is that under warmer and drier conditions both water withdrawals and consumptive use are likely to increase. Water withdrawals are known to increase as temperatures increase. People use more water on outdoor landscaping and there is a greater demand on electricity supplies to run cooling systems. Additionally, warmer and drier conditions cause a higher rate of evaporation and transpiration by plants. Even under non-drought conditions, withdrawals typically rise during the summer months. To the extent that drought and climate change cause warmer and drier conditions, consumptive use will rise.

The impact of climate change on consumptive use is highly dependent on the specific changes that will be experienced in West Virginia. Globally and in the Mid-Atlantic and Northeast regions, temperatures have been increasing and are expected to continue to do so (IPCC 2007; Ahmed et al. forthcoming). While the global climate models are being downscaled to better represent regional conditions and anticipated changes, there is still much uncertainty as to whether specific areas of the United States will receive more or less rainfall (Ahmed et al. forthcoming). The changes that are actually experienced in West Virginia will determine the magnitude of the impact that climate change has on consumptive use.

Consumptive use in some sectors is more likely to be affected by droughts and potential warmer and drier conditions under climate change. 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 greater demand for electricity, but the rate would remain at the same level. 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.

These predictions assume that withdrawals are conducted without any management or policy changes. 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 a moderate drought under climate change conditions. It also shows that if voluntary and mandatory restrictions on use are implemented, total withdrawals drop 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 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.

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Appendix A

Withdrawals by use type and watershed from the Large Quantity User database.

Gaps in the LQU database are filled in using the assumptions explained in **Table 2**. Results are shown in hundredths of billion gallons for display purposes. Withdrawals less than 0.01 billion gallons are represented as "<0.01" in the table. The actual value in gallons is reported below the table. Zeros ("0.00") indicate a reported zero in the LQU database. A "C" means that all intakes in that watershed or county were closed in that year. 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 rounding.

Table A-1. Mining withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Mining Withdrawals

HUC8	Withdrawals - Mining (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
South Branch Potomac	0.02	0.02	0.02	0.04	0.02	0.04	0.04
Potomac Direct Drains	0.41	0.40	0.36	0.39	0.39	0.39	0.39
Tygart Valley	0.01	0.01	0.03	0.23	0.03	0.04	0.28
West Fork	0.16	0.19	0.19	0.19	0.23	0.23	0.23
Monongahela	0.19	0.40	0.39	0.33	0.36	0.33	0.31
Cheat	0.01	0.01	<0.01[1]	0.01	0.01	C	C
Dunkard	0.59	0.61	0.53	0.65	0.60	0.60	0.60
Upper Ohio South	1.21	1.21	1.13	1.17	1.40	1.38	1.39
Lower New	0.00	0.00	0.00	0.15	0.15	0.17	0.21
Gauley	0.67	0.64	0.67	0.84	0.81	0.60	0.56
Upper Kanawha	0.96	0.96	0.96	1.07	1.55	3.27	3.29
Elk	0.19	0.20	0.22	0.20	0.25	0.22	0.22
Coal	3.77	3.93	4.08	5.00	5.01	4.48	3.72
Upper Guyandotte	1.34	1.35	1.47	1.50	1.42	1.56	1.52
Lower Guyandotte	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Tug Fork	1.13	1.08	1.36	1.23	1.05	0.94	0.83
Big Sandy	<0.01[2]	<0.01[3]	<0.01[4]	0.00	<0.01[5]	<0.01[6]	C
Lower Ohio	0.04	0.03	0.04	0.01	<0.01[7]	<0.01[8]	<0.01[9]
Twelvepole	0.28	0.33	0.34	0.19	0.31	0.23	0.24
TOTAL	11.15	11.54	11.96	13.37	13.76	14.65	14.00

[1] 4,568,115 gallons, [2] 3,207,266 gallons, [3] 2,140,756 gallons, [4] 2,628,974 gallons, [5] 1,589,910 gallons, [6] 1,296,000 gallons, [7] 3,175,300 gallons, [8] 1,496,000 gallons, [9] 990,000 gallons

(b) County Mining Withdrawals

County	Withdrawals - Mining (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Barbour	C	C	C	C	0.01	0.02	0.22
Boone	3.16	3.31	3.38	3.52	3.52	2.97	2.76
Clay	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Fayette	0.23	0.23	0.23	0.23	0.23	0.25	0.25
Harrison	0.16	0.19	0.19	0.19	0.23	0.23	0.23
Kanawha	0.77	0.78	0.79	0.89	1.37	3.07	3.09
Logan	0.64	0.67	0.72	1.51	1.49	1.51	1.49
Marion	0.11	0.34	0.29	0.27	0.27	0.27	0.27
Marshall	1.21	1.21	1.13	1.17	1.40	1.38	1.39
McDowell	0.38	0.38	0.36	0.35	0.20	0.13	0.14
Mingo	0.76	0.72	1.08	1.03	0.92	0.89	0.77
Monongalia	0.67	0.67	0.63	0.72	0.69	0.66	0.64
Morgan	0.41	0.40	0.36	0.39	0.39	0.39	0.39
Nicholas	0.51	0.49	0.41	0.51	0.52	0.34	0.34
Pendleton	0.02	0.02	0.02	0.04	0.02	0.04	0.04
Preston	0.01	0.01	<0.01[1]	0.21	C	C	C
Raleigh	1.05	1.07	1.07	1.23	1.26	1.27	0.77
Randolph	0.01	0.01	0.03	0.03	0.02	0.02	0.03
Upshur	C	C	C	C	<0.01[2]	0.01	0.03
Wayne	0.32	0.36	0.38	0.20	0.32	0.23	0.24
Webster	0.19	0.20	0.32	0.37	0.38	0.33	0.30
Wyoming	0.37	0.34	0.41	0.36	0.36	0.50	0.48
TOTAL	11.13	11.55	11.95	13.37	13.75	14.66	14.02

[1] 4,568,115 gallons, [2] 4,865,000 gallons

Table A-2. Petroleum withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Petroleum Withdrawals

HUC8	Withdrawals - Petroleum (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
West Fork	0.03	0.02	0.02	0.02	0.04	0.04	0.03
Upper Ohio North	0.25	0.25	0.32	0.30	0.34	0.39	0.37
Upper Ohio South	0.14	0.27	0.21	0.09	0.04	0.03	0.08
Middle Ohio North	0.21	0.19	0.14	0.29	0.26	0.21	0.19
TOTAL	0.63	0.73	0.69	0.70	0.68	0.67	0.67

(b) County Petroleum Withdrawals

County	Withdrawals - Petroleum (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Brooke	0.08	0.08	0.08	0.09	0.09	0.14	0.10
Hancock	0.16	0.17	0.24	0.20	0.25	0.25	0.27
Harrison	0.03	0.02	0.02	0.02	0.04	0.04	0.03
Marshall	0.14	0.27	0.21	0.09	0.04	0.03	0.08
Pleasants	0.08	0.04	0.03	0.05	0.05	C	C
Wetzel	0.13	0.14	0.11	0.24	0.21	0.21	0.19
TOTAL	0.62	0.72	0.69	0.69	0.68	0.67	0.67

Table A-3. Recreation withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Recreation Withdrawals

HUC8	Withdrawals - Recreation (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
South Branch Potomac	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cacapon	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Potomac Direct Drains	0.06	0.06	0.03	0.04	0.04	0.04	0.04
Shenandoah Jefferson	0.00	0.02	0.07	0.05	0.04	0.04	0.04
West Fork	0.02	0.03	0.04	0.04	0.04	0.04	0.03
Monongahela	C	C	C	0.02	0.02	0.02	<0.01[1]
Cheat	0.43	0.44	0.52	0.46	0.50	0.49	0.38
Upper Ohio North	0.07	0.07	0.08	0.11	0.09	0.09	0.09
Middle Ohio South	<0.01[2]	0.01	0.01	0.01	0.01	0.01	0.01
Greenbrier	0.86	0.86	0.87	0.86	0.99	0.68	0.68
Lower New	0.11	0.12	0.18	0.21	0.17	0.18	0.17
Elk	0.01	<0.01[3]	0.01	0.01	0.01	0.01	0.01
Lower Kanawha	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Tug Fork	<0.01[4]	<0.01[5]	<0.01[6]	<0.01[7]	<0.01[7]	<0.01[7]	<0.01[7]
TOTAL	1.59	1.64	1.84	1.84	1.94	1.63	1.48

[1] 4,785,744 gallons, [2] 3,699,500 gallons, [3] 4,551,913 gallons, [4] 2,775,500 gallons, [5] 2,630,000 gallons, [6] 2,750,000 gallons, [7] 2,718,500 gallons

(b) County Recreation Withdrawals

County	Withdrawals - Recreation (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Berkeley	0.05	0.04	0.02	0.03	0.03	0.03	0.03
Greenbrier	0.86	0.86	0.87	0.86	0.99	0.68	0.68
Hampshire	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Hancock	0.07	0.07	0.08	0.11	0.09	0.09	0.09
Hardy	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Jefferson	0.02	0.03	0.08	0.06	0.06	0.06	0.06
Kanawha	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lewis	0.02	0.03	0.04	0.04	0.04	0.04	0.03
Mingo	<0.01[1]	<0.01[2]	<0.01[3]	<0.01[4]	<0.01[5]	<0.01[6]	<0.01[7]
Monongalia	C	C	C	0.02	0.02	0.02	<0.01[8]
Pocahontas	0.43	0.44	0.52	0.46	0.50	0.50	0.38
Preston	<0.01[9]	<0.01[10]	<0.01[11]	<0.01[12]	<0.01[13]	<0.01[14]	<0.01[15]
Raleigh	0.11	0.12	0.18	0.21	0.17	0.18	0.17
Wood	<0.01[16]	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL	1.59	1.63	1.83	1.83	1.94	1.64	1.48

[1] 2,775,500 gallons, [2] 2,630,000 gallons, [3] 2,750,000 gallons, [4] 2,718,500 gallons, [5] 2,718,500 gallons, [6] 2,718,500 gallons, [7] 2,718,500 gallons, [8] 4,785,744 gallons, [9] 3,216,900 gallons, [10] 3,179,800 gallons, [11] 3,582,800 gallons, [12] 3,326,500 gallons, [13] 3,326,500 gallons, [14] 3,326,500 gallons, [15] 3,949,520 gallons, [16] 3,699,500 gallons

Table A-4. Timber withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Timber Withdrawals

HUC8	Withdrawals - Timber (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Shenandoah Jefferson	0.04	0.04	0.05	0.04	0.06	0.05	0.04
Monongahela	1.19	1.21	1.13	1.16	1.17	1.17	1.17
Cheat	0.16	0.16	0.16	0.02	0.02	0.02	0.03
Upper Ohio South	0.10	0.07	0.07	C	C	C	C
Greenbrier	0.02	0.02	0.02	0.02	0.02	C	C
Total	1.51	1.50	1.43	1.24	1.27	1.24	1.24

(b) County Timber Withdrawals

County	Withdrawals - Timber (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Brooke	0.10	0.07	0.07	C	C	C	C
Greenbrier	0.02	0.02	0.02	0.02	0.02	C	C
Jefferson	0.04	0.04	0.05	0.04	0.06	0.05	0.04
Marion	1.19	1.21	1.13	1.16	1.17	1.17	1.17
Tucker	0.16	0.16	0.16	0.02	0.02	0.02	0.03
TOTAL	1.51	1.50	1.43	1.24	1.27	1.24	1.24

Table A-5. Agriculture/Aquaculture withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Agriculture/Aquaculture Withdrawals

HUC8	Withdrawals – Agriculture/Aquaculture (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
South Branch Potomac	2.33	2.33	2.33	2.33	2.33	2.33	2.33
Potomac Direct Drains	0.91	0.99	0.94	1.29	0.88	0.86	0.91
Cheat	1.63	1.63	1.63	1.63	1.63	1.63	1.63
Upper Ohio South	0.03	0.02	0.03	C	C	C	C
Little Kanawha	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Upper New	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Greenbrier	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Upper Guyandotte	0.17	0.17	0.17	0.17	C	C	C
Lower Ohio	0.13	0.13	0.13	0.13	0.19	0.13	0.13
TOTAL	5.82	5.89	5.85	6.17	5.65	5.57	5.62

(b) County Agriculture/Aquaculture Withdrawals

County	Withdrawals - Agriculture/Aquaculture (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Cabell	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Grant	1.87	1.87	1.87	1.87	1.87	1.87	1.87
Jefferson	0.68	0.75	0.71	1.06	0.64	0.62	0.67
Logan	0.17	0.17	0.17	0.17	C	C	C
Mason	0.11	0.11	0.11	0.11	0.17	0.11	0.11
Mercer	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Morgan	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Ohio	0.03	0.02	0.03	C	C	C	C
Pendleton	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Pocahontas	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Randolph	1.63	1.63	1.63	1.63	1.63	1.63	1.63
Wirt	0.08	0.08	0.08	0.08	0.08	0.08	0.08
TOTAL	5.83	5.89	5.86	6.18	5.65	5.57	5.62

Table A-6. Public Water Supply withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Public Water Supply Withdrawals

HUC8	Withdrawals - Public Water Supply (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
South Branch Potomac	1.82	2.00	2.05	1.98	1.93	1.94	1.94
North Branch Potomac	0.52	0.52	0.55	0.75	0.68	0.81	0.78
Cacapon	0.06	0.06	0.06	0.06	0.06	0.07	0.06
Potomac Direct Drains	4.26	5.20	4.09	4.88	4.52	4.48	4.35
Shenandoah Jefferson	0.56	0.62	0.65	0.84	0.73	0.79	0.76
Tygart Valley	5.55	6.10	5.86	6.25	5.81	6.14	6.20
West Fork	3.14	3.18	3.05	3.14	3.13	3.11	3.08
Monongahela	7.60	7.45	7.47	7.51	7.44	3.74	3.74
Cheat	0.62	0.66	0.69	0.78	0.75	0.75	0.75
Youghiogheny	0.10	0.12	0.12	0.10	0.10	0.10	0.07

HUC8	Withdrawals - Public Water Supply (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Upper Ohio North	1.75	2.03	1.94	1.92	1.93	2.00	2.03
Upper Ohio South	3.90	3.86	3.98	3.88	3.96	3.94	3.99
Middle Ohio North	1.42	1.47	1.53	1.52	1.50	1.42	1.44
Middle Ohio South	3.64	3.67	3.55	3.42	3.50	3.54	8.42
Little Kanawha	1.07	1.14	1.14	1.14	1.21	1.22	1.23
Upper New	2.49	2.51	2.69	2.84	2.60	2.64	2.61
Greenbrier	1.09	1.12	1.25	1.28	1.24	1.28	1.31
Lower New	4.21	4.27	4.41	4.57	4.32	4.42	4.40
Gauley	1.14	1.08	1.19	1.21	1.26	1.26	1.28
Upper Kanawha	1.27	1.30	1.23	1.27	1.27	1.27	1.27
Elk	12.09	12.00	11.92	11.93	12.06	12.04	12.05
Lower Kanawha	0.90	0.81	0.85	0.98	0.88	0.88	0.88
Coal	0.36	0.61	0.68	0.63	0.63	0.67	0.67
Upper Guyandotte	1.43	1.44	1.41	1.34	1.35	1.34	1.34
Lower Guyandotte	0.83	0.91	0.89	1.65	1.07	1.07	1.04
Tug Fork	2.60	2.49	2.63	2.82	2.31	2.72	2.77
Big Sandy	0.83	0.92	0.96	0.90	0.76	0.76	0.76
Lower Ohio	4.74	4.67	4.90	4.80	4.80	5.02	5.05
Twelvepole	0.19	0.20	0.22	0.21	0.21	0.21	0.21
TOTAL	70.18	72.41	71.96	74.60	72.01	69.63	74.48

(b) County Public Water Supply Withdrawals

County	Withdrawals - Public Water Supply (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Barbour	0.40	0.35	0.42	0.47	0.50	0.49	0.49
Berkeley	3.86	4.70	3.59	4.35	4.07	4.05	3.95
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	0.70	0.66	0.73	0.69	0.72	0.78	0.79
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	2.19	1.94	2.02	2.03
Gilmer	0.14	0.20	0.22	0.19	0.22	0.24	0.23
Grant	0.39	0.38	0.38	0.39	0.35	0.35	0.35
Greenbrier	1.09	1.11	1.24	1.32	1.25	1.30	1.35
Hampshire	0.21	0.19	0.21	0.23	0.21	0.24	0.22
Hancock	1.37	1.67	1.52	1.53	1.52	1.52	1.55
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	0.67
Jefferson	0.74	0.85	0.94	1.11	0.99	1.04	1.00
Kanawha	12.19	12.41	12.34	12.27	12.27	12.32	12.30
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

