Water Supply Demands and Resources Analysis in the Potomac River Basin

Prepared for

The Maryland Department of the Environment

by

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I. Executive Summary

A. Introduction

The objectives of the study include an assessment of current and future water demands (with a focus on consumptive use) to the year 2030, and an estimate of available resources in the non-tidal portion of the Potomac River basin. The Potomac River basin upstream of, and including the Washington metropolitan area is defined as the non-tidal portion. The assessment of future water use in this study will assist the regulatory agencies and water utilities in addressing the future adequacy of fresh water resources in the Potomac River basin.

Consumptive use upstream in the Potomac River basin reduces the amount of water allocatable and available for further use by those downstream. The concept of *consumptive use* as used here is consistent with that of others in the field, including the U.S. Geological Survey (USGS): "That part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment," (USGS, 1998).

This is not a study that examines the environmental effects of low flow on the flora and fauna of the Potomac River, nor does this study attempt to evaluate future sources of water supply in the basin. This study does not identify potential instances where withdrawals may be greater than flow at the local scale, i.e., in particular tributaries in the headwaters of the Potomac River basin; but instead compares consumptive demand to Potomac River flows at a broader spatial scale.

Two main approaches were used in the study. The first approach provided a summary of water use forecasts by state and the District of Columbia. This approach provides **annual average** values of consumptive use. Analyses by state were not adjusted to include dry year or seasonal effects on consumptive use. No resource analysis was conducted based on the summary of forecasts by state.

The second approach provided a summary of water use forecasts by watershed, Hydrologic Unit Code[1] (HUC). This approach provided estimates of consumptive use that were adjusted to represent **dry year** and **seasonal** effects on consumptive use.

A major element of the study is the resource analysis, which was conducted using the seasonal estimates of consumptive use via the HUC watershed approach. The conclusions of the report are based on the resource analysis conducted using the HUC watershed approach.

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[1]A Hydrologic Unit Code refers to a USGS designated natural drainage basin or hydrologic area. There are 9 HUC regions in the Potomac River basin upstream of the Washington DC area. The USGS provides its water use data by HUC region.

This study relies on data and information compiled and analyzed from a wide range of sources. The data and information are associated with almost as many time periods as the sources from which they are drawn. The present study focuses on a forecast of water demand out to the year 2030. Although it was intended to use existing data and information as much as possible, in many cases forecasts have had to be extended to consistently reach the year 2030. The discussion of the analysis describes those cases where documented information has been extended for completeness and consistency.

It should be noted that extended forecasts are an extrapolation of prior trends, and were not conducted with regard to economic considerations or capacity issues.

B. Study method used to develop state and county based forecasts of consumptive water use

USGS water use data were summarized in the basin on a state and county-level basis in order to provide a readily recognizable geo-political frame of reference. In general, water use was assessed for the broad categories: domestic, commercial, industrial, and agricultural, separately for water that is supplied by community systems and for that which is self-supplied by the consumer. Water consumptively used was tallied for each of the broad use categories for a base year. Forecasts were performed at 10-year intervals for the forecast period: 2000 through 2030.

C. Study method used to develop forecasts of consumptive water use by HUC region

The USGS has compiled uniformly collected baseline estimates of water use data for the nation at 5-year intervals since 1950. Consumptive water use estimates were obtained from the USGS (1995) by categories of domestic, commercial, industrial, thermoelectric, mining, livestock and irrigation water use. In the present study, the data were compiled for the Potomac River basin for a base year (1995) and were extrapolated using forecasts of households, population and irrigated acreage as appropriate. USGS consumptive use data for 1995 provided the basis of the forecast for all but the domestic category. The method for developing forecasts of domestic consumptive water use was based on calculations of regional per household consumptive use for the Washington metropolitan area and on projections of the number of households in the basin.

In order to compare the total consumptive use to summertime low flows, potential variation in **seasonal water use** patterns and in **drought year use** were quantified. Seasonal year variation in agricultural irrigation withdrawals and outdoor domestic water use could change the magnitude of summertime consumptive use, especially as compared to annual average values. Domestic outdoor water use and irrigation water use are also higher during drought years. Estimates of current and future domestic and irrigation consumptive use were estimated for the peak use months of June, July and August and were also adjusted to represent demands during drought years. Commercial, industrial, thermoelectric, mining, and livestock consumptive demands were assumed to be unchanged by drought versus normal year conditions or by seasonal factors.

D. Demand forecast results

Forecasts of population and other water use factors were based on forecasts derived from state, county and regional planning agencies, and the Chesapeake Bay Program of the U.S. EPA; and on the expected water use impacts of the Federal Energy Policy Act of 1992.

Forecasts of consumptive water use and population are presented by county and by state (Figure ES - 1) for the following water use sectors: domestic, commercial, industrial, and agricultural categories and are further defined by supply source (self supplied or public supply).

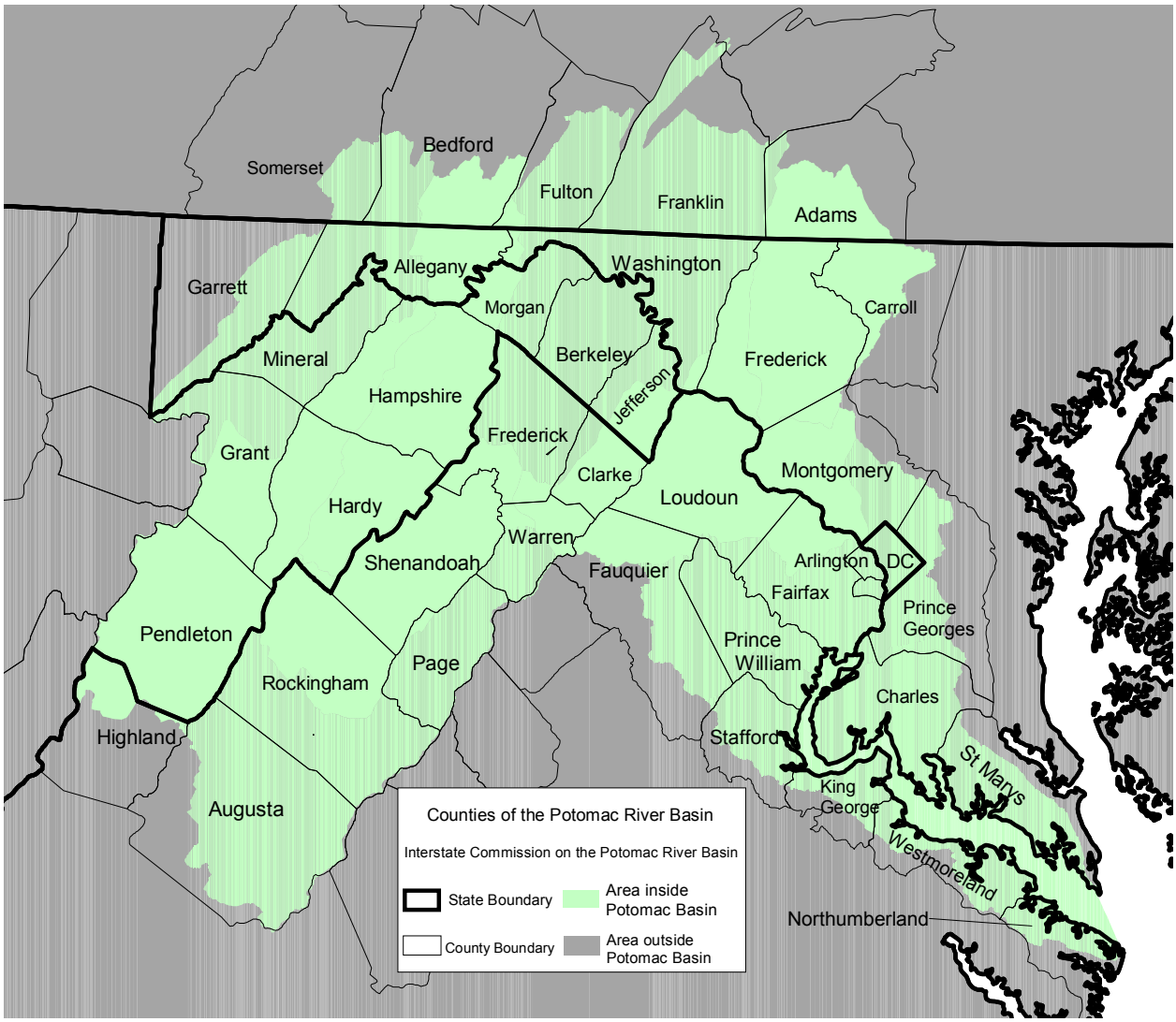

Figure ES - 1: Counties entirely or partially within the Potomac River basin

The water use forecast results are also presented by 8-digit HUC region (Figure ES - 2) for the following water use sectors: domestic, commercial, industrial, thermoelectric, mining, livestock, and irrigation.