County	Withdrawals - Public Water Supply (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Logan	1.28	1.37	1.29	2.17	1.58	1.53	1.53
Marion	2.79	2.74	2.83	3.24	2.85	3.03	3.10
Marshall	1.05	1.08	1.17	1.09	1.16	1.14	1.18
Mason	0.80	0.83	0.85	0.92	0.99	1.16	1.21
McDowell	0.94	0.91	0.91	0.98	1.03	1.00	0.96
Mercer	1.49	1.45	1.69	1.64	1.51	1.51	1.51
Mineral	0.44	0.44	0.47	0.67	0.60	0.73	0.71
Mingo	1.36	1.34	1.36	1.57	1.03	1.44	1.49
Monongalia	7.34	7.18	7.19	7.24	7.24	3.62	3.62
Monroe	0.17	0.16	0.18	0.26	0.27	0.31	0.31
Morgan	0.23	0.29	0.22	0.27	0.21	0.20	0.17
Nicholas	0.86	0.81	0.90	0.85	0.91	0.90	0.92
Ohio	2.49	2.45	2.48	2.47	2.47	2.47	2.47
Pendleton	0.14	0.16	0.13	0.14	0.14	0.13	0.13
Pleasants	0.21	0.26	0.25	0.23	0.23	0.23	0.23
Pocahontas	0.13	0.12	0.13	0.16	0.18	0.18	0.17
Preston	0.57	0.63	0.67	0.71	0.66	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	1.17	1.17
Ritchie	0.14	0.16	0.15	0.15	0.16	0.16	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	0.69
Tucker	0.26	0.26	0.26	0.28	0.26	0.28	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	1.07	1.08
Webster	0.16	0.16	0.16	0.17	0.17	0.16	0.16
Wetzel	0.65	0.62	0.65	0.66	0.66	0.67	0.67
Wood	3.19	3.20	3.05	2.88	2.84	2.87	7.75
Wyoming	0.67	0.65	0.71	0.53	0.52	0.59	0.60
TOTAL	70.18	72.44	71.96	74.57	71.98	69.60	74.45

Table A-7. Industrial withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Industrial Withdrawals

HUC8	Withdrawals - Industrial (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
North Branch Potomac	0.05	0.07	0.07	0.07	0.10	0.10	0.10
Potomac Direct Drains	3.79	3.81	3.85	3.70	3.70	1.37	1.37
Upper Ohio North	55.89	55.80	44.64	64.00	66.05	61.52	63.32
Upper Ohio South	0.25	0.23	0.22	0.23	0.23	0.13	0.13
Middle Ohio South	0.77	0.81	0.89	0.76	0.65	0.17	0.10
Upper New	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Upper Kanawha	9.49	9.49	9.49	9.49	2.22	2.20	2.21
Lower Guyandotte	0.27	0.24	0.25	0.28	0.25	0.26	0.30
TOTAL	70.53	70.47	59.43	78.55	73.22	65.77	67.55

(b) County Industrial Withdrawals

County	Withdrawals - Industrial (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Berkeley	3.69	3.69	3.69	3.69	3.69	1.36	1.36
Brooke	2.42	2.41	2.13	5.84	1.54	1.73	2.95
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	58.37	64.72	59.90	60.48
Jackson	0.77	0.81	0.89	0.76	0.65	0.17	0.10
Jefferson	0.10	0.12	0.16	0.01	0.01	0.01	0.01
Marshall	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mineral	0.05	0.07	0.07	0.07	0.10	0.10	0.10
Monroe	0.02	0.02	0.02	0.02	0.02	0.02	0.02
TOTAL	70.52	70.47	59.44	78.55	73.22	65.77	67.55

Table A-8. Chemical withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Chemical Withdrawals

HUC8	Withdrawals – Chemical (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Upper Ohio South	0.12	0.07	0.07	0.09	0.09	0.07	0.07
Middle Ohio North	59.80	59.65	59.44	58.58	46.07	46.40	45.92
Middle Ohio South	16.98	16.98	19.53	17.83	17.61	17.61	17.77
Upper Kanawha	35.74	35.84	35.84	37.42	37.32	37.32	37.32
Lower Kanawha	66.82	69.72	65.60	67.29	62.13	67.62	64.68
Big Sandy	0.16	0.09	0.10	0.08	0.09	0.06	0.07
Lower Ohio	0.37	0.35	0.38	0.34	0.26	0.29	0.29
TOTAL	179.99	182.70	180.96	181.63	163.57	169.37	166.12

(b) County Chemical Withdrawals

County	Withdrawals - Chemical (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Kanawha	102.56	105.56	101.44	104.71	99.45	104.94	102.00
Marshall	55.55	55.47	55.38	55.33	42.67	42.90	42.75
Mason	0.37	0.35	0.38	0.34	0.26	0.29	0.29
Pleasants	1.94	2.14	2.16	1.36	1.32	1.50	1.33
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	17.61	17.61	17.77
TOTAL	180.00	182.70	180.96	181.63	163.58	169.37	166.12

Table A-9. Thermoelectric withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Thermoelectric Withdrawals

HUC8	Withdrawals - Thermoelectric (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
North Branch Potomac	383.18	421.41	405.03	403.22	403.22	403.21	403.20
Shenandoah Jefferson	C	C	C	C	161.35	156.68	213.43
West Fork	14.15	14.44	13.57	14.47	12.23	14.76	13.69
Monongahela	53.69	43.70	40.32	35.95	30.99	33.08	30.95
Cheat	53.97	38.39	50.76	29.81	584.40	448.77	852.59
Upper Ohio South	206.63	204.09	199.56	182.30	129.00	115.13	141.15
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
Upper Kanawha	134.31	125.59	128.27	129.39	96.06	71.06	94.83
Lower Kanawha	16.87	14.95	15.01	15.61	15.61	13.27	13.27
TOTAL	1,308.60	1,284.23	1,260.11	1,229.70	1,714.05	1,503.09	1,901.60

(b) County Thermoelectric Withdrawals

County	Withdrawals - Thermoelectric (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Grant	383.18	421.41	405.03	403.22	403.22	403.21	403.20
Harrison	14.15	14.44	13.57	14.47	12.23	14.76	13.69
Jefferson	C	C	C	C	161.35	156.68	213.43
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	612.91	479.57	882.25
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	13.27
TOTAL	1,308.60	1,284.23	1,260.12	1,229.70	1,714.05	1,503.09	1,901.61

Table A-10. Hydroelectric withdrawals from the LQU database by watershed (a) and by county (b).

(a) Watershed Hydroelectric Withdrawals

HUC8	Withdrawals - Hydroelectric (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Middle Ohio North	C	C	C	C	4,787.22	4,015.59	4,490.78
Middle Ohio South	C	C	C	C	111,683.55	111,683.55	111,683.55
Lower New	2,001.51	1,916.13	1,498.50	1,805.38	1,630.85	1,309.32	1,470.09
Gauley	C	C	C	C	339.24	278.21	360.83
Upper Kanawha	C	C	C	C	2,847.40	2,121.90	2,363.76
Lower Kanawha	C	C	C	C	1,920.80	1,458.20	1,277.51
TOTAL	2,001.51	1,916.13	1,498.50	1,805.38	123,209.06	120,866.77	121,646.52

(b) County Hydroelectric Withdrawals

County	Withdrawals - Hydroelectric (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Fayette	2,001.51	1,916.13	1,498.50	1,805.38	1,630.85	1,309.32	1,470.09
Kanawha	C	C	C	C	2,847.40	2,121.90	2,363.76
Nicholas	C	C	C	C	339.24	278.21	360.83
Putnam	C	C	C	C	1,920.80	1,458.20	1,277.51
Wetzel	C	C	C	C	4,787.22	4,015.59	4,490.78
Wood	C	C	C	C	111,683.55	111,683.55	111,683.55
TOTAL	2,001.51	1,916.13	1,498.50	1,805.38	123,209.06	120,866.77	121,646.52

Appendix B

Marcellus Shale withdrawals and consumptive use methods and estimates.

<u>Marcellus Shale Watershed Withdrawal and Consumptive Use Method</u>

Past withdrawal by HUC8

1. Sum past and planned withdrawals by HUC8 to estimate withdrawals between 2009 and 2015.

Average per well withdrawal by HUC8

2. Sum past withdrawals by well pad.
3. Divide total past withdrawal from step 2 by the number of wells on the pad to estimate the withdrawal per well.
4. Combine the DEP lists of past withdrawals by well (step 3) and planned well withdrawals.
    a. Calculate average withdrawal per well.

Future (2020) withdrawals by HUC8

5. Estimate number of wells in West Virginia in 2020 (Considine 2010).
    a. High scenario – 752
    b. Low scenario – 273
6. Multiply estimated number of wells in 2020 (step 5) by the average withdrawal per well (step 4a).
7. Divide withdrawal by HUC8 (step 1) by the total withdrawal in the Marcellus Shale category to get proportion of the total withdrawal in a given HUC8.
8. Multiply 2020 estimated total withdrawals by each HUC8's percentage to get withdrawal estimate by HUC8.

Future (2030) withdrawals by HUC8

9. High scenario – Divide past HUC8 withdrawals (step 1) by 5.
10. Low scenario – Divide past HUC8 withdrawals (step 1) by 10.

Future (2040) withdrawals by HUC8

11. High scenario – Divide 2020 high scenario HUC8 projections by 2.
12. Low scenario – Divide 2020 low scenario HUC8 projections by 2.

Future consumptive use estimates by HUC8

13. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficient.
    a. High scenario – Multiply high scenario withdrawals by 100%
14. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficient.
    a. Low scenario – Multiply low scenario withdrawals by 91%

<u>Marcellus Shale County Withdrawal and Consumptive Use Method</u>

Past withdrawal by county

1. Sum past and planned withdrawals by county to estimate withdrawals between 2009 and 2015.

Average per well withdrawal by county

2. Sum past withdrawals by well pad.
3. Divide total past withdrawal from step 2 by the number of wells on the pad to estimate the withdrawal per well.
4. Combine the DEP lists of past withdrawals by well (step 3) and planned well withdrawals.
   a. Calculate average withdrawal per well.

Future (2020) withdrawals by county

5. Estimate number of wells in West Virginia in 2020 (Considine 2010).
   a. High scenario – 752
   b. Low scenario – 273
6. Multiply estimated number of wells in 2020 (step 5) by the average withdrawal per well (step 4a).
7. Divide withdrawal by county (step 1) by the total withdrawal in the Marcellus Shale category to get proportion of the total withdrawal in a given county.
8. Multiply 2020 estimated total withdrawals by each county's percentage to get withdrawal estimate by county.

Future (2030) withdrawals by county

9. High scenario – Divide past county withdrawals (step 1) by 5.
10. Low scenario – Divide past county withdrawals (step 1) by 10.

Future (2040) withdrawals by county

11. High scenario – Divide 2020 high county scenario projections by 2.
12. Low scenario – Divide 2020 low county scenario projections by 2.

Future consumptive use estimates by county

13. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. High scenario – Multiply high scenario withdrawals by 100%
14. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. Low scenario – Multiply low scenario withdrawals by 91%

Table B-1. Marcellus Shale withdrawals and consumptive use estimates by HUC. Data provided by DEP outside of the LQU database. Results are shown in hundredths of billion gallons for display purposes.

County	Sum of Past and Planned Wells (2009-2015) (Bgal)		
	Withdrawal	HIGH Consumptive Use	LOW Consumptive Use
Barbour	0.61	0.61	0.55
Braxton	0.00	0.00	0.00
Brooke	2.19	2.19	1.99
Doddridge	11.54	11.54	10.50
Gilmer	0.50	0.50	0.45
Greenbrier	0.01	0.01	0.01
Hancock	0.11	0.11	0.10
Harrison	12.18	12.18	11.08
Lewis	0.53	0.53	0.48
Marion	0.55	0.55	0.50
Marshall	2.43	2.43	2.21
Monongalia	0.06	0.06	0.06
Nicholas	0.08	0.08	0.07
Ohio	3.15	3.15	2.86
Pleasants	0.09	0.09	0.08
Preston	0.26	0.26	0.24
Ritchie	4.10	4.10	3.73
Taylor	0.48	0.48	0.44
Tyler	1.20	1.20	1.09
Upshur	0.39	0.39	0.36
Webster	0.01	0.01	0.01
Wetzel	5.58	5.58	5.08
TOTAL	46.05	46.05	41.89

Table B-2. Withdrawal totals for past and planned (2009-2015) and future (2020) Marcellus Shale development by county. Results are shown in hundredths of billion gallons for display purposes.

County	Past and Planned Withdrawals (Bgal)	Percent of total withdrawal	Predicted 2020 Withdrawals (Bgal)	
			HIGH Scenario	LOW Scenario
Barbour	0.61	1.00%	0.05	0.02
Braxton*	0.0001	0.0003%	0.00001	0.000004
Brooke	2.19	5.00%	0.18	0.07
Doddridge	11.54	25.00%	0.97	0.35
Gilmer	0.50	1.00%	0.04	0.02
Greenbrier*	0.01	0.01%	0.001	0.0002
Hancock*	0.11	0.20%	0.01	0.003
Harrison	12.18	26.00%	1.02	0.37
Lewis	0.53	1.00%	0.04	0.02
Marion	0.55	1.00%	0.05	0.02
Marshall	2.43	5.00%	0.20	0.07
Monongalia*	0.06	0.10%	0.01	0.002
Nicholas*	0.08	0.20%	0.01	0.002
Ohio	3.15	7.00%	0.26	0.10
Pleasants*	0.09	0.20%	0.01	0.003
Preston	0.26	1.00%	0.02	0.01
Ritchie	4.10	9.00%	0.34	0.12
Taylor	0.48	1.00%	0.04	0.01
Tyler	1.20	3.00%	0.10	0.04
Upshur	0.39	1.00%	0.03	0.01
Webster*	0.01	0.03%	0.001	0.0004
Wetzel	5.58	12.00%	0.47	0.17
TOTAL	46.05	100.00%	3.85	1.41

*Values rounded to additonal decimal places when result was less than 0.01 Bgal.

Table B-3. High and low scenario Marcellus Shale withdrawal projections for 2030 and 2040 by county.

County	2030 Withdrawal (Bgal)		2040 Withdrawal (Bgal)	
	HIGH	LOW	HIGH	LOW
Barbour	0.12	0.06	0.03	0.01
Braxton*	0.00003	0.00001	0.00001	0.000002
Brooke	0.44	0.22	0.09	0.03
Doddridge	2.31	1.15	0.48	0.18
Gilmer	0.10	0.05	0.02	0.01
Greenbrier*	0.001	0.001	0.0003	0.0001
Hancock*	0.02	0.01	0.004	0.002
Harrison	2.44	1.22	0.51	0.19
Lewis	0.11	0.05	0.02	0.01
Marion	0.11	0.05	0.02	0.01
Marshall	0.49	0.24	0.10	0.04
Monongalia*	0.01	0.01	0.003	0.001
Nicholas*	0.02	0.01	0.003	0.001
Ohio	0.63	0.31	0.13	0.05
Pleasants*	0.02	0.01	0.004	0.001
Preston*	0.05	0.03	0.01	0.004
Ritchie	0.82	0.41	0.17	0.06
Taylor	0.10	0.05	0.02	0.01
Tyler	0.24	0.12	0.05	0.02
Upshur	0.08	0.04	0.02	0.01
Webster*	0.003	0.001	0.001	0.0002
Wetzel	1.12	0.56	0.23	0.08
TOTAL	9.23	4.60	1.92	0.72

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

Table B-4. High and low consumptive use scenario estimates by county.

County	HIGH Scenario Consumptive Use (Bgal)			LOW Scenario Consumptive Use (Bgal)		
	2020	2030	2040	2020	2030	2040
Barbour	0.05	0.12	0.03	0.02	0.06	0.01
Braxton*	0.00001	0.00003	0.00	0.000004	0.00001	0.000002
Brooke	0.18	0.44	0.09	0.06	0.2	0.03
Doddridge	0.97	2.31	0.48	0.32	1.05	0.16
Gilmer	0.04	0.10	0.02	0.01	0.05	0.01
Greenbrier*	0.001	0.001	0.0003	0.0002	0.001	0.0001
Hancock*	0.01	0.02	0.004	0.003	0.01	0.001
Harrison	1.02	2.44	0.51	0.34	1.11	0.17
Lewis	0.04	0.11	0.02	0.01	0.05	0.01
Marion	0.05	0.11	0.02	0.02	0.05	0.01
Marshall	0.20	0.49	0.10	0.07	0.22	0.03
Monongalia*	0.01	0.01	0.003	0.002	0.01	0.001
Nicholas*	0.01	0.02	0.003	0.002	0.01	0.001
Ohio	0.26	0.63	0.13	0.09	0.29	0.04
Pleasants*	0.01	0.02	0.004	0.003	0.01	0.001
Preston*	0.02	0.05	0.01	0.01	0.02	0.004
Ritchie	0.34	0.82	0.17	0.11	0.37	0.06
Taylor	0.04	0.10	0.02	0.01	0.04	0.01
Tyler	0.10	0.24	0.05	0.03	0.11	0.02
Upshur	0.03	0.08	0.02	0.01	0.04	0.01
Webster*	0.001	0.003	0.001	0.0004	0.001	0.0002
Wetzel	0.47	1.12	0.23	0.15	0.51	0.08
TOTAL	3.85	9.23	1.92	1.27	4.21	0.66

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

Table B-5. High and low consumptive use scenario estimates by watershed.

HUC8	HIGH Scenario Consumptive Use (Bgal)			LOW Scenario Consumptive Use (Bgal)		
	2020	2030	2040	2020	2030	2040
North Branch Potomac*	0.004	0.01	0.002	0.001	0.004	0.001
Tygart Valley	0.08	0.19	0.04	0.03	0.09	0.01
West Fork	1.10	2.63	0.55	0.36	1.19	0.18
Monongahela	0.04	0.10	0.02	0.01	0.05	0.01
Cheat*	0.01	0.02	0.005	0.003	0.01	0.001
Dunkard*	0.002	0.01	0.001	0.001	0.002	0.0003
Youghiogheny*	0.002	0.00	0.001	0.001	0.002	0.0003
Upper Ohio North	0.06	0.15	0.03	0.02	0.07	0.01
Upper Ohio South	0.64	1.52	0.32	0.21	0.69	0.11
Middle Ohio North	1.34	3.19	0.67	0.44	1.45	0.22
Little Kanawha	0.57	1.37	0.29	0.19	0.62	0.09
Gauley*	0.01	0.02	0.003	0.002	0.01	0.001
Elk*	0.001	0.002	0.001	0.0003	0.001	0.0002
TOTAL	3.86	9.20	1.93	1.28	4.19	0.64

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

Appendix C

High and low consumptive use methods and estimates for each use type by watershed and county.

Results are shown in hundredths of billion gallons for display purposes. Some results were rounded to additional decimal places when they were less than 0.01 Bgal to show a value. (A value in gallons is not displayed as in Appendix A since these are estimated numbers.) A "C" means that all intakes in that watershed or county were closed in that year. 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 rounding.

Withdrawals for the Mining and Petroleum and Manufacturing sectors by watershed and county are also included in this appendix. These two water use types were combined from separate water use categories in the LQU database. The Mining and Petroleum category in this section combines the withdrawals in the LQU database for Mining (**Table A-1**) and the Petroleum (**Table A-2**). The Manufacturing category combines LQU database sectors of Timber (**Table A-4**), Industrial (**Table A-7**), and Chemical (**Table A-8**).

Table C-1. Combined Mining and Petroleum withdrawals by watershed (a) and by county (b).

(a)Watershed Mining and Petroleum Withdrawals

HUC8	Withdrawals (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
South Branch Potomac	0.02	0.02	0.02	0.04	0.02	0.04	0.04
Potomac Direct Drains	0.41	0.40	0.36	0.39	0.39	0.39	0.39
Tygart Valley	0.01	0.01	0.03	0.23	0.03	0.04	0.28
West Fork	0.19	0.21	0.21	0.21	0.27	0.27	0.26
Monongahela	0.19	0.40	0.39	0.33	0.36	0.33	0.31
Cheat	0.01	0.01	0.005	0.01	0.01	C	C
Dunkard	0.59	0.61	0.53	0.65	0.60	0.60	0.60
Upper Ohio North	0.25	0.25	0.32	0.30	0.34	0.39	0.37
Upper Ohio South	1.35	1.48	1.34	1.26	1.44	1.41	1.47
Middle Ohio North	0.21	0.19	0.14	0.29	0.26	0.21	0.19
Lower New	C	C	C	0.15	0.15	0.17	0.21
Gauley	0.67	0.64	0.67	0.84	0.81	0.60	0.56
Upper Kanawha	0.96	0.96	0.96	1.07	1.55	3.27	3.29
Elk	0.19	0.20	0.22	0.20	0.25	0.22	0.22
Coal	3.77	3.93	4.08	5.00	5.01	4.48	3.72
Upper Guyandotte	1.34	1.35	1.47	1.50	1.42	1.56	1.52
Lower Guyandotte	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Tug Fork	1.13	1.08	1.36	1.23	1.05	0.94	0.83
Big Sandy*	0.003	0.002	0.003	0.00	0.002	0.001	C
Lower Ohio*	0.04	0.03	0.04	0.01	0.003	0.001	0.001
Twelvepole	0.28	0.33	0.34	0.19	0.31	0.23	0.24
TOTAL	11.78	12.27	12.66	14.07	14.45	15.32	14.67

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

(b) County Mining and Petroleum Withdrawals

County	Withdrawals (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Barbour	C	C	C	C	0.01	0.02	0.22
Boone	3.16	3.31	3.38	3.52	3.52	2.97	2.76
Brooke	0.08	0.08	0.08	0.09	0.09	0.14	0.10
Clay	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Fayette	0.23	0.23	0.23	0.23	0.23	0.25	0.25
Hancock	0.16	0.17	0.24	0.20	0.25	0.25	0.27
Harrison	0.19	0.21	0.21	0.21	0.27	0.27	0.26
Kanawha	0.77	0.78	0.79	0.89	1.37	3.07	3.09
Logan	0.64	0.67	0.72	1.51	1.49	1.51	1.49
Marion	0.11	0.34	0.29	0.27	0.27	0.27	0.27
Marshall	1.35	1.48	1.34	1.26	1.44	1.41	1.47
McDowell	0.38	0.38	0.36	0.35	0.20	0.13	0.14
Mingo	0.76	0.72	1.08	1.03	0.92	0.89	0.77
Monongalia	0.67	0.67	0.63	0.72	0.69	0.66	0.64
Morgan	0.41	0.40	0.36	0.39	0.39	0.39	0.39
Nicholas	0.51	0.49	0.41	0.51	0.52	0.34	0.34
Pendleton	0.02	0.02	0.02	0.04	0.02	0.04	0.04
Pleasants	0.08	0.04	0.03	0.05	0.05	C	C
Preston*	0.01	0.01	0.005	0.21	C	C	C
Raleigh	1.05	1.07	1.07	1.23	1.26	1.27	0.77
Randolph	0.01	0.01	0.03	0.03	0.02	0.02	0.03
Upshur*	C	C	C	C	0.005	0.01	0.03
Wayne	0.32	0.36	0.38	0.20	0.32	0.23	0.24
Webster	0.19	0.20	0.32	0.37	0.38	0.33	0.30
Wetzel	0.13	0.14	0.11	0.24	0.21	0.21	0.19
Wyoming	0.37	0.34	0.41	0.36	0.36	0.50	0.48
TOTAL	11.75	12.27	12.65	14.06	14.44	15.33	14.69

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

Table C-2. Mining and Petroleum consumptive use estimates by watershed (a) and by county (b).

(a) Watershed Mining and Petroleum Consumptive Use Estimates

HUC8	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
South Branch Potomac*	0.004	0.004	0.004	0.01	0.004	0.01	0.01	0.003	0.003	0.003	0.01	0.003	0.01	0.01
Potomac Direct Drains	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.06	0.06	0.05	0.05	0.05	0.05	0.05
Tygart Valley*	0.002	0.002	0.01	0.05	0.01	0.01	0.06	0.001	0.001	0.004	0.03	0.004	0.01	0.04
West Fork	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.04	0.04	0.04
Monongahela	0.04	0.08	0.08	0.07	0.07	0.07	0.06	0.03	0.06	0.05	0.05	0.05	0.05	0.04
Cheat*	0.002	0.002	0.001	0.002	0.002	C	C	0.001	0.001	0.001	0.001	0.001	C	C
Dunkard	0.12	0.12	0.11	0.13	0.12	0.12	0.12	0.08	0.09	0.07	0.09	0.08	0.08	0.08
Upper Ohio North	0.05	0.05	0.06	0.06	0.07	0.08	0.07	0.04	0.04	0.04	0.04	0.05	0.05	0.05
Upper Ohio South	0.27	0.30	0.27	0.25	0.29	0.28	0.29	0.19	0.21	0.19	0.18	0.20	0.20	0.21
Middle Ohio North	0.04	0.04	0.03	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.04	0.04	0.03	0.03
Lower New	C	C	C	0.03	0.03	0.03	0.04	C	C	C	0.02	0.02	0.02	0.03
Gauley	0.13	0.13	0.13	0.17	0.16	0.12	0.11	0.09	0.09	0.09	0.12	0.11	0.08	0.08
Upper Kanawha	0.19	0.19	0.19	0.21	0.31	0.65	0.66	0.13	0.13	0.13	0.15	0.22	0.46	0.46
Elk	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.03
Coal	0.75	0.79	0.82	1.00	1.00	0.90	0.74	0.53	0.55	0.57	0.70	0.70	0.63	0.52
Upper Guyandotte	0.27	0.27	0.29	0.30	0.28	0.31	0.30	0.19	0.19	0.21	0.21	0.20	0.22	0.21
Lower Guyandotte	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Tug Fork	0.23	0.22	0.27	0.25	0.21	0.19	0.17	0.16	0.15	0.19	0.17	0.15	0.13	0.12
Big Sandy*	0.001	0.0004	0.001	0.00	0.0004	0.0002	C	0.0004	0.0003	0.0004	0.00	0.0003	0.0001	C
Lower Ohio*	0.01	0.01	0.01	0.002	0.001	0.0002	0.0002	0.01	0.004	0.01	0.001	0.0004	0.0001	0.0001
Twelvepole	0.06	0.07	0.07	0.04	0.06	0.05	0.05	0.04	0.05	0.05	0.03	0.04	0.03	0.03
TOTAL	2.36	2.47	2.53	2.82	2.88	3.06	2.92	1.67	1.74	1.76	1.97	2.02	2.14	2.05

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

(b) County Mining and Petroleum Consumptive Use Estimates

County	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
Barbour*	C	C	C	C	0.002	0.004	0.04	C	C	C	C	0.001	0.003	0.03
Boone	0.63	0.66	0.68	0.70	0.70	0.59	0.55	0.44	0.46	0.47	0.49	0.49	0.42	0.39
Brooke	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Clay	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Fayette	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.04	0.04
Hancock	0.03	0.03	0.05	0.04	0.05	0.05	0.05	0.02	0.02	0.03	0.03	0.04	0.04	0.04
Harrison	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.04	0.04	0.04
Kanawha	0.15	0.16	0.16	0.18	0.27	0.61	0.62	0.11	0.11	0.11	0.12	0.19	0.43	0.43
Logan	0.13	0.13	0.14	0.30	0.30	0.30	0.30	0.09	0.09	0.10	0.21	0.21	0.21	0.21
Marion	0.02	0.07	0.06	0.05	0.05	0.05	0.05	0.02	0.05	0.04	0.04	0.04	0.04	0.04
Marshall	0.27	0.30	0.27	0.25	0.29	0.28	0.29	0.19	0.21	0.19	0.18	0.20	0.20	0.21
McDowell	0.08	0.08	0.07	0.07	0.04	0.03	0.03	0.05	0.05	0.05	0.05	0.03	0.02	0.02
Mingo	0.15	0.14	0.22	0.21	0.18	0.18	0.15	0.11	0.10	0.15	0.14	0.13	0.12	0.11
Monongalia	0.13	0.13	0.13	0.14	0.14	0.13	0.13	0.09	0.09	0.09	0.10	0.10	0.09	0.09
Morgan	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.06	0.06	0.05	0.05	0.05	0.05	0.05
Nicholas	0.10	0.10	0.08	0.10	0.10	0.07	0.07	0.07	0.07	0.06	0.07	0.07	0.05	0.05
Pendleton*	0.004	0.004	0.004	0.01	0.004	0.01	0.01	0.003	0.003	0.003	0.01	0.003	0.01	0.01
Pleasants	0.02	0.01	0.01	0.01	0.01	C	C	0.01	0.01	0.00	0.01	0.01	C	C
Preston*	0.002	0.002	0.001	0.04	C	C	C	0.00	0.00	0.00	0.03	C	C	C
Raleigh	0.21	0.21	0.21	0.25	0.25	0.25	0.15	0.15	0.15	0.15	0.17	0.18	0.18	0.11
Randolph*	0.002	0.002	0.01	0.01	0.004	0.004	0.01	0.001	0.001	0.004	0.004	0.003	0.003	0.004
Upshur*	C	C	C	C	0.001	0.002	0.01	C	C	C	C	0.001	0.001	0.004
Wayne	0.06	0.07	0.08	0.04	0.06	0.05	0.05	0.04	0.05	0.05	0.03	0.04	0.03	0.03
Webster	0.04	0.04	0.06	0.07	0.08	0.07	0.06	0.03	0.03	0.04	0.05	0.05	0.05	0.04
Wetzel	0.03	0.03	0.02	0.05	0.04	0.04	0.04	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Wyoming	0.07	0.07	0.08	0.07	0.07	0.10	0.10	0.05	0.05	0.06	0.05	0.05	0.07	0.07
TOTAL	2.35	2.46	2.55	2.81	2.87	3.06	2.94	1.64	1.71	1.76	1.95	2.02	2.17	2.08

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

Table C-3. Manufacturing withdrawals (combines Industrial, Chemical, and Timber DEP water use categories) by watershed (a) and by county (b).

(a)Watershed Manufacturing Withdrawals

HUC8	Withdrawals (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
North Branch Potomac	0.05	0.07	0.07	0.07	0.10	0.10	0.10
Potomac Direct Drains	3.79	3.81	3.85	3.70	3.70	1.37	1.37
Shenandoah Jefferson	0.04	0.04	0.05	0.04	0.06	0.05	0.04
Monongahela	1.19	1.21	1.13	1.16	1.17	1.17	1.17
Cheat	0.16	0.16	0.16	0.02	0.02	0.02	0.03
Upper Ohio North	55.89	55.80	44.64	64.00	66.05	61.52	63.32
Upper Ohio South	0.47	0.37	0.36	0.32	0.32	0.20	0.20
Middle Ohio North	59.80	59.65	59.44	58.58	46.07	46.40	45.92
Middle Ohio South	17.74	17.78	20.42	18.59	18.27	17.78	17.86
Upper New	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Greenbrier	0.02	0.02	0.02	0.02	0.02	C	C
Upper Kanawha	45.23	45.33	45.33	46.91	39.53	39.52	39.52
Lower Kanawha	66.82	69.72	65.60	67.29	62.13	67.62	64.68
Lower Guyandotte	0.27	0.24	0.25	0.28	0.25	0.26	0.30
Big Sandy	0.16	0.09	0.10	0.08	0.09	0.06	0.07
Lower Ohio	0.37	0.35	0.38	0.34	0.26	0.29	0.29
TOTAL	252.02	254.66	241.82	261.42	238.06	236.38	234.89

(b) County Manufacturing Withdrawals

County	Withdrawals (Bgal)						
	2003	2004	2005	2008	2009	2010	2011
Berkeley	3.69	3.69	3.69	3.69	3.69	1.36	1.36
Brooke	2.52	2.48	2.2	5.84	1.54	1.73	2.95
Cabell	0.27	0.24	0.25	0.28	0.25	0.26	0.3
Fayette	9.49	9.49	9.49	9.49	2.22	2.2	2.21
Greenbrier	0.02	0.02	0.02	0.02	0.02	C	C
Hancock	53.69	53.6	42.72	58.37	64.72	59.9	60.48
Jackson	0.77	0.81	0.89	0.76	0.65	0.17	0.1
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	102
Marion	1.19	1.21	1.13	1.16	1.17	1.17	1.17
Marshall	55.57	55.49	55.4	55.35	42.69	42.92	42.77
Mason	0.37	0.35	0.38	0.34	0.26	0.29	0.29
Mineral	0.05	0.07	0.07	0.07	0.1	0.1	0.1
Monroe	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Pleasants	1.94	2.14	2.16	1.36	1.32	1.5	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	0.1	0.08	0.09	0.06	0.07
Wood	16.98	16.98	19.53	17.83	17.61	17.61	17.77
TOTAL	252.02	254.67	241.83	261.43	238.06	236.38	234.91

Table C-4. Manufacturing consumptive use estimates by watershed (a) and by county (b).