The vast majority of the population of the study area lives in the Maryland and Virginia suburbs of the District of Columbia, and in the city itself. Water use is reflected in this population pattern. The largest increases in population and water use are forecast to follow the same pattern – extending to a somewhat wider area around the current metropolitan area.

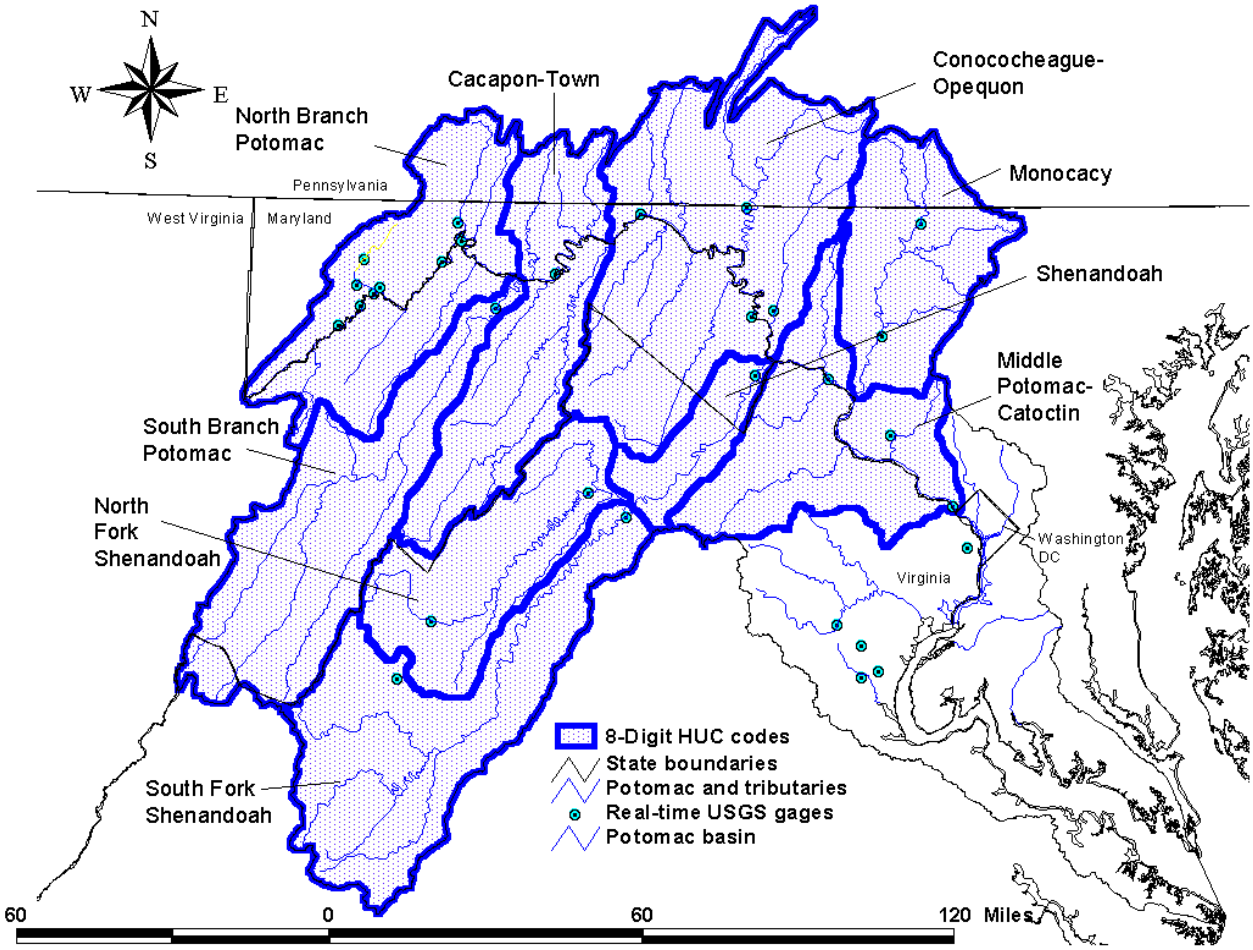

Figure ES - 2: Hydrologic Unit Code boundaries for the non-tidal Potomac River basin

A summary of daily water use forecasts, including the increase from 2000 to 2030, is presented by state and the District of Columbia in Table ES - 1, as values averaged over a whole year. Values from this table have not been adjusted to include dry year or seasonal effects on consumptive use.