(a) Watershed Manufacturing Consumptive Use Estimates

HUC8	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
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	0.18	0.38	0.38	0.39	0.37	0.37	0.14	0.14
Shenandoah Jefferson	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00
Monongahela	0.15	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
Cheat	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.00	0.00
Upper Ohio North	7.27	7.25	5.80	8.32	8.59	8.00	8.23	5.59	5.58	4.46	6.40	6.61	6.15	6.33
Upper Ohio South	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.05	0.04	0.04	0.03	0.03	0.02	0.02
Middle Ohio North	7.77	7.75	7.73	7.62	5.99	6.03	5.97	5.98	5.97	5.94	5.86	4.61	4.64	4.59
Middle Ohio South	2.31	2.31	2.65	2.42	2.38	2.31	2.32	1.77	1.78	2.04	1.86	1.83	1.78	1.79
Upper New*	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Greenbrier*	0.003	0.003	0.003	0.003	0.003	C	C	0.002	0.002	0.002	0.002	0.002	C	C
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
Lower Kanawha	8.69	9.06	8.53	8.75	8.08	8.79	8.41	6.68	6.97	6.56	6.73	6.21	6.76	6.47
Lower Guyandotte	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.03
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
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
TOTAL	32.78	33.11	31.44	34.00	30.95	30.73	30.54	25.21	25.47	24.19	26.14	23.82	23.65	23.49

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

(b) County Manufacturing Consumptive Use Estimates

County	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	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	0.18	0.37	0.37	0.37	0.37	0.37	0.14	0.14
Brooke	0.33	0.32	0.29	0.76	0.20	0.22	0.38	0.25	0.25	0.22	0.58	0.15	0.17	0.30
Cabell	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.02	0.03	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
Greenbrier*	0.003	0.003	0.003	0.003	0.003	C	C	0.002	0.002	0.002	0.002	0.002	C	C
Hancock	6.98	6.97	5.55	7.59	8.41	7.79	7.86	5.37	5.36	4.27	5.84	6.47	5.99	6.05
Jackson	0.10	0.11	0.12	0.10	0.08	0.02	0.01	0.08	0.08	0.09	0.08	0.07	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	0.01
Kanawha	13.33	13.72	13.19	13.61	12.93	13.64	13.26	10.26	10.56	10.14	10.47	9.95	10.49	10.20
Marion	0.15	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	7.20	5.55	5.58	5.56	5.56	5.55	5.54	5.54	4.27	4.29	4.28
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*	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Pleasants	0.25	0.28	0.28	0.18	0.17	0.20	0.17	0.19	0.21	0.22	0.14	0.13	0.15	0.13
Tucker*	0.02	0.02	0.02	0.003	0.003	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	2.29	2.29	2.31	1.70	1.70	1.95	1.78	1.76	1.76	1.78
TOTAL	32.77	33.11	31.45	34.00	30.93	30.74	30.54	25.22	25.48	24.19	26.17	23.83	23.65	23.52

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

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Table C-5. Public Water Supply consumptive use estimates by watershed (a) and by county (b).

(a) Watershed Public Water Supply Consumptive Use Estimates

HUC8	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
South Branch Potomac	0.36	0.40	0.41	0.40	0.39	0.39	0.39	0.27	0.30	0.31	0.30	0.29	0.29	0.29
North Branch Potomac	0.10	0.10	0.11	0.15	0.14	0.16	0.16	0.08	0.08	0.08	0.11	0.10	0.12	0.12
Cacapon	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	0.85	1.04	0.82	0.98	0.90	0.90	0.87	0.64	0.78	0.61	0.73	0.68	0.67	0.65
Shenandoah Jefferson	0.11	0.12	0.13	0.17	0.15	0.16	0.15	0.08	0.09	0.10	0.13	0.11	0.12	0.11
Tygart Valley	1.11	1.22	1.17	1.25	1.16	1.23	1.24	0.83	0.92	0.88	0.94	0.87	0.92	0.93
West Fork	0.63	0.64	0.61	0.63	0.63	0.62	0.62	0.47	0.48	0.46	0.47	0.47	0.47	0.46
Monongahela	1.52	1.49	1.49	1.50	1.49	0.75	0.75	1.14	1.12	1.12	1.13	1.12	0.56	0.56
Cheat	0.12	0.13	0.14	0.16	0.15	0.15	0.15	0.09	0.10	0.10	0.12	0.11	0.11	0.11
Youghiogheny	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01
Upper Ohio North	0.35	0.41	0.39	0.38	0.39	0.40	0.41	0.26	0.30	0.29	0.29	0.29	0.30	0.30
Upper Ohio South	0.78	0.77	0.80	0.78	0.79	0.79	0.80	0.59	0.58	0.60	0.58	0.59	0.59	0.60
Middle Ohio North	0.28	0.29	0.31	0.30	0.30	0.28	0.29	0.21	0.22	0.23	0.23	0.23	0.21	0.22
Middle Ohio South	0.73	0.73	0.71	0.68	0.70	0.71	1.68	0.55	0.55	0.53	0.51	0.53	0.53	1.26
Little Kanawha	0.21	0.23	0.23	0.23	0.24	0.24	0.25	0.16	0.17	0.17	0.17	0.18	0.18	0.18
Upper New	0.50	0.50	0.54	0.57	0.52	0.53	0.52	0.37	0.38	0.40	0.43	0.39	0.40	0.39
Greenbrier	0.22	0.22	0.25	0.26	0.25	0.26	0.26	0.16	0.17	0.19	0.19	0.19	0.19	0.20
Lower New	0.84	0.85	0.88	0.91	0.86	0.88	0.88	0.63	0.64	0.66	0.69	0.65	0.66	0.66
Gauley	0.23	0.22	0.24	0.24	0.25	0.25	0.26	0.17	0.16	0.18	0.18	0.19	0.19	0.19
Upper Kanawha	0.25	0.26	0.25	0.25	0.25	0.25	0.25	0.19	0.20	0.18	0.19	0.19	0.19	0.19
Elk	2.42	2.40	2.38	2.39	2.41	2.41	2.41	1.81	1.80	1.79	1.79	1.81	1.81	1.81
Lower Kanawha	0.18	0.16	0.17	0.20	0.18	0.18	0.18	0.14	0.12	0.13	0.15	0.13	0.13	0.13
Coal	0.07	0.12	0.14	0.13	0.13	0.13	0.13	0.05	0.09	0.10	0.09	0.09	0.10	0.10
Upper Guyandotte	0.29	0.29	0.28	0.27	0.27	0.27	0.27	0.21	0.22	0.21	0.20	0.20	0.20	0.20
Lower Guyandotte	0.17	0.18	0.18	0.33	0.21	0.21	0.21	0.12	0.14	0.13	0.25	0.16	0.16	0.16
Tug Fork	0.52	0.50	0.53	0.56	0.46	0.54	0.55	0.39	0.37	0.39	0.42	0.35	0.41	0.42
Big Sandy	0.17	0.18	0.19	0.18	0.15	0.15	0.15	0.12	0.14	0.14	0.14	0.11	0.11	0.11
Lower Ohio	0.95	0.93	0.98	0.96	0.96	1.00	1.01	0.71	0.70	0.74	0.72	0.72	0.75	0.76
Twelvepole	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03

HUC8	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
TOTAL	14.03	14.45	14.40	14.93	14.40	13.91	14.90	10.50	10.88	10.78	11.21	10.81	10.43	11.16

(b) County Public Water Supply Consumptive Use Estimates

County	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
Barbour	0.08	0.07	0.08	0.09	0.10	0.10	0.10	0.06	0.05	0.06	0.07	0.08	0.07	0.07
Berkeley	0.77	0.94	0.72	0.87	0.81	0.81	0.79	0.58	0.71	0.54	0.65	0.61	0.61	0.59
Boone	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
Braxton	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.05	0.05	0.05	0.06	0.06	0.06	0.06
Brooke	0.14	0.13	0.15	0.14	0.14	0.16	0.16	0.11	0.10	0.11	0.10	0.11	0.12	0.12
Cabell	0.96	0.95	0.99	0.97	0.97	0.97	0.97	0.72	0.71	0.74	0.73	0.73	0.73	0.73
Calhoun	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Clay	0.03	0.02	0.03	0.03	0.04	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Doddridge	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
Fayette	0.38	0.39	0.38	0.44	0.39	0.40	0.41	0.28	0.29	0.29	0.33	0.29	0.30	0.30
Gilmer	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.02	0.03	0.03	0.03	0.03	0.04	0.03
Grant	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.05
Greenbrier	0.22	0.22	0.25	0.26	0.25	0.26	0.27	0.16	0.17	0.19	0.20	0.19	0.20	0.20
Hampshire	0.04	0.04	0.04	0.05	0.04	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.03
Hancock	0.27	0.33	0.30	0.31	0.30	0.30	0.31	0.21	0.25	0.23	0.23	0.23	0.23	0.23
Hardy	0.24	0.28	0.29	0.27	0.27	0.27	0.27	0.18	0.21	0.22	0.20	0.20	0.20	0.20
Harrison	0.54	0.54	0.51	0.53	0.53	0.53	0.53	0.40	0.40	0.39	0.40	0.40	0.40	0.40
Jackson	0.12	0.12	0.13	0.12	0.13	0.14	0.13	0.09	0.09	0.09	0.09	0.10	0.10	0.10
Jefferson	0.15	0.17	0.19	0.22	0.20	0.21	0.20	0.11	0.13	0.14	0.17	0.15	0.16	0.15
Kanawha	2.44	2.48	2.47	2.45	2.45	2.46	2.46	1.83	1.86	1.85	1.84	1.84	1.85	1.85
Lewis	0.09	0.10	0.10	0.10	0.10	0.09	0.09	0.07	0.07	0.07	0.07	0.07	0.07	0.06
Lincoln	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Logan	0.26	0.27	0.26	0.43	0.32	0.31	0.31	0.19	0.21	0.19	0.33	0.24	0.23	0.23
Marion	0.56	0.55	0.57	0.65	0.57	0.61	0.62	0.42	0.41	0.42	0.49	0.43	0.45	0.47
Marshall	0.21	0.22	0.23	0.22	0.23	0.23	0.24	0.16	0.16	0.18	0.16	0.17	0.17	0.18
Mason	0.16	0.17	0.17	0.18	0.20	0.23	0.24	0.12	0.12	0.13	0.14	0.15	0.17	0.18
McDowell	0.19	0.18	0.18	0.20	0.21	0.20	0.19	0.14	0.14	0.14	0.15	0.15	0.15	0.14
Mercer	0.30	0.29	0.34	0.33	0.30	0.30	0.30	0.22	0.22	0.25	0.25	0.23	0.23	0.23

County	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
Mineral	0.09	0.09	0.09	0.13	0.12	0.15	0.14	0.07	0.07	0.07	0.10	0.09	0.11	0.11
Mingo	0.27	0.27	0.27	0.31	0.21	0.29	0.30	0.20	0.20	0.20	0.24	0.15	0.22	0.22
Monongalia	1.47	1.44	1.44	1.45	1.45	0.72	0.72	1.10	1.08	1.08	1.09	1.09	0.54	0.54
Monroe	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.03	0.02	0.03	0.04	0.04	0.05	0.05
Morgan	0.05	0.06	0.04	0.05	0.04	0.04	0.03	0.03	0.04	0.03	0.04	0.03	0.03	0.03
Nicholas	0.17	0.16	0.18	0.17	0.18	0.18	0.18	0.13	0.12	0.14	0.13	0.14	0.14	0.14
Ohio	0.50	0.49	0.50	0.49	0.49	0.49	0.49	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Pendleton	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Pleasants	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.04	0.04	0.03	0.03	0.03	0.03
Pocahontas	0.03	0.02	0.03	0.03	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.03
Preston	0.11	0.13	0.13	0.14	0.13	0.13	0.13	0.09	0.09	0.10	0.11	0.10	0.10	0.09
Putnam	0.17	0.15	0.16	0.19	0.17	0.17	0.17	0.13	0.12	0.12	0.14	0.12	0.12	0.12
Raleigh	0.67	0.68	0.70	0.68	0.68	0.68	0.68	0.50	0.51	0.53	0.51	0.51	0.51	0.51
Randolph	0.20	0.33	0.25	0.24	0.22	0.23	0.23	0.15	0.25	0.19	0.18	0.16	0.18	0.18
Ritchie	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Roane	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Summers	0.20	0.21	0.21	0.20	0.20	0.20	0.20	0.15	0.16	0.16	0.15	0.15	0.15	0.15
Taylor	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.11	0.11	0.11	0.11	0.11	0.10	0.10
Tucker	0.05	0.05	0.05	0.06	0.05	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Tyler	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.02
Upshur	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Wayne	0.22	0.24	0.25	0.24	0.21	0.21	0.22	0.17	0.18	0.19	0.18	0.16	0.16	0.16
Webster	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.02	0.02
Wetzel	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.10	0.09	0.10	0.10	0.10	0.10	0.10
Wood	0.64	0.64	0.61	0.58	0.57	0.57	1.55	0.48	0.48	0.46	0.43	0.43	0.43	1.16
Wyoming	0.13	0.13	0.14	0.11	0.10	0.12	0.12	0.10	0.10	0.11	0.08	0.08	0.09	0.09
TOTAL	14.03	14.47	14.39	14.90	14.39	13.93	14.88	10.53	10.88	10.82	11.22	10.82	10.46	11.16

Table C-6. Recreation consumptive use estimates by watershed (a) and by county (b).

(a) Watershed Recreation Consumptive Use Estimates

HUC8	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
South Branch Potomac*	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Cacapon*	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Potomac Direct Drains	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Shenandoah Jefferson	0.00	0.01	0.04	0.03	0.02	0.02	0.02	0.00	0.01	0.04	0.03	0.02	0.02	0.02
West Fork	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Monongahela*	C	C	C	0.01	0.01	0.01	0.003	C	C	C	0.01	0.01	0.01	0.003
Cheat	0.24	0.25	0.29	0.26	0.28	0.28	0.21	0.24	0.24	0.29	0.25	0.28	0.27	0.21
Upper Ohio North	0.04	0.04	0.05	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.06	0.05	0.05	0.05
Middle Ohio South*	0.002	0.006	0.006	0.006	0.006	0.006	0.006	0.002	0.003	0.006	0.004	0.004	0.004	0.004
Greenbrier	0.49	0.49	0.49	0.49	0.56	0.38	0.38	0.47	0.47	0.48	0.47	0.54	0.37	0.37
Lower New	0.06	0.07	0.10	0.12	0.10	0.10	0.10	0.06	0.07	0.10	0.12	0.09	0.10	0.09
Elk*	0.006	0.003	0.006	0.006	0.006	0.006	0.006	0.006	0.003	0.006	0.006	0.006	0.006	0.006
Lower Kanawha*	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Tug Fork*	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.001	0.001	0.001	0.001
TOTAL	0.90	0.94	1.04	1.04	1.09	0.91	0.84	0.88	0.91	1.02	1.01	1.06	0.89	0.81

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

(b) County Recreation Consumptive Use Estimates

County	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
Berkeley	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.02	0.02	0.02	0.02
Greenbrier	0.49	0.49	0.49	0.49	0.56	0.38	0.38	0.47	0.47	0.48	0.47	0.54	0.37	0.37
Hampshire*	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Hancock	0.04	0.04	0.05	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.06	0.05	0.05	0.05
Hardy*	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Jefferson	0.01	0.02	0.05	0.03	0.03	0.03	0.03	0.01	0.02	0.04	0.03	0.03	0.03	0.03
Kanawha*	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Lewis	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Mingo*	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.001	0.001	0.001	0.001
Monongalia*	C	C	C	0.01	0.01	0.01	0.003	C	C	C	0.01	0.01	0.01	0.003
Pocahontas	0.24	0.25	0.29	0.26	0.28	0.28	0.21	0.24	0.24	0.29	0.25	0.28	0.28	0.21
Preston*	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Raleigh	0.06	0.07	0.10	0.12	0.10	0.10	0.10	0.06	0.07	0.10	0.12	0.09	0.10	0.09
Wood*	0.002	0.006	0.006	0.006	0.006	0.006	0.006	0.002	0.006	0.006	0.006	0.006	0.006	0.006
TOTAL	0.90	0.94	1.04	1.04	1.10	0.92	0.84	0.88	0.91	1.01	1.01	1.07	0.91	0.82

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

Table C-7. Thermoelectric consumptive use estimates by watershed (a) and by county (b).

(a) Watershed Thermoelectric Consumptive Use Estimates

HUC8	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
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
Shenandoah Jefferson	C	C	C	C	6.45	6.27	8.54	C	C	C	C	3.23	3.13	4.27
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
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
Cheat	2.16	1.54	2.03	1.19	23.38	17.95	34.10	1.08	0.77	1.02	0.60	11.69	8.98	17.05
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
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
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
Lower Kanawha	0.67	0.60	0.60	0.62	0.62	0.53	0.53	0.34	0.30	0.30	0.31	0.31	0.27	0.27
TOTAL	52.35	51.38	50.39	49.19	68.56	60.12	76.06	26.17	25.68	25.21	24.60	34.27	30.06	38.03

(b) County Thermoelectric Consumptive Use Estimates

County	HIGH Consumptive Use (Bgal)							LOW Consumptive Use (Bgal)						
	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
Jefferson	C	C	C	C	6.45	6.27	8.54	C	C	C	C	3.23	3.13	4.27
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	24.52	19.18	35.29	0.60	0.68	0.61	0.62	12.26	9.59	17.65
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	0.53	0.34	0.30	0.30	0.31	0.31	0.27	0.27
TOTAL	52.35	51.37	50.40	49.19	68.56	60.13	76.06	26.18	25.68	25.20	24.60	34.27	30.05	38.03

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Appendix D

Development of the Mining and Petroleum withdrawal and consumptive use scenarios.

Historic withdrawals in the Mining and Petroleum sector can be found in **Table C-1**. Results are shown in hundredths of billion gallons 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.

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 was used if a Marcellus withdrawal was reported in a HUC8.
    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.

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.
    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.
    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.
10. If employment data were not for a HUC8 apply the rates of change directly to the 2011 withdrawal.

Future consumptive use estimates by HUC8

11. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. High scenario – 20% (Shaffer and Runkle 2007)
12. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. Low scenario – 14% (Shaffer and Runkle 2007)

<u>Mining and Petroleum County Withdrawal and Consumptive Use Method</u>

Past withdrawal by County

1. Sum Mining and Petroleum withdrawals by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.

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.

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.
    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.
    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.
7. If employment data were not available for a county, apply the rate of change directly to the 2011 withdrawal.

Future consumptive use estimates by County

8. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
   a. High scenario – 20% (Shaffer and Runkle 2007)
9. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
   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 the estimation methodologies described above.

Table D-1. Number of employees by county in the NAICS category 21 or 212. The notes column explains which category was used for each county and why. The field also explains any other assumptions. Employment data is only recorded for those counties that had a Mining and Petroleum withdrawal in 2011 (Pleasants and Preston counties had withdrawals until 2008). A dash (-) indicates that data were not available. Data source: WorkForce West Virginia.

County	Number of Employees							Notes
	2003	2004	2005	2008	2009	2010	2011	
Barbour	47	42	48	348	348	348	348	NAICS 212 since there are Marcellus withdrawals. In 2010 and 2011, data under code 21 was not available. A sub-category of code 21, 212111, Bituminous coal and lignite surface mining, reported employees. Since this is a subcategory, with a low employee figure, the 2008 and 2009 number were assumed for 2010 and 2011.
Boone	3,256	3,745	3,864	3,972	3,712	3,625	3,716	NAICS code 21 since there are no Marcellus withdrawals.
Brooke	-	-	-	-	-	-	-	No mining data provided on WorkForce West Virginia.
Clay	374	404	434	462	491	374	422	NAICS code 21 since there are no Marcellus withdrawals.
Fayette	431	422	416	739	698	668	835	NAICS code 21 since there are no Marcellus withdrawals.
Hancock	-	-	-	-	-	-	-	No mining data provided on WorkForce West Virginia.
Harrison	420	535	247	149	142	141	178	NAICS 212 since there are Marcellus withdrawals.
Kanawha	2,191	2,297	2,499	3,057	2,823	2,409	2,607	NAICS code 21 since there are no Marcellus withdrawals.
Logan	1,195	1,329	1,449	1,668	1,652	1,719	2,253	NAICS code 21 since there are no Marcellus withdrawals.
Marion	967	1,113	1,418	1,482	1,557	1,599	1,707	NAICS code 212 since there are Marcellus withdrawals.
Marshall	1,114	1,208	1,366	1,250	1,251	1,549	1,689	County has Marcellus withdrawals, 2003 and 2011 were the only years with NAICS code 212. For 2003, used code 21 because there were no Marcellus withdrawals, then used code 212 in 2011.
McDowell	738	838	906	1,501	1,400	1,552	1,958	NAICS code 21 since there are no Marcellus withdrawals.
Mingo	1,648	1,591	1,879	2,739	2,341	2,303	2,447	NAICS code 21 since there are no Marcellus withdrawals.
Monongalia	332	337	351	486	501	559	703	NAICS 212 since there are Marcellus withdrawals.
Morgan	168	168	168	168	168	168	168	There was only mining data for NAICS code 21 in 2003. This value was used for all subsequent years.
Nicholas	631	611	649	964	1,024	1,115	1,248	NAICS code 21 since there are no Marcellus withdrawals.
Pendleton	-	-	-	-	-	-	-	No mining data provided on WorkForce West Virginia.
Raleigh	1,184	1,385	1,750	1,909	1,943	2,053	2,528	NAICS code 21 since there are no Marcellus withdrawals.
Randolph	150	150	150	150	150	201	254	NAICS code 21 since there are no Marcellus withdrawals. Employment data in the sector were not provided prior to 2009 so the 2009 employment number was assumed for the previous years.
Upshur	183	133	116	216	183	148	158	NAICS 212 used since there are Marcellus withdrawals; In 2010 and 2011, data were not provided for code 212. Therefore, code 21 numbers minus the number of jobs in the other subsectors were used for 2010 and 2011.
Wayne	484	544	585	759	837	844	886	NAICS code 21 since there are no Marcellus withdrawals.
Webster	-	375	393	385	386	353	321	NAICS code 21 was used even though there are Marcellus withdrawals in the county. There was not an increase in the 2008, 2009, 2010, or 2011 employment numbers, which would have indicated an effect from Marcellus Shale development.
Wetzel	21	21	21	29	29	35	32	For the years when data were available, they were only for NAICS code 21, even though there are Marcellus withdrawals. Employment in 2003 and 2004 was assumed to be equal to that in 2005. 2008 and 2009 were assumed to be the average of the know years of data – 2005, 2010, and 2011.
Wyoming	938	952	1,207	1,072	1,042	1,192	1,280	NAICS code 21 since there are no Marcellus withdrawals

Table D-2. The past and projected number of employees in the Mining and Petroleum sector by watershed. Watersheds where there was no withdrawal facility in 2011 are not shown (Cheat, Big Sandy). 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). The method for transform county employee data to watershed employees is explained in **Box 3**.

HUC8	Employment							HIGH Employment Projection			LOW Employment Projection		
	2003	2004	2005	2008	2009	2010	2011	2020	2030	2040	2020	2030	2040
South Branch Potomac*	-	-	-	-	-	-	-	-	-	-	-	-	-
Potomac Direct Drains	168	168	168	168	168	168	168	177	187	197	143	123	103
Tygart Valley	150	150	150	150	681	697	760	787	817	847	652	549	463
West Fork	420	535	247	149	142	141	178	187	197	207	151	129	109
Monongahela	956	1,061	1,412	1,444	1,534	1,565	1,664	1,727	1,797	1,867	1,426	1,201	1,012
Dunkard	343	389	357	520	520	593	746	773	803	833	640	539	454
Upper Ohio North*	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Ohio South	1,114	1,208	1,366	1,250	1,251	1,549	1,689	1,752	1,822	1,894	1,448	1,220	1,028
Middle Ohio North	82	44	62	147	146	35	32	32	32	32	29	29	29
Lower New‡				229	233	267	695	722	752	782	596	502	423
Gauley	1,005	1,015	1,209	1,603	1,653	1,606	1,750	1,813	1,884	1,964	1,500	1,264	1,066
Upper Kanawha	2,493	2,585	2,735	3,627	3,420	3,038	3,401	3,527	3,670	3,820	2,915	2,456	2,069
Elk	375	375	267	208	248	236	241	250	260	270	205	175	145
Coal	4,055	4,711	5,317	6,170	5,883	5,786	6,055	6,277	6,533	6,799	5,190	4,372	3,683
Upper Guyandotte	2,770	2,949	3,219	3,004	2,718	2,909	3,545	3,674	3,824	3,980	3,040	2,561	2,157
Lower Guyandotte	172	196	195	192	180	208	229	238	248	258	196	166	139
Tug Fork	2,091	2,118	2,504	3,436	3,177	3,311	3,699	3,834	3,991	4,152	3,168	2,669	2,248
Lower Ohio	56	46	60	31	8	5	4	4	4	4	4	4	4
Twelvepole	423	494	520	728	824	834	882	918	958	998	756	637	537

*Employment data not available.

‡There was no withdrawal in the Lower New watershed in 2003, 2004, or 2005.

Table D-3. Per employee water use for the Mining and Petroleum water use category by watershed. Watersheds where there was no withdrawal facility in 2011 are not shown (Cheat, Big Sandy). Results rounded to hundredths of million gallons per employee for display purposes.

HUC8	Per Employee Withdrawal (Mgal)							Average (Mgal)
	2003	2004	2005	2008	2009	2010	2011	
South Branch Potomac*	-	-	-	-	-	-	-	-
Potomac Direct Drains	2.42	2.36	2.15	2.31	2.31	2.31	2.31	2.31
Tygart Valley	0.07	0.05	0.18	1.56	0.05	0.06	0.37	0.33
West Fork	0.44	0.39	0.86	1.43	1.87	1.93	1.48	1.20
Monongahela	0.20	0.38	0.28	0.23	0.23	0.21	0.19	0.24
Dunkard	1.73	1.58	1.48	1.26	1.15	1.01	0.80	1.29
Upper Ohio North*	-	-	-	-	-	-	-	-
Upper Ohio South	1.21	1.23	0.98	1.01	1.15	0.91	0.87	1.05
Middle Ohio North	2.55	4.21	2.34	1.98	1.81	6.03	6.08	3.57
Lower New‡				0.64	0.65	0.62	0.30	0.55
Gauley	0.66	0.64	0.55	0.52	0.49	0.38	0.32	0.51
Upper Kanawha	0.38	0.37	0.35	0.30	0.45	1.08	0.97	0.56
Elk	0.51	0.53	0.82	0.96	1.00	0.94	0.92	0.81
Coal	0.93	0.83	0.77	0.81	0.85	0.77	0.62	0.80
Upper Guyandotte	0.48	0.46	0.46	0.50	0.52	0.53	0.43	0.48
Lower Guyandotte	0.97	0.88	0.88	0.89	0.95	0.82	0.74	0.88
Tug Fork	0.54	0.51	0.54	0.36	0.33	0.28	0.22	0.40
Lower Ohio	0.66	0.67	0.65	0.26	0.40	0.30	0.25	0.46
Twelvepole	0.66	0.67	0.64	0.26	0.38	0.28	0.27	0.45

* Employment data not available.

‡ There were no withdrawals in the Lower New watershed in 2003, 2004, or 2005.

Table D-4. High and low scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by watershed for the Mining and Petroleum water use sector. Projections were completed for only those watersheds in which there was a 2011 withdrawal in the LQU database. Results are rounded to hundredths of billion gallons for display purposes.

HUC8	Withdrawals (Bgal)						Consumptive Use (Bgal)					
	HIGH			LOW			HIGH			LOW		
	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
South Branch Potomac*	0.04	0.05	0.05	0.04	0.03	0.03	0.01	0.01	0.01	0.005	0.004	0.004
Potomac Direct Drains	0.41	0.43	0.46	0.33	0.28	0.24	0.08	0.09	0.09	0.05	0.04	0.03
Tygart Valley	0.26	0.27	0.28	0.22	0.18	0.16	0.05	0.05	0.06	0.03	0.03	0.02
West Fork	0.22	0.24	0.25	0.18	0.15	0.13	0.04	0.05	0.05	0.03	0.02	0.02
Monongahela	0.42	0.44	0.46	0.35	0.29	0.25	0.08	0.09	0.09	0.05	0.04	0.03
Dunkard	1.00	1.03	1.07	0.82	0.69	0.58	0.20	0.21	0.21	0.12	0.10	0.08
Upper Ohio North	0.38	0.40	0.41	0.31	0.27	0.22	0.08	0.08	0.08	0.04	0.04	0.03
Upper Ohio South	1.84	1.91	1.99	1.52	1.28	1.08	0.37	0.38	0.40	0.21	0.18	0.15
Middle Ohio North	0.11	0.11	0.11	0.10	0.10	0.10	0.02	0.02	0.02	0.01	0.01	0.01
Lower New	0.40	0.42	0.43	0.33	0.28	0.23	0.08	0.08	0.09	0.05	0.04	0.03
Gauley	0.92	0.96	1.00	0.76	0.64	0.54	0.18	0.19	0.20	0.11	0.09	0.08
Upper Kanawha	1.97	2.05	2.13	1.63	1.37	1.15	0.39	0.41	0.43	0.23	0.19	0.16
Elk	0.20	0.21	0.22	0.17	0.14	0.12	0.04	0.04	0.04	0.02	0.02	0.02
Coal	5.00	5.21	5.42	4.14	3.49	2.94	1.00	1.04	1.08	0.58	0.49	0.41
Upper Guyandotte	1.78	1.85	1.92	1.47	1.24	1.04	0.36	0.37	0.38	0.21	0.17	0.15
Lower Guyandotte	0.21	0.22	0.23	0.17	0.15	0.12	0.04	0.04	0.05	0.02	0.02	0.02
Tug Fork	1.53	1.59	1.65	1.26	1.06	0.90	0.31	0.32	0.33	0.18	0.15	0.13
Lower Ohio*	0.002	0.002	0.002	0.002	0.002	0.002	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003
Twelvepole	0.41	0.43	0.45	0.34	0.29	0.24	0.08	0.09	0.09	0.05	0.04	0.03
TOTAL	17.12	17.82	18.54	14.15	11.95	10.08	3.42	3.56	3.71	1.98	1.67	1.41

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

Table D-5. Per employee withdrawal rate by county for the Mining and Petroleum water use sector. Counties where there was no withdrawal facility in 2011 are not shown (Preston, Pleasants).

County	Per Employee Withdrawal (Mgal)							Average (Mgal)
	2003	2004	2005	2008	2009	2010	2011	
Barbour‡					0.02	0.04	0.64	0.23
Boone	0.97	0.88	0.88	0.89	0.95	0.82	0.74	0.87
Brooke*	-	-	-	-	-	-	-	-
Clay	0.41	0.38	0.35	0.33	0.31	0.41	0.36	0.36
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	1.87	1.93	1.48	1.20
Kanawha	0.35	0.34	0.31	0.29	0.49	1.28	1.19	0.61
Logan	0.54	0.51	0.50	0.90	0.90	0.88	0.66	0.70
Marion	0.12	0.31	0.20	0.18	0.17	0.17	0.16	0.19
Marshall	1.21	1.23	0.98	1.01	1.15	0.91	0.87	1.05
McDowell	0.51	0.45	0.39	0.24	0.14	0.08	0.07	0.27
Mingo	0.46	0.45	0.58	0.38	0.40	0.39	0.31	0.42
Monongalia	2.01	2.00	1.79	1.49	1.38	1.18	0.91	1.54
Morgan	2.42	2.36	2.15	2.31	2.31	2.31	2.31	2.31
Nicholas	0.81	0.80	0.63	0.53	0.51	0.31	0.27	0.55
Pendleton*	-	-	-	-	-	-	-	-
Raleigh	0.89	0.77	0.61	0.64	0.65	0.62	0.30	0.64
Randolph	0.07	0.05	0.18	0.18	0.15	0.12	0.10	0.12
Upshur‡					0.03	0.04	0.22	0.09
Wayne	0.66	0.67	0.64	0.26	0.38	0.28	0.27	0.45
Webster	0.51	0.53	0.82	0.96	1.00	0.94	0.92	0.81
Wetzel	6.25	6.76	5.40	8.29	7.38	6.03	6.08	6.60
Wyoming	0.39	0.36	0.34	0.33	0.34	0.42	0.37	0.36

*Employment data not available.

‡ There were no withdrawals in the Barbour and Upshur watersheds in 2003, 2004, 2005, or 2008.

Table D-6. The projected number of employees in the Mining and Petroleum sector in 2020, 2030, and 2040 by county. The high scenario increases employment annually by 0.4 percent (BLS 2012). The low scenario decreases employment annually by 1.7 percent (WVU 2012).

County	HIGH Projected Employees			LOW Projected Employees		
	2020	2030	2040	2020	2030	2040
Barbour	357	367	379	298	251	211
Boone	3,851	4,009	4,171	3,185	2,684	2,261
Brooke*	-	-	-	-	-	-
Clay	440	460	480	362	305	256
Fayette	862	897	937	716	603	508
Hancock*	-	-	-	-	-	-
Harrison	187	197	207	151	129	109
Kanawha	2,704	2,814	2,928	2,234	1,882	1,587
Logan	2,334	2,429	2,529	1,931	1,626	1,369
Marion	1,770	1,840	1,915	1,462	1,232	1,037
Marshall	1,752	1,822	1,894	1,448	1,220	1,028
McDowell	2,030	2,110	2,198	1,677	1,412	1,189
Mingo	2,537	2,638	2,748	2,096	1,765	1,486
Monongalia	730	760	790	602	507	427
Morgan	177	187	197	143	123	103
Nicholas	1,293	1,343	1,396	1,070	901	759
Pendleton*	-	-	-	-	-	-
Raleigh	2,618	2,727	2,837	2,167	1,825	1,538
Randolph	263	273	283	218	184	154
Upshur	167	177	187	136	116	96
Wayne	922	962	1,002	759	640	539
Webster	330	340	350	276	233	196
Wetzel	32	32	32	29	29	29
Wyoming	1,325	1,375	1,435	1,097	924	779

*Employment data not available.

Table D-7. High and low scenario withdrawal projections for the Mining and Petroleum water use category by county. Employment data were not available for these sectors in three counties – Brooke, Hancock, and Pendleton. For these counties, the projected rates of change were applied directly to the water withdrawal value in 2011. Results are rounded to hundredths of billion gallons for display purposes.