Table ES - 1: Population, Total Water Use, and Consumptive Use: Non-tidal Potomac River Basin

Non-Tidal Potomac Basin Part or Whole Jurisdiction	Year 2000		Year 2030		2000 to 2030 Increase	
	Population (thousands)	Total Use (mgd)	Population (thousands)	Total Use (mgd)	Population (thousands)	Total Use (mgd)
Maryland	2,036.2	338.3	2,546.6	410.4	510.4	72.1
District of Columbia	518.1	130.4	669.0	154.5	150.9	24.1
Pennsylvania	179.8	29.7	195.8	31.0	16.0	1.3
Virginia	2,135.1	303.7	2,984.8	414.1	849.7	110.4
West Virginia	207.5	62.3	270.3	74.8	62.7	12.5
Total	5,076.8	864.4	6,666.5	1,084.8	1,589.8	220.4

Notes:

1. All data are shown as average annual values.
2. Population is resident population served by sources in the non-tidal Potomac River basin and by the associated sources: Patuxent reservoirs and Occoquan/Manassas reservoirs.
3. Total use refers to water used for all purposes: domestic, commercial, industrial, agricultural, and unaccounted.
4. The consumptive use in the area served by the Washington, DC metropolitan area water utilities is not calculated or included in this table, because its impact is assumed to be negligible on the non-tidal Potomac River.
5. Water use presented in the table is the sum of all use, including consumptive use, and does not take into account sequential down stream re-use of treated waste water after it is returned to rivers and streams. However, cumulative consumptive use is addressed in the Hydrologic Unit Code (HUC) sub-watershed analyses later in this report.

When seasonal and drought year factors are included in the HUC region analyses, a higher estimate of consumptive use is derived than that of the state analyses shown in Table ES-1. Estimates of average June through August consumptive use assuming dry year conditions are presented by HUC region in Table ES-2. Agricultural water use was forecast differently between the two analyses. The state analyses assumed agricultural use would remain constant at 1995 levels; whereas, more detailed analyses were conducted by HUC region in which resource adequacy was also assessed. In the HUC region analyses consumptive use by livestock was assumed to increase in proportion to increases in human population, and use by irrigation was assumed to increase in proportion to forecast increases in irrigated acreage.

Table ES-2. Estimated 1995 levels of June through August Potomac River basin consumptive use by HUC watershed and by category of use estimated for a drought year.

HUC 8 Name	Domestic	Commercial	Industrial	Thermo-electric	Mining	Livestock	Irrigation	**Totals**
South Branch Potomac	1.5	1	2.4	0	0	0.9	0	**5.8**
North Branch Potomac	5.6	0.2	7	10.5 (b)	0.3	0.5	0.3	**24.5**
Cacapon-Town	1.2	0	0	0	0	0.6	0.1	**1.9**
Conococheague-Opequon	21.2	1.2	2.6	0.3	0.3	3.3	4.8	**33.6**
South Fork Shenandoah	10.8	1.1	2.9	0	0	1.6	1.8	**18.2**
North Fork Shenandoah	3.1	0.5	0.4	0	0	2.6	1.4	**8**
Shenandoah	2.3	0.5	0.9	0	0	1.5	0.4	**5.6**
Middle Pot.-Catoctin (a)	4.7	0.2	0.1	3.3	0	1.1	3.4	**12.8**
Monocacy	12.3	0.7	0.8	0	0.3	2	5.9	**21.9**
Totals	**62.8**	**5.3**	**17.3**	**14**	**0.9**	**14.1**	**18.1**	**132.4**
Totals excluding Mt. Storm (b)	**62.8**	**5.3**	**17.3**	**3.6**	**0.9**	**14.1**	**18.1**	**121.9**

Notes:
(a) The middle Potomac-Catoctin HUC only includes those totals for the non-metro portions of the Washington metropolitan area.
(b) Mount Storm in the North Branch is upstream of river regulating reservoirs and its consumptive demand is mitigated by minimum streamflow releases from the downstream reservoirs.

The data in Table ES-2 show that consumptive use in a hot dry year would have been approximately 122 million gallons per day (mgd) in 1995 during the months of June, July and August. The most significant consumptive uses of water are the domestic (62.8 mgd), irrigation (18.1 mgd), and industrial (17.3 mgd) categories of water use. These three categories would have accounted for about 80 percent of the consumptive use in the basin during June through August, had a drought occurred in 1995.

The data in Table ES-3 show a forecast of consumptive use for the basin through 2030 given a repeat of drought conditions, and adjusted to represent June through August consumptive use patterns.

Table ES-3: Forecast of average June through August consumptive water use by HUC given hot and dry conditions

HUC 8 name	2000	2010	2020	2030
South Branch Potomac	5.9	6	6.1	6.2
North Branch Potomac	24.5	24.6	24.7	24.7
Cacapon-Town	2	2.1	2.2	2.4
Conococheague-Opequon	35.4	38.4	40.9	43.5
South Fork Shenandoah	18.9	19.9	20.9	21.9
North Fork Shenandoah	8.5	9.2	9.9	10.6
Shenandoah	6	6.6	7.2	7.8
Middle Potomac-Catoctin (a)	13.8	15.6	17	18.5
Monocacy	24.1	27.9	30.4	33.5
Totals	**139.1**	**150.4**	**159.3**	**169.1**
Totals without Mount Storm (b)	**128.6**	**139.9**	**148.8**	**158.6**

Notes:
(a) The middle Potomac-Catoctin HUC only includes those totals for the non-metro portions of the Washington metropolitan area.
(b) Mount Storm in the North Branch is upstream of river regulating reservoirs and its consumptive demand is mitigated by minimum streamflow releases from the downstream reservoirs.

Table ES-3 shows that consumptive demand is expected to grow from 129 mgd in 2000 to159 mgd in 2030 (a net change of 30 mgd over 30 years) during hot and dry conditions for the months of June through August.

The effect of potential climate change on resources was not considered in the present study. There are numerous and substantial uncertainties associated with anticipated climate change, not least of which is the lack of any clear climate result for this region from the five different global circulation models previously examined; therefore, no potential climate change impacts were incorporated in the analysis of resources for the present study.

A sensitivity analysis shows a ten percent change in the growth factors for each sector had the biggest impact on the domestic sector, accounting for 48 percent of the total change in demand for all sectors. The next biggest change was irrigation at 15 percent of the total change, followed by thermoelectric at 12 percent and industrial at 10 percent. Commercial and mining categories accounted for less than 5 percent each of the total change.

E. Resource Assessment

A resource assessment was conducted to compare consumptive demands with Potomac River flow at several scales. Table ES-4 provides a summary of the resource assessment results.

Table ES-4: Summary of resource assessment results

Scale	Conclusion
Individual HUCs	Consumptive withdrawals in some parts of the Middle Potomac HUC region appear to be nearly equal to total low flow during drought periods. The Monocacy HUC's consumptive withdrawals are presently nearly equal to total low flow during drought periods, and are predicted to increase higher than the minimum 1930 historical streamflow by 2030. For the remaining HUC regions, the estimates of consumptive demands for 2000 are approximately 7 to 43 percent of the minimum flow for each HUC. The estimates of consumptive demand for 2030 are 8 to 56 percent of the minimum flow
Regional (grouped HUCs)	Resources will be adequate to meet water supply demands in the Potomac River upstream of Washington DC in the year 2030. Withdrawals were calculated to be 13 to 27 percent of the minimum flow in 2000 and 14 to 33 percent of the minimum flow in 2030 for all groups evaluated. Withdrawals were calculated to be 10 to 16 percent of the 7Q10 flow in 2000 and 11 to 20 percent of the minimum flow in 2030.