County	Withdrawals (Bgal)						Consumptive Use (Bgal)					
	HIGH			LOW			HIGH			LOW		
	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
Barbour	0.08	0.09	0.09	0.07	0.06	0.05	0.02	0.02	0.02	0.01	0.01	0.01
Boone	3.37	3.51	3.65	2.79	2.35	1.98	0.67	0.70	0.73	0.39	0.33	0.28
Brooke	0.10	0.10	0.10	0.10	0.10	0.10	0.02	0.02	0.02	0.01	0.01	0.01
Clay	0.16	0.17	0.18	0.13	0.11	0.09	0.03	0.03	0.04	0.02	0.02	0.01
Fayette	0.36	0.38	0.40	0.30	0.25	0.21	0.07	0.08	0.08	0.04	0.04	0.03
Hancock	0.27	0.27	0.27	0.27	0.27	0.27	0.05	0.05	0.05	0.04	0.04	0.04
Harrison	0.22	0.24	0.25	0.18	0.15	0.13	0.04	0.05	0.05	0.03	0.02	0.02
Kanawha	1.64	1.71	1.78	1.35	1.14	0.96	0.33	0.34	0.36	0.19	0.16	0.13
Logan	1.63	1.70	1.77	1.35	1.13	0.96	0.33	0.34	0.35	0.19	0.16	0.13
Marion	0.33	0.35	0.36	0.27	0.23	0.19	0.07	0.07	0.07	0.04	0.03	0.03
Marshall	1.84	1.91	1.99	1.52	1.28	1.08	0.37	0.38	0.40	0.21	0.18	0.15
McDowell	0.55	0.57	0.59	0.45	0.38	0.32	0.11	0.11	0.12	0.06	0.05	0.04
Mingo	1.07	1.12	1.16	0.89	0.75	0.63	0.21	0.22	0.23	0.12	0.10	0.09
Monongalia	1.12	1.17	1.21	0.93	0.78	0.66	0.22	0.23	0.24	0.13	0.11	0.09
Morgan	0.41	0.43	0.46	0.33	0.28	0.24	0.08	0.09	0.09	0.05	0.04	0.03
Nicholas	0.71	0.74	0.77	0.59	0.50	0.42	0.14	0.15	0.15	0.08	0.07	0.06
Pendleton	0.04	0.04	0.04	0.04	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.01
Raleigh	1.68	1.75	1.82	1.39	1.17	0.99	0.34	0.35	0.36	0.19	0.16	0.14
Randolph*	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.004	0.003	0.003
Upshur*‡	0.02	0.02	0.02	0.01	0.01	0.01	0.003	0.003	0.004	0.002	0.002	0.002
Wayne	0.41	0.43	0.45	0.34	0.29	0.24	0.08	0.09	0.09	0.05	0.04	0.03
Webster	0.27	0.28	0.28	0.22	0.19	0.16	0.05	0.06	0.06	0.03	0.03	0.02
Wetzel	0.21	0.21	0.21	0.19	0.19	0.19	0.04	0.04	0.04	0.03	0.03	0.03
Wyoming	0.48	0.50	0.52	0.40	0.34	0.28	0.10	0.10	0.10	0.06	0.05	0.04
TOTAL	17.00	17.72	18.40	14.14	12.01	10.22	3.39	3.54	3.67	1.98	1.70	1.43

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

‡Consumptive use totals in these counties are shown to additional decimal places to show that the total is not equal to the withdrawal estimate.

Appendix E

Development of the Manufacturing withdrawal and consumptive use scenarios.

Historic Manufacturing withdrawals can be found in **Table C-3**. Results are shown in hundredths of billion gallons for display purposes.

<u>Manufacturing Watershed Withdrawal and Consumptive Use Method</u>

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.

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.

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.
    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.
    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.

10. If employment data were not available for a HUC8, apply the rate of change directly to the 2011 withdrawal.

Future consumptive use estimates by HUC8

11. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. High scenario – 13% (Shaffer and Runkle 2007)
12. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. Low scenario – 10% (Shaffer and Runkle 2007)

<u>Manufacturing County Withdrawal and Consumptive Use Method</u>

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.

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 by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.

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.
    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.
    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.
7. If employment data were not available for a county, apply the rate of change directly to the 2011 withdrawal.

Future consumptive use estimates by county

8. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. High scenario – 13% (Shaffer and Runkle 2007)
9. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    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 E-1. Number of employees in the Manufacturing sector by county and year using NAICS code 31-33. Counties where there was no withdrawal facility in 2011 are not shown (Greenbrier). Data source: WorkForce West Virginia.

County	Number of Employees						
	2003	2004	2005	2008	2009	2010	2011
Berkeley	2,570	2,403	2,589	1,893	1,446	1,366	1,393
Brooke	2,344	2,184	2,137	2,118	1,920	1,960	2,010
Cabell	4,884	4,948	5,071	5,120	4,685	4,592	4,705
Fayette	712	665	626	616	543	536	494
Hancock	5,187	4,579	4,298	2,869	2,830	2,839	2,808
Jackson	2,069	2,148	2,164	2,175	1,488	1,273	1,242
Jefferson	1,343	1,152	1,058	974	830	824	856
Kanawha	5,573	5,293	4,663	3,904	3,508	3,299	3,248
Marion	1,455	1,388	1,360	1,470	1,253	1,140	1,209
Marshall	1,913	1,847	1,759	1,518	1,326	1,218	1,217
Mason	606	548	589	657	619	649	666
Mineral	1,280	1,308	1,386	1,804	1,994	1,919	1,898
Monroe*	-	-	-	-	-	-	-
Pleasants	561	545	571	502	397	394	391
Tucker	302	287	286	257	241	247	251
Tyler	780	689	696	669	606	587	544
Wayne	707	758	741	672	565	553	554
Wood	5,370	5,016	4,403	3,644	3,466	3,244	3,162

*Employment data not available.

Table E-2. Past and projected number of employees by watershed for the Manufacturing water use sector. The high scenario increases employment by 1.5 percent annually (WVU 2012) and the low scenario decreases employment by 0.1 percent annually (BLS 2012). Watersheds where there was no withdrawal facility in 2011 are not shown (Greenbrier).

HUC8	Employees							HIGH Projected Employees			LOW Projected Employees		
	2003	2004	2005	2008	2009	2010	2011	2020	2030	2040	2020	2030	2040
North Branch Potomac	1,280	1,308	1,386	1,804	1,994	1,919	1,898	2,170	2,520	2,925	1,880	1,860	1,840
Potomac Direct Drains	960	864	811	237	106	124	226	259	299	348	226	226	226
Shenandoah Jefferson	383	288	247	737	724	700	630	720	835	970	621	611	601
Monongahela	1,455	1,388	1,360	1,470	1,253	1,140	1,209	1,382	1,604	1,862	1,200	1,190	1,180
Cheat	302	287	286	257	241	247	251	287	333	386	251	251	251
Upper Ohio North	7,231	6,516	6,172	4,910	4,486	4,674	4,740	5,419	6,290	7,300	4,695	4,645	4,595
Upper Ohio South	305	250	266	80	267	127	80	89	99	118	80	80	80
Middle Ohio North	3,249	3,078	3,023	2,686	2,326	2,197	2,150	2,458	2,853	3,310	2,132	2,112	2,092
Middle Ohio South	7,439	7,164	6,567	5,819	4,954	4,517	4,404	5,034	5,843	6,781	4,368	4,328	4,288
Upper New*	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper Kanawha	2,654	2,462	2,273	2,011	1,859	1,709	1,682	1,923	2,233	2,592	1,664	1,644	1,624
Lower Kanawha	3,631	3,496	3,016	2,509	2,192	2,126	2,060	2,355	2,732	3,171	2,042	2,022	2,002
Lower Guyandotte	4,884	4,948	5,071	5,120	4,685	4,592	4,705	5,381	6,245	7,248	4,660	4,610	4,560
Big Sandy	707	758	741	672	565	553	554	633	735	853	545	535	525
Lower Ohio	606	548	589	657	619	649	666	761	883	1,024	657	647	637

*Employment data not available.

Table E-3. Per employee Manufacturing water use by watershed. Watersheds where there was no withdrawal facility in 2011 are not shown (Greenbrier). Results rounded to hundredths of million gallons per employee for display purposes.

HUC8	Per Employee Withdrawal (Mgal)							Average (Mgal)
	2003	2004	2005	2008	2009	2010	2011	
North Branch Potomac	0.04	0.06	0.05	0.04	0.05	0.05	0.05	0.05
Potomac Direct Drains	3.94	4.41	4.75	15.63	34.89	11.02	6.07	11.53
Shenandoah Jefferson	0.10	0.14	0.20	0.06	0.08	0.07	0.06	0.10
Monongahela	0.82	0.87	0.83	0.79	0.93	1.03	0.97	0.89
Cheat	0.52	0.55	0.55	0.07	0.07	0.09	0.11	0.28
Upper Ohio North	7.73	8.56	7.23	13.04	14.72	13.16	13.36	11.12
Upper Ohio South	1.53	1.48	1.36	4.00	1.20	1.55	2.52	1.95
Middle Ohio North	18.41	19.38	19.66	21.81	19.81	21.12	21.36	20.22
Middle Ohio South	2.39	2.48	3.11	3.19	3.69	3.94	4.06	3.26
Upper New*	-	-	-	-	-	-	-	-
Upper Kanawha	17.04	18.41	19.94	23.33	21.27	23.13	23.50	20.94
Lower Kanawha	18.40	19.94	21.75	26.82	28.35	31.81	31.40	25.50
Lower Guyandotte	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.05
Big Sandy	0.22	0.12	0.13	0.12	0.16	0.10	0.13	0.14
Lower Ohio	0.61	0.64	0.64	0.52	0.43	0.45	0.44	0.53

*Employment data not available.

Table E-4. High and low Manufacturing scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by watershed. Projections were completed for only those watersheds in which there was a 2011 withdrawal in the LQU database. Results are rounded to hundredths of billion gallons for display purposes.

HUC8	Withdrawals (Bgal)						Consumptive Use (Bgal)					
	HIGH			LOW			HIGH			LOW		
	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
North Branch Potomac	0.11	0.12	0.14	0.09	0.09	0.09	0.01	0.02	0.02	0.01	0.01	0.01
Potomac Direct Drains	2.99	3.45	4.01	2.61	2.61	2.61	0.39	0.45	0.52	0.26	0.26	0.26
Shenandoah Jefferson	0.07	0.08	0.10	0.06	0.06	0.06	0.01	0.01	0.01	0.01	0.01	0.01
Monongahela	1.23	1.43	1.66	1.07	1.06	1.05	0.16	0.19	0.22	0.11	0.11	0.11
Cheat	0.08	0.09	0.11	0.07	0.07	0.07	0.01	0.01	0.01	0.01	0.01	0.01
Upper Ohio North	60.23	69.92	81.14	52.19	51.63	51.08	7.83	9.09	10.55	5.22	5.16	5.11
Upper Ohio South	0.17	0.19	0.23	0.16	0.16	0.16	0.02	0.03	0.03	0.02	0.02	0.02
Middle Ohio North	49.70	57.69	66.93	43.11	42.70	42.30	6.46	7.50	8.70	4.31	4.27	4.23
Middle Ohio South	16.43	19.07	22.14	14.26	14.13	14.00	2.14	2.48	2.88	1.43	1.41	1.40
Upper New*	0.02	0.03	0.03	0.02	0.02	0.02	0.003	0.003	0.004	0.002	0.002	0.002
Upper Kanawha	40.28	46.77	54.29	34.85	34.43	34.01	5.24	6.08	7.06	3.49	3.44	3.40
Lower Kanawha	60.04	69.65	80.85	52.06	51.55	51.04	7.81	9.05	10.51	5.21	5.16	5.10
Lower Guyandotte	0.29	0.34	0.39	0.25	0.25	0.25	0.04	0.04	0.05	0.03	0.03	0.02
Big Sandy	0.09	0.10	0.12	0.08	0.08	0.07	0.01	0.01	0.02	0.01	0.01	0.01
Lower Ohio	0.40	0.47	0.54	0.35	0.34	0.34	0.05	0.06	0.07	0.03	0.03	0.03
TOTAL	232.13	269.40	312.68	201.23	199.18	197.15	30.18	35.02	40.65	20.15	19.93	19.72

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

Table E-5. Per employee Manufacturing water use by county. Results rounded to hundredths of million gallons per employee for display purposes. Counties where there was no withdrawal facility in 2011 are not shown (Greenbrier).

County	Per Employee Withdrawal (Mgal)							Average (Mgal)
	2003	2004	2005	2008	2009	2010	2011	
Berkeley	1.44	1.54	1.43	1.95	2.55	0.99	0.97	1.55
Brooke	1.08	1.14	1.03	2.76	0.80	0.88	1.47	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	20.35	22.87	21.10	21.54	16.84
Jackson	0.37	0.38	0.41	0.35	0.44	0.13	0.08	0.31
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	31.40	25.50
Marion	0.82	0.87	0.83	0.79	0.93	1.03	0.97	0.89
Marshall	29.05	30.04	31.49	36.47	32.19	35.24	35.14	32.80
Mason	0.61	0.64	0.64	0.52	0.43	0.45	0.44	0.53
Mineral	0.04	0.06	0.05	0.04	0.05	0.05	0.05	0.05
Monroe*	-	-	-	-	-	-	-	-
Pleasants	3.46	3.93	3.78	2.71	3.31	3.80	3.39	3.48
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	5.08	5.43	5.62	4.57

*Employment data not available.

Table E-6. Projected number of employees in the Manufacturing sector by county in 2020, 2030, and 2040. The high scenario increases employment by 1.5 percent annually (WVU 2012) and the low scenario decreases employment by 0.1 percent annually (BLS 2012). Counties where there was no withdrawal facility in 2011 are not shown (Greenbrier).

County	HIGH Employment Projection			LOW Employment Projection		
	2020	2030	2040	2020	2030	2040
Berkeley	1,594	1,850	2,147	1,384	1,374	1,364
Brooke	2,298	2,667	3,095	1,992	1,972	1,952
Cabell	5,381	6,245	7,248	4,660	4,610	4,560
Fayette	565	656	761	494	494	494
Hancock	3,210	3,725	4,323	2,781	2,751	2,721
Jackson	1,420	1,648	1,912	1,233	1,223	1,213
Jefferson	978	1,136	1,318	847	837	827
Kanawha	3,713	4,310	5,005	3,221	3,191	3,161
Marion	1,382	1,604	1,862	1,200	1,190	1,180
Marshall	1,392	1,617	1,877	1,208	1,198	1,188
Mason	761	883	1,024	657	647	637
Mineral	2,170	2,520	2,925	1,880	1,860	1,840
Monroe*	-	-	-	-	-	-
Pleasants	446	518	601	391	391	391
Tucker	287	333	386	251	251	251
Tyler	622	722	837	535	525	515
Wayne	633	735	853	545	535	525
Wood	3,615	4,195	4,870	3,135	3,105	3,075

*Employment data not available.

Table E-7. High and low Manufacturing scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by county. Employment data were not available for Monroe County. To complete the projection for this county, the rates of change were applied directly to the water withdrawal value in 2011.

County	Withdrawals (Bgal)						Consumptive Use (Bgal)					
	HIGH			LOW			HIGH			LOW		
	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
Berkeley	2.47	2.87	3.33	2.15	2.13	2.12	0.32	0.37	0.43	0.21	0.21	0.21
Brooke*‡	3.00	3.49	4.05	0.001	0.001	0.001	0.39	0.45	0.53	0.0001	0.0001	0.0001
Cabell	0.29	0.34	0.39	0.25	0.25	0.25	0.04	0.04	0.05	0.03	0.03	0.02
Fayette	5.72	6.64	7.70	5.00	5.00	5.00	0.74	0.86	1.00	0.50	0.50	0.50
Hancock	54.04	62.71	72.78	46.82	46.32	45.81	7.03	8.15	9.46	4.68	4.63	4.58
Jackson	0.44	0.51	0.59	0.38	0.38	0.37	0.06	0.07	0.08	0.04	0.04	0.04
Jefferson	0.10	0.11	0.13	0.08	0.08	0.08	0.01	0.01	0.02	0.01	0.01	0.01
Kanawha	94.67	109.90	127.62	82.13	81.36	80.60	12.31	14.29	16.59	8.21	8.14	8.06
Marion	1.23	1.43	1.66	1.07	1.06	1.05	0.16	0.19	0.22	0.11	0.11	0.11
Marshall	45.66	53.04	61.57	39.63	39.30	38.97	5.94	6.90	8.00	3.96	3.93	3.90
Mason	0.40	0.47	0.54	0.35	0.34	0.34	0.05	0.06	0.07	0.03	0.03	0.03
Mineral	0.11	0.12	0.14	0.09	0.09	0.09	0.01	0.02	0.02	0.01	0.01	0.01
Monroe*	0.02	0.03	0.03	0.02	0.02	0.02	0.003	0.003	0.004	0.002	0.002	0.002
Pleasants	1.55	1.80	2.09	1.36	1.36	1.36	0.20	0.23	0.27	0.14	0.14	0.14
Tucker	0.08	0.09	0.11	0.07	0.07	0.07	0.01	0.01	0.01	0.01	0.01	0.01
Tyler	2.01	2.33	2.70	1.73	1.69	1.66	0.26	0.30	0.35	0.17	0.17	0.17
Wayne	0.09	0.10	0.12	0.08	0.08	0.07	0.01	0.01	0.02	0.01	0.01	0.01
Wood	16.53	19.18	22.27	14.33	14.20	14.06	2.15	2.49	2.89	1.43	1.42	1.41
TOTAL	228.43	265.17	307.83	195.54	193.73	191.93	29.70	34.47	40.02	19.55	19.37	19.19

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

‡Consumptive use totals in these counties are shown to additional decimal places to show that the total is not equal to the withdrawal estimate.

Appendix F

Development of the Recreation withdrawal and consumptive use scenarios.

Historic Recreation withdrawals can be found in **Table A-3**. Results are shown in hundredths of billion gallons for display purposes.

<u>Recreation Watershed Withdrawal and Consumptive Use Method</u>

Past withdrawal by HUC8

1. Sum Recreation withdrawals by HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.

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.

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.
    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.
    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

Future consumptive use estimates by HUC8

10. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    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.
    a. Low scenario – 55%, the average of median industrial and irrigation coefficients (Shaffer and Runkle 2007)

<u>Recreation County Withdrawal and Consumptive Use Method</u>

Past withdrawal by county

1. Sum Recreation withdrawals by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.

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.

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.
    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.
    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

Future consumptive use estimates by county

7. Multiply high scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    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.
    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 F-1. Number of employees in the Recreation sector by county and year using available information from NAICS codes 71 and 72 and the overarching category of Leisure and Hospitality (L&H). The notes column explains how the available employment data were used to estimate employment for the Recreation sector in each county. Data source: WorkForce West Virginia.

County	Employment							Notes						
	2003	2004	2005	2008	2009	2010	2011	2003	2004	2005	2008	2009	2010	2011
Berkeley	544	561	599	666	675	616	620	71+721	71+721	71+721	71+721	71+721	71+721	71+721
Greenbrier	1,910	1,881	1,852	1,632	1,410	1,889	2,929	71+72-722	no data – avg. of 2003 and 2004	71+72-7221-7222-7224	71+721	71+721	71+72-7221-7222	71+72-7224
Hampshire	157	159	151	189	172	189	189	L&H-72+721	L&H-72+721	71+721	L&H-72+721	L&H-72+721	L&H-72+721	L&H-72+721
Hancock	1,720	1,747	1,796	346	328	328	308	L&H-72	L&H-72	L&H-72	L&H-72	L&H-72	L&H-72	L&H-72
Hardy	57	84	94	71	53	67	50	71+721	71+721	71+72-7221-7222	71+721	721	71+721	721
Jefferson	1,865	2,016	1,949	2,085	1,958	2,318	726	L&H-72+721	L&H-72+721	L&H-72+721	71+721	71+721	L&H-72+721	L&H-72+72111+72119
Kanawha	2,518	2,475	2,558	2,643	2,762	2,683	2,611	71+721	71+721	71+721	71+721	71+721	71+721	71+721
Lewis	309	342	354	380	338	334	354	71+721	L&H-72+721	71+72-7221-7222	71+72-7221-7222	71+721	71+721	71+721
Mingo	83	85	67	76	76	72	75	71+721	71+721	L&H-72+721	71+721	71+721	71+721	71+721
Monongalia	841	1,135	1,220	1,210	1,222	1,294	1,341	71+721	71+721	71+721	71+721	71+721	71+721	71+721
Pocahontas	2	3	19	3	5	7	8	L&H-72	L&H-72	L&H-72	L&H-72	L&H-72	L&H-72	L&H-72
Preston	146	177	175	151	132	128	161	71+721	71+72-7221-7222	71+72-7221-7222	71+721	71+721	71+721	71+721
Raleigh	1,002	984	992	817	781	767	938	71+721	71+721	71+721	71+721	71+721	71+721	71+721
Wood	651	735	813	805	797	770	799	71+721	71+721	71+721	71+721	71+721	71+721	71+721

Table F-2. Past and projected number of employees in the Recreation sector by watershed. The high scenario increases employment by 1 percent annually (BLS 2012) and the low scenario did not change employment into the future WVUS 2012).

HUC8	Employees							HIGH Projected Employees			LOW Projected Employees		
	2003	2004	2005	2008	2009	2010	2011	2020	2030	2040	2020	2030	2040
South Branch Potomac	57	84	94	71	53	67	50	59	69	79	50	50	50
Cacapon	157	159	151	189	172	189	189	207	227	247	189	189	189
Potomac Direct Drains	2,409	1,477	861	1,154	1,160	1,190	800	874	965	1,066	800	800	800
Shenandoah Jefferson*	-	1,100	1,687	1,597	1,473	1,744	546	599	660	730	546	546	546
West Fork	309	342	354	380	338	334	354	390	430	475	354	354	354
Monongahela*	-	-	-	1,210	1,222	1,294	1,341	1,467	1,621	1,791	1,341	1,341	1,341
Cheat	148	180	194	154	137	135	169	187	207	227	169	169	169
Upper Ohio North	1,720	1,747	1,796	346	328	328	308	335	370	410	308	308	308
Middle Ohio South	651	735	813	805	797	770	799	873	964	1,065	799	799	799
Greenbrier	1,910	1,881	1,852	1,632	1,410	1,889	2,929	3,203	3,538	3,908	2,929	2,929	2,929
Lower New	1,002	984	992	817	781	767	938	1,026	1,133	1,251	938	938	938
Elk‡	1	1	1	1	1	1	1	1	1	1	1	1	1
Lower Kanawha	2,518	2,475	2,558	2,643	2,762	2,683	2,611	2,855	3,154	3,485	2,611	2,611	2,611
Tug Fork	83	85	67	76	76	72	75	84	94	104	75	75	75

*Dashes indicate that there was no withdrawal in the given year, and therefore employment data are not needed.

‡Employment in Elk watershed was rounded up to a whole number to ensure the withdrawal was represented.

Table F-3. Per employee Recreation water use by watershed. Results rounded to hundredths of million gallons per employee for display purposes.

HUC8	Per Employee Withdrawal (Mgal)							Average (Mgal)
	2003	2004	2005	2008	2009	2010	2011	
South Branch Potomac	0.12	0.08	0.12	0.12	0.15	0.12	0.16	0.12
Cacapon	0.04	0.04	0.06	0.04	0.04	0.04	0.04	0.04
Potomac Direct Drains	0.03	0.04	0.04	0.04	0.04	0.04	0.06	0.04
Shenandoah Jefferson	0.00	0.02	0.04	0.03	0.03	0.02	0.08	0.04
West Fork	0.07	0.10	0.11	0.10	0.11	0.11	0.08	0.10
Monongahela*‡	-	-	-	0.02	0.02	0.02	0.004	0.01
Cheat	2.89	2.44	2.66	2.99	3.63	3.65	2.22	2.93
Upper Ohio North	0.04	0.04	0.04	0.33	0.27	0.27	0.28	0.18
Middle Ohio South	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Greenbrier	0.45	0.46	0.47	0.53	0.70	0.36	0.23	0.46
Lower New	0.11	0.12	0.19	0.25	0.21	0.23	0.18	0.18
Elk	5.77	4.55	7.26	5.86	5.83	10.83	7.47	6.80
Lower Kanawha*	0.005	0.005	0.005	0.005	0.004	0.005	0.005	0.005
Tug Fork	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

‡There was not an intake facility in the Monongahela watershed in 2003, 2004, or 2005.

Table F-4. High and low Recreation scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by watershed. Projections were completed for only those watersheds in which there was a 2011 withdrawal in the LQU database. Results are shown in hundredths of billion gallons for display purposes.

HUC8	Withdrawals (Bgal)						Consumptive Use (Bgal)					
	HIGH			LOW			HIGH			LOW		
	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
South Branch Potomac*‡	0.01	0.01	0.01	0.0001	0.0001	0.0001	0.004	0.005	0.006	0.00007	0.00007	0.00007
Cacapon*‡	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.006	0.006	0.005	0.005	0.005
Potomac Direct Drains	0.03	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Shenandoah Jefferson	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
West Fork	0.04	0.04	0.05	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.02
Monongahela	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Cheat	0.55	0.61	0.66	0.49	0.49	0.49	0.31	0.34	0.38	0.27	0.27	0.27
Upper Ohio North*	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Middle Ohio South*‡	0.01	0.01	0.01	0.01	0.01	0.01	0.004	0.005	0.005	0.004	0.004	0.004
Greenbrier	1.47	1.62	1.79	1.34	1.34	1.34	0.83	0.92	1.01	0.74	0.74	0.74
Lower New	0.19	0.21	0.23	0.17	0.17	0.17	0.11	0.12	0.13	0.10	0.10	0.10
Elk*‡	0.01	0.01	0.01	0.01	0.01	0.01	0.004	0.004	0.004	0.004	0.004	0.004
Lower Kanawha*‡	0.01	0.01	0.02	0.01	0.01	0.01	0.008	0.008	0.01	0.007	0.007	0.007
Tug Fork*	0.003	0.003	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.001	0.001	0.001
TOTAL	2.36	2.60	2.87	2.13	2.13	2.13	1.33	1.47	1.62	1.19	1.19	1.19

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

‡Consumptive use totals in these counties are shown to additional decimal places to show that the total is not equal to the withdrawal estimate.

Table F-5. Per employee Recreation water use by county. Results are shown in hundredths of million gallons for display purposes.

County	Per Employee Withdrawal (Mgal)							Average (Mgal)
	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	0.7	0.36	0.23	0.46
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*	0.005	0.005	0.005	0.005	0.004	0.005	0.005	0.005
Lewis	0.07	0.1	0.11	0.1	0.11	0.11	0.08	0.1
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	214.83	146.75	27.33	154.36	99.92	71.53	47.4	108.87
Preston	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02
Raleigh	0.11	0.12	0.19	0.25	0.21	0.23	0.18	0.18
Wood	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

*Values rounded to additional decimal places when result was less than 0.01 Mgal.
‡There was no intake facility in Monongalia County in 2003, 2004, or 2005.

Table F-6. Projected number of employees in the Recreation sector by county in 2020, 2030, and 2040. The high scenario increases employment by 1 percent annually (BLS 2012) and the low scenario did not change employment into the future (WVU 2012).

County	HIGH Projected Employees			LOW Projected Employees		
	2020	2030	2040	2020	2030	2040
Berkeley	678	748	827	620	620	620
Greenbrier	3203	3538	3908	2929	2929	2929
Hampshire	207	227	247	189	189	189
Hancock	335	370	410	308	308	308
Hardy	59	69	79	50	50	50
Jefferson	794	877	968	726	726	726
Kanawha	2855	3154	3485	2611	2611	2611
Lewis	390	430	475	354	354	354
Mingo	84	94	104	75	75	75
Monongalia	1467	1621	1791	1341	1341	1341
Pocahontas	8	8	8	8	8	8
Preston	179	199	219	161	161	161
Raleigh	1026	1133	1251	938	938	938
Wood	873	964	1065	799	799	799

Table F-7. High and low Recreation scenario withdrawal and consumptive use projections for 2020, 2030, and 2040 by county. Results are shown in hundredths of billion gallons for display purposes.

County	Withdrawals (Bgal)						Consumptive Use (Bgal)					
	HIGH			LOW			HIGH			LOW		
	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
Berkeley	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.02
Greenbrier	1.47	1.62	1.79	1.34	1.34	1.34	0.83	0.92	1.01	0.74	0.74	0.74
Hampshire*‡	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.006	0.006	0.005	0.005	0.005
Hancock	0.06	0.07	0.07	0.06	0.06	0.06	0.03	0.04	0.04	0.03	0.03	0.03
Hardy*‡	0.01	0.01	0.01	0.01	0.01	0.01	0.004	0.005	0.006	0.003	0.003	0.003
Jefferson	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01
Kanawha*‡	0.01	0.01	0.02	0.01	0.01	0.01	0.008	0.008	0.009	0.007	0.007	0.007
Lewis	0.04	0.04	0.05	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.02
Mingo*	0.003	0.003	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.001	0.001	0.001
Monongalia	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Pocahontas	0.87	0.87	0.87	0.87	0.87	0.87	0.17	0.17	0.17	0.48	0.48	0.48
Preston*	0.004	0.004	0.005	0.004	0.004	0.004	0.001	0.001	0.001	0.002	0.002	0.002
Raleigh	0.19	0.21	0.23	0.17	0.17	0.17	0.04	0.04	0.05	0.10	0.10	0.10
Wood*‡	0.01	0.01	0.01	0.01	0.01	0.01	0.002	0.002	0.002	0.004	0.004	0.004
TOTAL	2.77	2.95	3.16	2.59	2.59	2.59	1.15	1.26	1.39	1.43	1.43	1.43

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

‡Consumptive use totals in these counties are shown to additional decimal places to show that the total is not equal to the withdrawal estimate.

Appendix G

Development of the Public Water Supply withdrawal and consumptive use scenarios.

Historic Public Water Supply withdrawals can be found in **Table A-6**. Results are shown in hundredths of billion gallons for display purposes.

<u>Public Water Supply Watershed Withdrawal and Consumptive Use Method</u>

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)

<u>Public Water Supply County Withdrawal and Consumptive Use Method</u>

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)/2020

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 G-1. Past population and future population projections by county. Population data for 2000 and 2010 were provided by DEP from the U.S. Census. Population figures for 2003, 2004, 2005, 2008, and 2009, were interpolated from known years of data, and 2011 was extrapolated. Population projections for 2020 and 2030 are from *Population Projection for West Virginia Counties* (Cristiadi 2011). Population in 2040 was extrapolated from Cristiadi (2011) estimates. Wirt County is not included in this table because there was not Public Water Supply withdrawal in that county in the LQU database.

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
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

County	Population							Population Projection		
	2003	2004	2005	2008	2009	2010	2011	2020	2030	2040
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
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
TOTAL	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

Table G-2. Past and projected population by watershed. Watersheds with no Public Water Supply withdrawals in the LQU database are not listed (Dunkard, James, Shenandoah Hardy). Note that the totals between the county population and watershed population tables are slightly different due to the assumptions used to apportion county population numbers to the watershed level.

HUC8	Population							Population Projection		
	2003	2004	2005	2008	2009	2010	2011	2020	2030	2040
South Branch Potomac	30,624	30,775	30,927	31,380	31,531	31,682	31,833	33,022	33,116	31,866
North Branch Potomac	30,789	30,918	31,047	31,434	31,563	31,692	31,821	32,709	32,689	31,602
Cacapon	21,997	22,376	22,755	23,891	24,270	24,649	25,028	27,216	28,599	28,529
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
Tygart Valley	86,406	86,797	87,188	88,362	88,753	89,144	89,535	92,142	92,373	89,745
West Fork	103,280	103,425	103,571	104,008	104,153	104,299	104,445	106,039	105,759	103,415
Monongahela	112,630	113,892	115,155	118,942	120,205	121,467	122,730	131,294	142,568	155,815
Cheat	35,032	35,516	36,000	37,452	37,936	38,420	38,904	39,917	40,765	41,071
Youghiogheny	3,771	3,795	3,820	3,893	3,918	3,942	3,967	4,014	3,970	3,810
Upper Ohio North	46,969	46,696	46,424	45,605	45,332	45,059	44,786	42,660	39,340	35,312
Upper Ohio South	93,772	93,142	92,513	90,624	89,995	89,365	88,736	85,092	79,536	72,994
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
Little Kanawha	100,942	100,983	101,024	101,146	101,187	101,228	101,269	101,051	98,023	92,351
Upper New	75,699	75,692	75,685	75,663	75,656	75,649	75,642	74,573	72,188	68,593
Greenbrier	43,564	43,627	43,690	43,878	43,941	44,004	44,067	44,575	43,498	40,827
Lower New	93,586	93,743	93,901	94,373	94,531	94,688	94,846	94,595	92,150	87,471
Gauley	42,617	42,510	42,403	42,082	41,975	41,868	41,761	41,970	40,936	38,804
Upper Kanawha	65,833	65,324	64,816	63,289	62,781	62,272	61,763	61,527	59,687	56,833
Elk	59,752	59,505	59,259	58,520	58,273	58,027	57,781	56,382	53,925	50,738
Lower Kanawha	161,361	161,481	161,602	161,964	162,084	162,205	162,326	163,928	161,885	156,035
Coal	58,067	57,927	57,788	57,368	57,229	57,089	56,949	56,122	53,952	50,699
Upper Guyandotte	54,712	54,292	53,872	52,612	52,192	51,772	51,352	49,087	45,208	40,403
Lower Guyandotte	85,984	86,156	86,328	86,843	87,014	87,186	87,358	86,134	83,922	80,708
Tug Fork	53,154	52,488	51,822	49,823	49,157	48,491	47,825	45,321	41,277	36,598
Big Sandy	6,825	6,838	6,850	6,887	6,900	6,912	6,924	6,757	6,398	5,860
Lower Ohio	55,728	55,490	55,253	54,539	54,301	54,063	53,825	53,947	53,477	52,673
Twelvepole	30,141	30,127	30,113	30,070	30,056	30,042	30,028	29,341	27,799	25,530
TOTAL	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

Table G-3. Per capita Public Water Supply withdrawal by watershed. Results rounded to hundredths of million gallons for display purposes. Watersheds with no Public Water Supply withdrawals in the LQU database are not listed (Dunkard, James, Shenandoah Hardy).