Scale	Conclusion
Basin-wide (Potomac at DC)	Resources will be adequate to meet water supply demands and current environmental flow recommendations in the Potomac River at Washington DC in the year 2030 under a repeat of the historical drought of record, but resources nearly would be depleted in this scenario. If climate change were to occur, demands could increase and streamflow resources could decrease relative to historical conditions. Sensitivity analysis shows that given a reduction in historical streamflow of 5 percent and a 9.5 percent increase in Washington area water supply demands, the system of reservoirs could meet demands in 2020 but reserve storage would be nearly depleted. Consumptive demands have an impact on long-term water supply resource availability at DC, decreasing the amount of remaining water supply in the reservoirs and increasing the frequency of voluntary and mandatory restrictions required to meet demands for the Washington metropolitan area in the year 2030. Consumptive demands increase the frequency and duration of low flows in the Potomac River at Little Falls; however, the release of water from upstream reservoirs to meet local environmental flow requirements limits the effect of the increased consumptive demand on the magnitude of extreme low flows.

F. Conclusions

Cumulative consumptive demands for the Potomac basin upstream of the WMA were combined with current and forecast water supply withdrawals for the WMA and compared to historical river flow at Little Falls near Washington, D.C., which is downstream of all major Potomac River basin water supply intakes. For the Washington metropolitan area, resources will be adequate to meet demands in the year 2030 under a repeat of the historical drought of record but resources would be nearly depleted in this scenario. Consumptive demands have an impact on long-term water supply resource availability at DC, decreasing the amount of remaining water supply in the reservoirs in future years and increasing the frequency of voluntary and mandatory restrictions required so that demands can be met for the WMA. Consumptive demands increase the frequency and duration of low flows in the Potomac River at Little Falls, but because of reservoir regulation to meet environmental flow requirements, the magnitude of extreme low flows is not affected by increasing consumptive demands.

Cumulative demands on the Potomac River itself were evaluated throughout the basin through the medium scale analysis (grouped HUC region analysis). Resources will be adequate to meet water supply demands in the year 2030 in the Potomac River upstream of Washington DC. Consumptive demands throughout the basin upstream of DC are currently at most about a quarter of the total flow in the free flowing Potomac during a repeat of the historical lowest flows. The consumptive demand is forecast to increase to up to a third of the historic low flow by 2030. Given flows that have a ten percent probability of occurring in any year, the current consumptive demand throughout the basin is less than a sixth of the flow at any point, and is forecast to be up to about a fifth of the flow in 2030.

At the individual HUC scale, two of the seven HUC regions evaluated may not have enough flow

to meet current and predicted consumptive demand during a repeat of the lowest historical minimum flow (Monocacy and Middle Potomac Catoctin). For the remaining individual HUC regions, estimates of consumptive demands range from approximately 7 to 43 percent of the minimum flow in 2000 and from 8 to 56 percent of the minimum daily flow in 2030.

This analysis did not attempt to identify potential problems at the local scale, i.e., for individual tributary streams in the headwaters of the Potomac.

G. Future Work

Although the present study was expected to rely primarily on existing data and information, a significant amount of important new work was performed in the course of producing the results presented herein. During the study, several other potentially important areas of investigation were identified, but limitations on time and resources did not permit further work. Future effort spent on the following issues would lead to significant refinements in the forecast of water demand and the adequacy of resources to meet those demands in the future.

- Analyses of demands and resources within small watersheds (HUCs) would identify potential future resource availability problems at the local scale. In order to address the problems noted above for the Monocacy and Middle Potomac HUC regions, and to identify potential problems at the local scale, a forecast for each of the major components of seasonal demand (for the Potomac the major components are domestic, commercial, industrial, thermoelectric, livestock, and irrigation) would need to be identified spatially. GIS tools could be used to assist in combination with soil type, gage information, and areal adjustment could be used to identify 7Q10 and minimum historical flows at each withdrawal point. Cumulative upstream withdrawals could be accounted for using these spatial tools. The contribution to supply from small locally important upstream reservoirs would also be considered.

- Consumptive water use forecasts for the largest water using sector would be more confidently conducted if the assumption that outdoor domestic water use for the several housing types is the same throughout the basin as it is for the WMA could be tested.

- Future work might verify the USGS estimates of consumptive use for commercial, industrial, thermoelectric, livestock, and irrigation withdrawals in the basin, and resolve whether seasonal variations in consumptive demands for these categories of water use were significant.

- A more detailed consideration of ground water as a resource would provide useful refinements to the results.

- A thorough discussion of other issues (e.g. climate change, minimum instream flow requirements) impacting or potentially impacting demands and resources throughout the watershed would help integrate resources management issues for the Potomac basin.