HUC8	Per Capita Withdrawal (Mgal)							Average (Mgal)
	2003	2004	2005	2008	2009	2010	2011	
South Branch Potomac	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.06
North Branch Potomac	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02
Cacapon*	0.003	0.003	0.002	0.003	0.003	0.003	0.003	0.003
Potomac Direct Drains	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.03
Shenandoah Jefferson	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02
Tygart Valley	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07
West Fork	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Monongahela	0.07	0.07	0.06	0.06	0.06	0.03	0.03	0.05
Cheat	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Youghiogheny	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.03
Upper Ohio North	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04
Upper Ohio South	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Middle Ohio North	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.04
Middle Ohio South	0.05	0.05	0.05	0.04	0.05	0.05	0.11	0.05
Little Kanawha	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Upper New	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03
Greenbrier	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Lower New	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Gauley	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Upper Kanawha	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Elk	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.20
Lower Kanawha	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Coal	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Upper Guyandotte	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Lower Guyandotte	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Tug Fork	0.05	0.05	0.05	0.06	0.05	0.06	0.06	0.05
Big Sandy	0.12	0.13	0.14	0.13	0.11	0.11	0.11	0.12
Lower Ohio	0.09	0.08	0.09	0.09	0.09	0.09	0.09	0.09
Twelvepole	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

*Values rounded to additional decimal places when result was less than 0.01 Bgal.

Table G-4. Projected withdrawals and high and low consumptive use estimates by watershed in 2020, 2030, and 2040 for the Public Water Supply water use sector. Watersheds with no Public Water Supply withdrawals in the LQU database are not listed (Dunkard, James, Shenandoah Hardy). Results are shown in hundredths of billion gallons for display purposes.

HUC8	Withdrawal (Bgal)			HIGH Consumptive Use (Bgal)			LOW Consumptive Use (Bgal)		
	2020	2030	2040	2020	2030	2040	2020	2030	2040
South Branch Potomac	2.06	2.07	1.99	0.41	0.41	0.40	0.31	0.31	0.30
North Branch Potomac	0.69	0.68	0.66	0.14	0.14	0.13	0.10	0.10	0.10
Cacapon	0.07	0.08	0.08	0.01	0.02	0.02	0.01	0.01	0.01
Potomac Direct Drains	5.95	7.05	8.17	1.19	1.41	1.63	0.89	1.06	1.23
Shenandoah Jefferson	0.89	1.01	1.11	0.18	0.20	0.22	0.13	0.15	0.17
Tygart Valley	6.27	6.28	6.10	1.25	1.26	1.22	0.94	0.94	0.92
West Fork	3.18	3.18	3.11	0.64	0.64	0.62	0.48	0.48	0.47
Monongahela	7.20	7.82	8.55	1.44	1.56	1.71	1.08	1.17	1.28
Cheat	0.77	0.78	0.79	0.15	0.16	0.16	0.12	0.12	0.12
Youghiogheny	0.11	0.11	0.10	0.02	0.02	0.02	0.02	0.02	0.02
Upper Ohio North	1.81	1.67	1.50	0.36	0.33	0.30	0.27	0.25	0.22
Upper Ohio South	3.67	3.43	3.15	0.73	0.69	0.63	0.55	0.51	0.47
Middle Ohio North	1.40	1.28	1.13	0.28	0.26	0.23	0.21	0.19	0.17
Middle Ohio South	4.36	4.34	4.21	0.87	0.87	0.84	0.65	0.65	0.63
Little Kanawha	1.16	1.13	1.06	0.23	0.23	0.21	0.17	0.17	0.16
Upper New	2.59	2.51	2.38	0.52	0.50	0.48	0.39	0.38	0.36
Greenbrier	1.25	1.22	1.14	0.25	0.24	0.23	0.19	0.18	0.17
Lower New	4.39	4.27	4.06	0.88	0.85	0.81	0.66	0.64	0.61
Gauley	1.20	1.17	1.11	0.24	0.23	0.22	0.18	0.18	0.17
Upper Kanawha	1.23	1.19	1.13	0.25	0.24	0.23	0.18	0.18	0.17
Elk	11.53	11.03	10.38	2.31	2.21	2.08	1.73	1.65	1.56
Lower Kanawha	0.89	0.88	0.85	0.18	0.18	0.17	0.13	0.13	0.13
Coal	0.59	0.57	0.54	0.12	0.11	0.11	0.09	0.09	0.08
Upper Guyandotte	1.28	1.17	1.05	0.26	0.23	0.21	0.19	0.18	0.16
Lower Guyandotte	1.06	1.03	0.99	0.21	0.21	0.20	0.16	0.15	0.15
Tug Fork	2.36	2.15	1.91	0.47	0.43	0.38	0.35	0.32	0.29
Big Sandy	0.83	0.78	0.72	0.17	0.16	0.14	0.12	0.12	0.11
Lower Ohio	4.79	4.74	4.67	0.96	0.95	0.93	0.72	0.71	0.70
Twelvepole	0.20	0.19	0.18	0.04	0.04	0.04	0.03	0.03	0.03
TOTAL	73.78	73.81	72.82	14.76	14.78	14.57	11.05	11.07	10.96

Table G-5. Per capita Public Water Supply withdrawal in each county. Results are shown in hundredths of million gallons for display purposes.

County	Per Capita Withdrawal (Mgal)							Average (Mgal)
	2003	2004	2005	2008	2009	2010	2011	
Barbour	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Berkeley	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04
Boone*	0.003	0.002	0.002	0.002	0.003	0.003	0.003	0.002
Braxton	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.02
Brooke	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Cabell	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Calhoun	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Clay	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Doddridge	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fayette	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04
Gilmer	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.02
Grant	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Greenbrier	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
Hampshire	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Hancock	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Hardy	0.09	0.10	0.11	0.10	0.10	0.10	0.10	0.10
Harrison	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Jackson	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Jefferson	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Kanawha	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Lewis	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Lincoln	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Logan	0.03	0.04	0.03	0.06	0.04	0.04	0.04	0.04
Marion	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05
Marshall	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03
Mason	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
McDowell	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.04
Mercer	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02
Mineral	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02
Mingo	0.05	0.05	0.05	0.06	0.04	0.05	0.06	0.05
Monongalia	0.09	0.08	0.08	0.08	0.08	0.04	0.04	0.07
Monroe	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Morgan	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01
Nicholas	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03
Ohio	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.05
Pendleton	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Pleasants	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Pocahontas	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Preston	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Putnam	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02
Raleigh	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Randolph	0.03	0.06	0.04	0.04	0.04	0.04	0.04	0.04
Ritchie	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02
Roane	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

County	Per Capita Withdrawal (Mgal)							Average (Mgal)
	2003	2004	2005	2008	2009	2010	2011	
Summers	0.07	0.08	0.08	0.07	0.07	0.07	0.07	0.07
Taylor	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Tucker	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Tyler	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Upshur	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Wayne	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03
Webster	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Wetzel	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Wood	0.04	0.04	0.03	0.03	0.03	0.03	0.09	0.04
Wyoming	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.03

*Values rounded to additional decimal places when result was less than 0.01 Mgal.

Table G-6. Projected withdrawals and high and low consumptive use estimates by county in 2020, 2030, and 2040 for the Public Water Supply water use sector. Counties with no Public Water Supply withdrawals in the LQU database are not listed (Wirt). Results are shown in hundredths of billion gallons for display purposes.

County	Withdrawals (Bgal)			HIGH Consumptive Use (Bgal)			LOW Consumptive Use (Bgal)		
	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	3.51	4.24	4.93	0.70	0.85	0.99	0.53	0.64	0.74
Boone	0.65	0.61	0.59	0.13	0.12	0.12	0.10	0.09	0.09
Braxton	0.39	0.38	0.37	0.08	0.08	0.07	0.06	0.06	0.06
Brooke	0.62	0.57	0.53	0.12	0.11	0.11	0.09	0.09	0.08
Cabell	2.62	2.61	2.60	0.52	0.52	0.52	0.39	0.39	0.39
Calhoun	0.21	0.20	0.20	0.04	0.04	0.04	0.03	0.03	0.03
Clay	0.23	0.20	0.17	0.05	0.04	0.03	0.03	0.03	0.03
Doddridge	0.22	0.20	0.19	0.04	0.04	0.04	0.03	0.03	0.03
Fayette	1.23	1.17	1.13	0.25	0.23	0.23	0.18	0.17	0.17
Gilmer	0.23	0.23	0.22	0.05	0.05	0.04	0.04	0.03	0.03
Grant	0.33	0.33	0.33	0.07	0.07	0.07	0.05	0.05	0.05
Greenbrier	1.01	1.01	1.04	0.20	0.20	0.21	0.15	0.15	0.16
Hampshire	0.72	0.75	0.81	0.14	0.15	0.16	0.11	0.11	0.12
Hancock	0.79	0.73	0.68	0.16	0.15	0.14	0.12	0.11	0.10
Hardy	0.42	0.45	0.48	0.08	0.09	0.10	0.06	0.07	0.07
Harrison	1.92	1.92	1.95	0.38	0.38	0.39	0.29	0.29	0.29
Jackson	0.84	0.86	0.90	0.17	0.17	0.18	0.13	0.13	0.13
Jefferson	1.71	1.94	2.19	0.34	0.39	0.44	0.26	0.29	0.33
Kanawha	5.21	5.07	4.99	1.04	1.01	1.00	0.78	0.76	0.75
Lewis	0.44	0.42	0.41	0.09	0.08	0.08	0.07	0.06	0.06
Lincoln	0.58	0.54	0.52	0.12	0.11	0.10	0.09	0.08	0.08
Logan	0.96	0.89	0.84	0.19	0.18	0.17	0.14	0.13	0.13
Marion	1.55	1.54	1.54	0.31	0.31	0.31	0.23	0.23	0.23
Marshall	0.84	0.77	0.70	0.17	0.15	0.14	0.13	0.11	0.11
Mason	0.76	0.74	0.75	0.15	0.15	0.15	0.11	0.11	0.11
McDowell	0.55	0.49	0.44	0.11	0.10	0.09	0.08	0.07	0.07
Mercer	1.69	1.64	1.62	0.34	0.33	0.32	0.25	0.25	0.24
Mineral	0.79	0.79	0.81	0.16	0.16	0.16	0.12	0.12	0.12

County	Withdrawals (Bgal)			HIGH Consumptive Use (Bgal)			LOW Consumptive Use (Bgal)		
	2020	2030	2040	2020	2030	2040	2020	2030	2040
Mingo	0.69	0.64	0.59	0.14	0.13	0.12	0.10	0.10	0.09
Monongalia	2.94	3.32	3.66	0.59	0.66	0.73	0.44	0.50	0.55
Monroe	0.35	0.33	0.32	0.07	0.07	0.06	0.05	0.05	0.05
Morgan	0.54	0.57	0.63	0.11	0.11	0.13	0.08	0.09	0.09
Nicholas	0.71	0.69	0.69	0.14	0.14	0.14	0.11	0.10	0.10
Ohio	1.17	1.12	1.08	0.23	0.22	0.22	0.18	0.17	0.16
Pendleton	0.20	0.18	0.17	0.04	0.04	0.03	0.03	0.03	0.03
Pleasants	0.20	0.19	0.18	0.04	0.04	0.04	0.03	0.03	0.03
Pocahontas	0.23	0.21	0.21	0.05	0.04	0.04	0.03	0.03	0.03
Preston	0.93	0.92	0.93	0.19	0.18	0.19	0.14	0.14	0.14
Putnam	1.59	1.62	1.68	0.32	0.32	0.34	0.24	0.24	0.25
Raleigh	2.18	2.16	2.17	0.44	0.43	0.43	0.33	0.32	0.33
Randolph	0.80	0.77	0.77	0.16	0.15	0.15	0.12	0.12	0.12
Ritchie	0.29	0.28	0.29	0.06	0.06	0.06	0.04	0.04	0.04
Roane	0.40	0.37	0.35	0.08	0.07	0.07	0.06	0.05	0.05
Summers	0.36	0.34	0.32	0.07	0.07	0.06	0.05	0.05	0.05
Taylor	0.50	0.52	0.55	0.10	0.10	0.11	0.07	0.08	0.08
Tucker	0.19	0.18	0.18	0.04	0.04	0.04	0.03	0.03	0.03
Tyler	0.23	0.21	0.19	0.05	0.04	0.04	0.03	0.03	0.03
Upshur	0.68	0.68	0.70	0.14	0.14	0.14	0.10	0.10	0.11
Wayne	1.13	1.07	1.04	0.23	0.21	0.21	0.17	0.16	0.16
Webster	0.25	0.23	0.23	0.05	0.05	0.05	0.04	0.04	0.03
Wetzel	0.42	0.39	0.35	0.08	0.08	0.07	0.06	0.06	0.05
Wood	2.38	2.33	2.33	0.48	0.47	0.47	0.36	0.35	0.35
Wyoming	0.60	0.55	0.50	0.12	0.11	0.10	0.09	0.08	0.07
TOTAL	51.47	51.67	52.57	10.32	10.33	10.55	7.70	7.75	7.90

Appendix H

Development of the Thermoelectric withdrawal and consumptive use scenarios.

Historic Thermoelectric withdrawals can be found in **Table A-9**. Results are shown in hundredths of billion gallons for display purposes.

Thermoelectric Watershed Withdrawal and Consumptive Use Method

Past withdrawal by HUC8

1. Sum Thermoelectic withdrawals by HUC8 for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.

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 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 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.

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)
5. Multiply low 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. Low scenario – 2% (Shaffer and Runkle 2007)

Thermoelectric County Withdrawal and Consumptive Use Method

Past withdrawal by county

1. Sum Thermoelectic withdrawals by county for 2003, 2004, 2005, 2008, 2009, 2010, and 2011.

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.

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)
5. Multiply low scenario 2020, 2030, and 2040 withdrawal estimates by consumptive use coefficients.
    a. Low scenario – 2% (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 H-1. Projected high and low scenario Thermoelectric withdrawals and consumptive use estimates by watershed. Results are shown in hundredths of billion gallons for display purposes.

HUC8	Withdrawals (Bgal)						Consumptive Use (Bgal)					
	HIGH			LOW			HIGH			LOW		
	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
North Branch Potomac	327.02	312.28	298.21	327.02	312.28	298.21	13.08	12.49	11.93	6.54	6.25	5.96
Shenandoah Jefferson	173.10	165.30	157.85	173.10	165.30	157.85	6.92	6.61	6.31	3.46	3.31	3.16
West Fork	11.10	10.60	10.12	11.10	10.60	10.12	0.44	0.42	0.40	0.22	0.21	0.20
Monongahela	25.11	23.97	22.89	24.62	23.51	22.45	1.00	0.96	0.92	0.49	0.47	0.45
Cheat	691.50	660.34	630.58	690.93	659.80	630.07	27.66	26.41	25.22	13.82	13.20	12.60
Upper Ohio South	114.48	109.32	104.40	7.10	6.78	6.48	4.58	4.37	4.18	0.14	0.14	0.13
Middle Ohio North	18.55	17.71	16.91	5.72	5.46	5.21	0.74	0.71	0.68	0.11	0.11	0.10
Middle Ohio South	93.77	89.55	85.51	4.87	4.65	4.44	3.75	3.58	3.42	0.10	0.09	0.09
Upper Kanawha*	76.91	73.44	70.14				3.08	2.94	2.81			
Lower Kanawha	10.76	10.28	9.82	10.76	10.28	9.82	0.43	0.41	0.39	0.22	0.21	0.20
TOTAL	1,542.30	1,472.79	1,406.43	1,255.22	1,198.66	1,144.65	61.68	58.90	56.26	25.10	23.99	22.89

*The low scenario eliminated all Thermoelectric withdrawals in the Upper Kanawha watershed.

Table H-2. Projected high and low scenario Thermoelectric withdrawals and consumptive use estimates by county. Results are shown in hundredths of billion gallons for display purposes.

County	Withdrawals (Bgal)						Consumptive Use (Bgal)					
	HIGH			LOW			HIGH			LOW		
	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
Grant	327.02	312.28	298.21	327.02	312.28	298.21	13.08	12.49	11.93	6.54	6.25	5.96
Harrison	11.10	10.60	10.12	11.10	10.60	10.12	0.44	0.42	0.40	0.22	0.21	0.20
Jefferson	173.10	165.30	157.85	173.10	165.30	157.85	6.92	6.61	6.31	3.46	3.31	3.16
Kanawha*	76.91	73.44	70.14				3.08	2.94	2.81			
Marion*	0.48	0.46	0.44				0.02	0.02	0.02			
Marshall	114.48	109.32	104.40	7.10	6.78	6.48	4.58	4.37	4.18	0.14	0.14	0.13
Mason	93.77	89.55	85.51	4.87	4.65	4.44	3.75	3.58	3.42	0.10	0.09	0.09
Monongalia	715.55	683.31	652.52	715.55	683.31	652.52	28.62	27.33	26.10	14.31	13.67	13.05
Pleasants	18.55	17.71	16.91	5.72	5.46	5.21	0.74	0.71	0.68	0.11	0.11	0.10
Preston*	0.57	0.54	0.52				0.02	0.02	0.02			
Putnam	10.76	10.28	9.82	10.76	10.28	9.82	0.43	0.41	0.39	0.22	0.21	0.20
TOTAL	1,542.29	1,472.79	1,406.44	1,255.22	1,198.66	1,144.65	61.68	58.90	56.26	25.10	23.99	22.89

*The low scenario eliminated all Thermoelectric withdrawals in Kanawha, Marion, and Preston counties.